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Museums for all: Perspectives of Special Pedagogy for inclusion

Musei per tutti: prospettive di Pedagogia Speciale per l'inclusione

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Abstract Accessibility to cultural heritage represents a fundamental right for social inclusion (United Nations, 2006). It is a key principle to eliminate barriers and ensure the inclusive enjoyment of cultural experiences. Within this frame, in this paper, we will discuss how digital technologies, such as Augmented Reality (AR), Virtual Reality (VR), and Artificial Intelligence (AI), offer innovative solutions to meet the specific needs of people with disabilities, facilitating access and enriching the visitor experience. Specifically, this paper outlines a project undertaken by the Special Pedagogy research group at the University of Macerata to enhance the inclusivity of museum environments for people with intellectual disability and autism through the use of digital technologies. The findings highlight how the combined use of AR, VR, and AI fosters cultural participation and improves the well-being of people with disabilities, reinforcing the role of museums as inclusive spaces for learning and engagement.

KEYWORDS Museum Accessibility; Special Pedagogy; Technological Innovation; Intellectual Disability; Autism.

Sommario L'accessibilità al patrimonio culturale rappresenta un diritto fondamentale per l'inclusione sociale (ONU, 2006), diventando il principio chiave per eliminare le barriere e garantire una fruizione inclusiva delle esperienze culturali. In questa cornice, verrà discusso come le tecnologie digitali, quali la Realtà Aumentata (AR), la Realtà Virtuale (VR) e l'Intelligenza Artificiale (AI), offrano soluzioni innovative per soddisfare le esigenze specifiche delle persone con disabilità, facilitando l'accesso e arricchendo l'esperienza dei visitatori. Nello specifico, il presente lavoro illustra un progetto intrapreso dal gruppo di ricerca di Pedagogia Speciale dell'Università di Macerata, per migliorare l'inclusività degli ambienti museali per le persone con disabilità intellettiva e Disturbo dello Spettro Autistico attraverso l'uso di tecnologie digitali. I risultati evidenziano come l'uso combinato di AR, VR e AI favorisca la partecipazione culturale e migliori il benessere delle persone con disabilità, rafforzando il ruolo dei musei come spazi inclusivi per l'apprendimento e il coinvolgimento.

Parole chiave Accessibilità Museale; Pedagogia Speciale; Innovazione Tecnologica; Disabilità Intellettive; Disturbo dello Spettro Autistico.

1. Introduction

Accessibility to cultural heritage constitutes an indispensable right recognized as central to full social inclusion. This principle, enshrined in international treaties (United Nations, 2006), reflects

two complementary dimensions, namely physical accessibility to cultural places (Art. 9a) and cultural accessibility to content and experiences (Art. 9b). It suggests the role of accessing cultural heritage as an educational tool (Di Rosa, 2024; Jagielska-Burduk et al., 2021; Muscarà & Romano, 2021) as well as its potential impact on the general well-being of the person (Giaconi, 2015; Schalock & Verdugo Alonso, 2002, 2007) by fostering their active involvement and participation (World Health Organization, 2001).

In the museum field, innovative perspectives in the design of spaces and programs dedicated to ensuring accessibility, usability and inclusive enjoyment of cultural heritage have been consolidated over time (Bortolotti & Mastrogiuseppe, 2019; Gordon et al., 2016; Mace, 1985; Steinfeld & Maisel, 2012). These approaches identify adaptations to formal and informal contexts to reduce possible barriers between people and environments. Among them, Universal Design (UD) (Mace, 1985, 1997; Story et al., 1998) and Universal Design for Learning (UDL) (Gordon et al., 2016; Rose, 2000), focus on design that integrates flexibility and accessibility from the planning stage (Rappolt-Schlichtmann et al., 2013) to respond to the needs of an increasingly heterogeneous population. In this regard, the literature (Bortolotti & Paoletti, 2021; Gordon et al., 2016; Savia, 2016; Shogren et al., 2022) highlights how in the design of museum interventions considering variables such as expectations, cultural background and learning styles can produce positive results in terms of participation, engagement and involvement (D'Angelo et al., 2024; Garcia Carrizosa et al., 2020; Gordon et al., 2016; Münch et al., 2022). A further element of innovation is the integration of such approaches with technological tools, a combination that allows not only the adaptation of content to different needs but also the expansion of channels of access to information (Dudley et al., 2023; Giaconi et al., 2021; Shehade & Stylianou-Lambert, 2020). Technologies such as Virtual Reality (VR), Augmented Reality (AR) and Artificial Intelligence (AI) offer the possibility of designing immersive and multisensory experiences capable of breaking down barriers and facilitating the inclusive enjoyment of cultural heritage.

