



ACCESSIBILITY IN ONLINE MUSEUM EXPERIENCES: A Comparative Analysis of Virtual Tours

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ABSTRACT

This study examines the accessibility of online museum experiences from the perspective of disability. The object of research consists of the virtual tours offered by five museums in the Community of Madrid. The methodology is based on a comparative analysis using the accessibility indicators for online exhibitions and museums proposed by Marinho and Norberto (2022), in dialogue with the UNE-EN 301549 standard and the WCAG guidelines. The results reveal that virtual tours are primarily conceived as immersive visual experiences with limited and non-systematic accessibility. It is concluded that there is a need to integrate universal design as a structural principle. As a future line of research, it is proposed to extend the analysis to other digital resources and to communicational accessibility.

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1. Introduction

Over recent decades, museums have progressively incorporated digital technologies that have transformed modes of access and cultural mediation (Giannini & Bowen, 2022). Virtual tours, online exhibitions and immersive interfaces have become established tools in museum dissemination strategies and have been presented as key solutions for sustaining public participation and institutional visibility in contexts of restricted physical access, such as during the COVID-19 pandemic (Gherheş et al., 2025). This transition has strengthened the relationship between digitalisation and accessibility, by making it possible to overcome physical, geographical and temporal barriers. However, the incorporation of digital technologies does not automatically imply an improvement in the conditions of cultural participation, nor does it guarantee equitable interaction with content for all audiences (Angarita et al., 2025). For this reason, a critical analysis is required of the role that these technologies play in museums and of their real impact on access to culture.

From the perspective of disability, although museums have advanced towards more inclusive models, significant limitations persist (Balci, 2024). While physical access has improved, sensory, cognitive, attitudinal and digital barriers remain common (Brischetto et al., 2023). Effective inclusion requires a structural change that incorporates the participation of people with disabilities and the application of universal and multisensory design across all museum practices (Żuchowska-Skiba and Olszewska, 2024). In this context, virtual tours and interactive interfaces can promote cultural participation, provided they are developed in accordance with accessibility criteria.

The present research analyses the virtual tours of five museums in Madrid —selected according to museological and statistical criteria— based on the indicators proposed by Marinho and Norberto (2022), applied to virtual visits and digital resources. The results show that these visits are conceived as immersive visual experiences, with limited and non-systematic accessibility that fails to address functional diversity and reproduces barriers from the physical environment. Digital accessibility appears disconnected from the institutional mission, and the very characteristics of interactive environments —360° viewers, iconographic interfaces, immersive navigation— introduce specific barriers that the literature has not yet addressed systematically.

2. Objectives

The main objective of this research is to analyse the online experience of virtual tours offered by five museums located in the Community of Madrid, from an accessibility perspective for people with disabilities. To achieve this objective, the following specific objectives are proposed:

- Analyse the degree of alignment of the digital experiences in the virtual tours section of these museums with digital accessibility standards.
- Identify the main access barriers that emerge in these online museum experiences for individuals with different types of disabilities.
- Reflect on the cultural and social implications of digital accessibility in digital museums