This paper highlights ways these approaches can be used to design an inclusive museum experience, promoted by the research group in Didactics and Special Pedagogy at the University of Macerata. We specifically describe an investigation of how AR and VR technologies can be valuable tools to respond to the need for anticipation in the exploration of the museum space by people with autism, as well as how Artificial Intelligence can be a means of support for the creation of accessible museum captions in Easy-to-Read language.

2. Innovative technologies for inclusion

The concept of accessibility, as highlighted by the Special Pedagogy literature (Besio et al., 2023; Bortolotti & Paoletti, 2021; D'Angelo et al., 2024; Friso & Marchesani, 2022; Giaconi et al., 2023; Gimenez & Thomas, 2015; Greco, 2019; Pinnelli & Fiorucci, 2023; Straniero, 2023) necessitates in-depth reflection by cultural institutions on the usability of information and content to provide concrete opportunities for exploration, learning and engagement, particularly for people with disabilities. Specifically, we are going to focus on the evidence emerging from the literature on the merit of cultural and physical accessibility for people with autism and intellectual disabilities.

Scientific findings have highlighted that people with autism may need support with creating anticipatory models that can support them with predicting future experiences and actions (Barale et al., 2009), such as fluidly understanding the meaning of interpersonal exchanges or ongoing events, as there is a tendency to focus more on details (Giaconi, 2015; Happé & Frith, 2006). In fact, people with

autism often exhibit a detail-focused processing style, which results in a particularly attentive and analytical view of individual elements as opposed to the overall context (Giaconi, 2015). Considering this, technologies such as Virtual Reality and Augmented Reality can be rather promising tools for fostering museum accessibility. The complexities related to the creation of anticipatory models (Barale et al., 2009) can be supported by the use of technological solutions that offer visual anticipation of spaces and experiences. VR, for example, makes it possible to simulate the exploration of museum environments in a controlled and predictable context, allowing people with autism to familiarize themselves with places before the actual visit (Campitiello et al., 2022; Del Bianco et al., 2024; Drageset & Crippen, 2024; Giaconi et al., 2021). This type of experience allows for increased spatial understanding, providing a clear view of the temporal sequences and events that will follow, facilitating adaptation to new environments. AR, on the other hand, can enrich the museum experience through the overlay of visual information that guides the user and provides anticipation of objects or events taking place, allowing the user to focus on relevant details without losing the overall context. In addition, the use of AR devices also reduces sensory load by offering information in a customizable mode (e.g., with magnified text, modulated sounds, and specific colours), responding to the needs of each visitor (Campitiello et al., 2022; Hutson & Hutson, 2023).

When supporting people with intellectual disability, the relevant literature (Schalock, 2010; Wehmeyer et al., 2008) suggests the importance of considering support needs related to difficulties in processing abstract concepts and accessing complex information, especially in handling articulate texts, interpreting verbal and visual content and assimilating concepts that require some level of abstraction or critical thinking (Mayer, 2021; Poncelas & Murphy, 2007). Such challenges can, therefore, hinder full participation in cultural, educational and social experiences, including visiting museum spaces, where content structuring usually involves dealing with elaborate and often abstract information. In this direction, studies (Mayer, 2021; Poncelas & Murphy, 2007) show how it is possible to promote the full accessibility of knowledge and information through clear and easy-to-understand formats. In this regard, the Easy-to-Read guidelines (Bernabé Caro & Orero, 2019; Fajardo et al., 2014; Freyhoff et al., 1998; Madina et al., 2023; Nomura et al., 2010; Tronbacke, 1997) fit into this perspective, facilitating complex concepts through customized paths that meet individual communication needs. This adaptability is embodied in diversified modes of communication (e.g., written, audible, simplified tools and formats, human or alternative readers) that are aligned to the support needs of people with intellectual disability (Bortolotti & Paoletti, 2021).

As highlighted in the literature (Bernabé Caro & Orero, 2019; Fajardo et al., 2014; Madina et al., 2023; Nomura et al., 2010), adopting Easy-to-Read guidelines is a key element in fostering the acquisition of new skills, promoting knowledge exchange, encouraging active participation, and ultimately increasing self-determination (D'Angelo et al., 2024; Del Bianco et al., 2019; Fajardo et al., 2014; Shogren et al., 2022). In this context, technological tools such as Artificial Intelligence can support the enhancement of accessibility to museum content by facilitating the process of adapting information into Easy-to-Read formats (Aliseda et al., 2023; D'Angelo et al., 2024; Olmedo-Pagés & Arquero-Avilés, 2024). AI can accelerate the process of making text more accessible, enabling complex cultural content to be transformed into clear and understandable language, thereby avoiding ambiguity and reducing reading difficulty. The use of AI in creating Easy-to-Read content can also involve generating visual descriptions for complex concepts through the combination of images, icons, and symbols, making the information more easily understandable and increasing the efficiency of the process, rather than substituting it (D'Angelo et al., 2024).

These technologies can be leveraged to create various possibilities for interacting with the museum environment and activities that address specific personalization needs (D'Angelo et al., 2024; Hutson & Hutson, 2024; Kasemsarn et al., 2024). In this direction, we will present in the next section a path to design an accessible museum environment through innovative and technological solutions, with the co-participation of people with disabilities. After describing the research design and the activities, we will share the process carried out to customise the museum visit. We will focus specifically on co-designing paths with people with autism to build customized itineraries and thematic paths through AR and VR, and on creating paths with people with intellectual disabilities to experience museum captions in Easy-to-Read language through the support of Artificial Intelligence.

3. The research protocol

In line with regulatory provisions on the renewal of museum accessibility and inclusion plans mandated in 2018 by the Ministry for Cultural Heritage and Activities (Ministero per i beni e le attività culturali, 2018) and in continuity with previously conducted studies (D'Angelo et al., 2024; Del Bianco et al., 2024; Giaconi et al., 2021; Giaconi et al., 2023), the research group of the Chair of Pedagogy and Special Education at the University of Macerata, in the biennium 2022-2024, undertook a project aimed at making the museum experience more accessible and inclusive for all visitors, with particular attention to people with autism and intellectual disability.

This initiative is situated within a theoretical and methodological framework favouring a participatory approach (Cornwall & Jewkes, 1995) based on co-designing with people with disabilities at every stage of the process, from planning to developing and implementing the museum layout to testing the accessible and inclusive museum itineraries. This methodology made it possible to enhance the expertise of people with autism and intellectual disability and the research team, integrating their contributions into the definition of accessibility strategies. The decision to co-design with people with disability allowed the synergy of different skills in creating an inclusive museum context responsive to the real needs of all visitors.

Based on these assumptions, the participatory research was articulated concerning the following procedural steps (Table 1) (D'Angelo et al., 2024; Giaconi et al., 2023):

Table 1. The research procedure.

Phase 1. Mapping of critical issues related to accessibility, both physical and cultural, of the museum context involved in the project (6 months);
Phase 2. Co-design and development of integrated technological solutions to make museum spaces usable and develop accessible and inclusive paths (12 months);
Phase 3. Re-testing of the implemented solutions (6 months).

Respecting these phases, two parallel macro-pathways were articulated to move forward with addressing identified issues critical to accessibility, both physical and cultural (Giaconi et al., 2023):

– "Pathway a": involved co-design with people with autism to create predictable environments through integrated VR and AR technological solutions;
– "Pathway b": involved co-designing with people with intellectual disability to create accessible captions in Easy-to-Read language via AI technological solutions.

Two research teams were formed to address these distinct but related pathways. The research team that dealt with "Pathway a" involved an interdisciplinary team composed of museum experts, Special Pedagogists, Virtual and Augmented Reality experts and five university students with autism. "Pathway b", on the other hand, was curated by the teamwork of engineers, museum experts, Special Pedagogists and people with intellectual disabilities experts on Easy-to-Read affiliated with different associations from the Marche Region. This collaborative and interdisciplinary approach allowed for the development of a constant dialogue between theory and practice, ensuring that the proposed solutions aligned with the real needs of museum visitors.

3.1. "Pathway a"

"Pathway a" aimed to develop immersive and innovative environments for multimodal interaction, implemented with the support of people with autism using the methodology of participatory research; for this reason, the experimental procedure consists of the following activities:

1. Visit to the museum and data collection:
   1.1 Selection of the museum's relevant cultural contents and information made by a joint team of museum experts, Special Pedagogists, Virtual and Augmented Reality experts, and people with autism;
   1.2 Data collection activity conducted by the team of VR professionals to create the museum's virtual objects and spaces.
2. Observation and data collection concerning barriers and facilitators of the museum:
   2.1 Conduction of structured interviews with people with autism regarding their museum experience;
   2.2 Interview analysis conducted through the Grounded Theory methodology.
3. Creation of the museum VR prototypes.
4. Test and retest phase with a control group of people with and without disabilities;
   4.1 Final adjustments.

Specifically, in Activities 1.1, the teamwork visited the museum multiple times in order to select the most relevant cultural content to be transposed in the VR environment.

In activity 1.2, the team of VR experts captured the main museum spaces in spherical photos through a 360° camera and uploaded the pictures to the Web[1] that were integrated and edited using specific tools and software such as Ricoh Theta Converter Pro, Retouch3, and Marzipano Tool, the latter based on an open-source library. The development of the spherical photos was followed by the creation of 3D models (Caldarelli, 2023; Ceccacci et al., 2021).

During Activity 2, as done in previous research (Campitiello et al., 2022; Giaconi et al., 2021; Shogren et al., 2022), interviews with people with autism regarding their museum experience (Activity 2.1) allowed the research team to outline the most relevant difficulties connected to the access and fruition of the museum heritage. The interview analysis followed the Grounded Theory methodology (Strauss & Corbin, 1994), allowing us to identify and organize the main accessibility and usability issues of the museum through labels (Activity 2.2). The analysis of the interviews allowed the iden-

[1] Various tools and software were used for the project, such as a Ricoh Theta SC2 spherical camera, a smartphone equipped with Android 6.0 OS, the Ricoh Theta S apps, Ricoh Theta Converter Pro, and Retouch3 and Marzipano Tool4 that is a free web service based on an open-source library.

tification of two main macro-categories (Giaconi et al., 2023): barriers and facilitators, specifically in relation to the sensory, cognitive, and communicative characteristics commonly associated with autism. These categories, discussed and refined, were essential in understanding how people with autism perceive and experience museum environments. The first macro-category, referring to barriers, was conceptualised as a "fragmented experience". This included difficulties such as limited access to content not tailored to different processing styles, incoherent or disconnected information across exhibits, and the abstract nature of certain content that lacked concrete support. Added to this was the unclear function of museum spaces, which often complicated spatial orientation. Together, these factors contributed to cognitive overload, disorientation, and a diminished sense of engagement. On the other hand, the facilitators were framed under the theme of "involvement", highlighting elements that promote active and meaningful participation. These included the presence of concrete and experiential content, the opportunity for visitors to make choices and personalise their pathways, the availability of interactive modes of engagement – often supported by technology – and the structuring of content through narrative frameworks that support understanding and orientation. These aspects were recognised as essential to fostering accessible, predictable, and inclusive museum experiences for people with autism.

In relation to these findings, concerning Activity 3, to ensure greater accessibility to cultural content, the prototype was designed considering supporting visual thinking and reality-anchored concepts (Ceccacci et al., 2021). Interactive VR features, such as scene switching and information popups containing multimedia content, were integrated to make the pathway customizable and easily interrogated by users. This process was a crucial step in creating a true-to-life virtual tour that allowed people with autism to explore museum environments, both outdoor and indoor, in advance, increasing the predictability and the anticipation of the spaces. The need for adherence to reality, typical of people with autism (Morgan et al., 2003), led us to implement the prototype with explanations of symbols, codes, and signs of the museum through the impression of augmented spherical and real images. Specifically, the virtual prototype was created following the principles of Equitable Use; Flexibility in Use; Simple and intuitive use; Perceptible information; Tolerance of error; Low physical effort; Size and space for approach and use (Story et al., 1998). Starting from these assumptions the interface, which is intuitive and conforms to the principles of Universal Design (Story et al., 1998), integrates tactile, vocal and visual inputs, enabling realistic and immersive interaction with virtual objects. These solutions, in addition to making the museum experience accessible to an increasingly diverse audience, can facilitate the design of educational activities both before and after the visit.

The prototype, developed in collaboration between experts and people with autism, was subsequently tested inside the museum (Activity 4). Five additional university students with no previous experience in the museum context were involved in the final validation phase. The feedback gathered from these new users helped verify the prototype's effectiveness and appropriateness on different possible levels. Final adjustments (Activity 4.1) were made in relation to inconsistencies and critical issues that were detected.

3.2. "Pathway b"

"Pathway b" aimed to create accessible captions in Easy-to-Read language using Artificial Intelligence systems (D'Angelo et al., 2024). Our goal was not to replace co-design with automated systems but rather to employ technology as a tool to make the process of adapting information into an accessible format more efficient. For these reasons, in line with the principles of the *Inclusion Europe* move-

ment[2], all stages of the process of transforming texts into Easy-to-Read format, including content verification and revision, actively involved people with intellectual disability as experts on Easy-to-Read. Adapting documents in Easy-to-Read language is a cyclical process and involves three procedural steps: analysis, transformation, and validation. Through these steps, the active involvement of people with intellectual disability as experts in Easy-to-Read allows the production of information that effectively meets accessibility criteria. However, such participation requires a significant commitment and use of human resources, so scholars have sought alternative solutions (Suárez-Figueroa et al., 2020). In this regard, several semi-automatic systems based on AI have been proposed. The most useful AI tool was initially evaluated, with special reference to Large Language Models. Among LLM systems, ChatGPT has shown promise in supporting tasks related to natural language processing (Araújo & Aguiar, 2023; Liu et al., 2023; Min et al., 2023), facilitating both the analysis of texts and their compliance with Easy-to-Read guidelines (Suárez-Figueroa et al., 2020; Uricchio et al., 2024).

Therefore, ChatGPT's level of knowledge regarding the Easy-to-Read guidelines (Min et al., 2023) was tested by analyzing the responses provided to 20 open-ended questions that ChatGPT answered freely without any predetermined structure. The questions were sent to different versions of ChatGPT (3.5 and 4.0) using the OpenAI API, with the support of a Python script. The results showed that ChatGPT 4.0 has superior knowledge of Easy-to-Read guidelines compared to version 3.5. Based on these observations, a specialized prompt was developed to guide ChatGPT 4.0 in producing texts adhering to the Easy-to-Read guidelines (D'Angelo et al., 2024). This prompt was structured into three main sections:

(a) a contextual description directing the model to behave as an accessibility expert;
(b) a detailed explanation of the Easy-to-Read guidelines;
(c) explicit instructions on how to apply these guidelines in simplifying texts.

The tool thus configured was used to create 10 simplified museum captions. These texts were then submitted to the interdisciplinary working group which rated their consistency with the guidelines by adopting a Likert scale of 1 to 5 (D'Angelo et al., 2024):

1) Completely incorrect – The text does not significantly meet the standards for facilitated comprehension.
2) Insufficiently correct – The text shows an attempt to align with the guidelines, but several key aspects are missing.
3) Sufficiently correct – The text meets the guidelines by ensuring a basic level of understanding.
4) More than sufficiently correct – The text adequately meets the guidelines' requirements but offers room for improvement.
5) Completely correct – The text fully and flawlessly adheres to the Easy-to-Read guidelines.

The initial evaluation of the texts generated using ChatGPT 4 indicated that 7 out of 10 captions reached an average level of "sufficient" (Score 3), in compliance with the Easy-to-Read guidelines. Instead, the other 3 captions reached an average level of "insufficiently correct" (Score 2). Based on the score achieved, the tool demonstrated a good structural foundation but presented some issues. For this reason, beyond the quantitative analysis, experts also provided qualitative input for each caption text, identifying its strong points and areas needing development. Among the main critical aspects, experts underlined limited exemplification, abstract phrasing, and inconsistent clarity, which prevented

[2] https://www.inclusion-europe.eu/

Table 2. Example of Easy-to-Read facilitation process: from the original text to the latest version prepared by the team after the review process.

Original text[1]	First version of the facilitated text made with ChatGPT 4[2]	Latest version of the facilitated text, produced through the co-design process[3]
Le aristocrazie picene usavano riunirsi in occasione di pasti comuni (banchetti o simposi). Si tratta di un'usanza tipica di molte civiltà antiche e la sua introduzione in area picena è legata ad un'influenza proveniente dal mondo greco, ben attestata anche tra gli Etruschi. Nei corredi delle tombe troviamo spesso oggetti riconducibili al banchetto, in particolar modo vasellame legato alla mescita del vino. Tra i vasi più rappresentativi troviamo: – crateri, grandi vasi per la preparazione del vino; – stamnoi e anforette, vasi di medio-grandi dimensioni utili alla conservazione dei liquidi; – piccole brocche (oinochoi); – recipienti di varia forma utilizzati per bere come le kilikes, larghe coppe su piede con due anse, e gli skyphoi, più piccoli e profondi.	Le persone importanti di un tempo lontano chiamato epoca picena si incontravano per mangiare insieme durante grandi feste. Questo costume era comune anche in altre culture antiche e ha raggiunto i Piceni grazie all'influenza dei Greci, proprio come era successo per gli Etruschi. Durante gli scavi delle tombe si trovano cose che venivano usate per queste feste, soprattutto per bere il vino. Tra queste cose ci sono grandi vasi per preparare il vino, altri vasi un po' più piccoli per tenerlo, piccole brocche e anche tazze di varie forme per bere.	Le famiglie più ricche e potenti del passato si chiamavano aristocratiche. Le famiglie aristocratiche si riunivano per fare pasti insieme. Questi pasti si chiamano banchetti o simposi. Nelle tombe troviamo spesso oggetti che si usavano nei banchetti per dimostrare che quella persona era importante. Tra questi oggetti troviamo dei vasi che venivano usati per miscelare il vino con l'acqua e alcune spezie e aromi.

[1] Authors' translation of the original text: "The Picenian aristocracies used to gather for common meals (banquets or symposia). This was a custom typical of many ancient civilisations and its introduction in the Picenian area is linked to an influence from the Greek world, also well attested among the Etruscans. In the grave goods of the tombs of Tolentino we often find objects that can be traced back to the banquet, especially vases related to the pouring of wine. Among the most representative vessels we find: craters, large vases for preparing wine; stamnoi and amphorae, medium-large vessels for storing liquids; small jugs (oinochoi); vessels of various shapes used for drinking such as kilikes, large bowls on feet with two handles, and skyphoi, smaller and deeper".

[2] Authors' translation of the first version of the facilitated text made with ChatGPT 4: "Important people from a distant time called the Picenian era met to eat together during great feasts. This custom was common in other ancient cultures as well, and it reached the Picenes through the influence of the Greeks, just as it had for the Etruscans. When excavating ancient tombs in a place called Tolentino, we often find things that were used for these feasts, especially for drinking wine. Among these things are large vessels for making wine, other somewhat smaller vessels for holding it, small jugs, and even cups of various shapes for drinking".

[3] Authors' translation of the final version of the text: "The richest and most powerful Picenian families were called aristocrats. Aristocratic families gathered to have meals together. These meals were called banquets or symposia. In the tombs of Tolentino we often find objects that were used at banquets to show that the person was important. Among these objects we find vases that were used to mix wine with water and some spices and aromas".

achieving full accessibility standards. In light of this evidence, texts were revised and refined through a co-design process involving teamwork, which allowed for direct user feedback and iterative adjustments. As a result, the revised captions achieved higher levels of compliance, with most texts receiving an average score between 4 and 5, indicating a strong alignment with the Easy-to-Read criteria. These improvements reflected the value of integrating technological tools with participatory methodologies to

enhance both linguistic clarity and cultural accessibility. Table 2 shows the reviewing process, from the original version to the latest one.

4. Discussion

This project suggests that AR and VR technologies can be effective in mitigating support needs related to the lack of predictability of museum spaces and content. Specifically, the use of VR can enable the anticipation of exploration of environments through the creation of immersive 360° maps, significantly reducing perceptions of anxiety and uncertainty associated with entering unfamiliar contexts (Campitiello et al., 2022; Drageset & Crippen, 2024). In parallel, AR can facilitate the integration of physical and digital reality by transforming information into accessible formats, such as converting verbal descriptions into visual or audio elements and vice versa (Hutson & Hutson, 2023, 2024). Due to their multisensory and multimodal nature, these technological solutions can enhance the visual channel, explicitly responding to the predominant cognitive styles of people with autism and significantly improving their experience of cultural enjoyment (Campitiello et al., 2022).

In the context of intellectual disability, particular attention has been devoted to the accessibility of written content through adopting the Easy-to-Read format, implemented by the competencies of people with intellectual disabilities (Floridi, 2022). To this end, it becomes essential to develop co-design strategies based on prompt engineering, whereby people with intellectual disability are actively involved in the formulation and validation of input prompts and textual outputs. Such participatory approaches not only improve the linguistic and cognitive accessibility of museum-related texts but also contribute to enhancing the agency and inclusion of people with disabilities as co-creators of cultural content. This dual investment in technological innovation and people empowerment represents a key direction for advancing accessibility within museum contexts (Shogren et al., 2022; Suárez-Figueroa et al., 2020).

This study highlights how the involvement of people with disability in co-design can help to develop and improve inclusive museum itineraries, creating multiple pathways to a virtuous synergy between museum cultural activities and social inclusion (Re & Valente, 2022). Collaboration with diverse professionals and people with disability emerges as a meaningful process that generates inclusive museum pathways and strengthens participants' personal and social empowerment (Guedes et al., 2023). In addition, this participatory approach allowed for the precise identification of the core functionalities and specific requirements of the digital solutions tested. Consistent with the principles of UD (Story et al., 1998) and with the relevant literature described in the Introduction, it is essential to promote synergy between technology and innovation to foster greater active involvement of all museum visitors (Carci et al., 2019; Solima, 2007).

5. Conclusions

This study underscores the necessity of developing accessible museum pathways, particularly focusing on people with autism and intellectual disability. Museums play a crucial role in cultural and educational dissemination, yet accessibility remains a significant challenge. By leveraging innovative technologies such as Virtual Reality, Augmented Reality, and Artificial Intelligence, museums can provide inclusive and engaging experiences that cater to a diverse audience. These technologies serve as essential tools for overcoming barriers that hinder the museum experience and for enhancing the interpretative and interactive aspects of cultural heritage engagement (Aliseda et al., 2023; Balcazar et al., 1998;

D'Angelo et al., 2024; Del Bianco et al., 2024; Giaconi et al., 2023; Olmedo-Pagés & Arquero-Avilés, 2024). Integrating co-design and innovative technologies, in line with the principles of Universal Design (Story et al., 1998), is a starting point for rethinking cultural contexts as spaces for inclusion, participation, and development.

However, while these advancements provide useful guidelines for significant transformations and valuable insights into museum accessibility, certain limitations require further analysis and suggest directions for future research.

Firstly, the specificity of the sample presents a significant constraint due to the small and limited number of people involved, as it focuses primarily on people with autism and intellectual disability. Future studies should expand their scope to include participants with different support needs, allowing for a more comprehensive and inclusive understanding of museum accessibility challenges and creating further pathways (Mesquita & Carneiro, 2016; Rappolt-Schlichtmann et al., 2013). In this regard, numerous paths can be taken in museum settings for people with disability through adaptation of contexts that could involve, for example, the use of simple procedural accouterments up to AI systems that adapt to people's needs in real time.

Moreover, although the present study concentrates on the application of Augmented Reality, Virtual Reality, and Artificial Intelligence within the context of museum accessibility, future research trajectories should encompass a broader spectrum of emerging technologies. Among these, haptic feedback systems, brain-computer interfaces (BCIs), and multisensory immersive environments represent particularly promising avenues for investigation. Such technologies may not only function as complementary tools but also provide alternative modes of access to cultural heritage, thereby contributing to the construction of diversified and multimodal interpretative ecosystems (Diamantopoulou et al., 2024). In particular, the affordances generated by these innovations may be especially relevant for people with complex or multiple disabilities, offering unprecedented opportunities for interaction, engagement, and cognitive-emotional involvement with museum content.

Concomitantly, the implementation of inclusive digital strategies is not solely contingent upon the availability of technological infrastructure but critically hinges on the competences, attitudes, and preparedness of museum personnel. It is, therefore, important that forthcoming research initiatives incorporate the design, empirical validation, and systemic dissemination of professional development programs aimed at museum staff. These training initiatives should be multidimensional in scope, encompassing both technical skills pertaining to the operation and contextual adaptation of assistive technologies, as well as relational competences, including inclusive communication strategies (Klavina et al., 2024). Only through the integration of technological innovation with personalized approaches can the goal of systemic accessibility in cultural institutions be meaningfully pursued.

Based on this evidence, this study aimed to highlight the crucial importance of adopting a systemic and collaborative approach that involves experts, institutions, and people with disability at every stage of design to promote a genuinely participatory and inclusive culture. Through the synergistic integration of technological innovation, inclusive design, and co-design, museum settings can increase their educational and cultural role and strengthen their social function as places of inclusion, participation, and sharing of cultural heritage.

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7. References

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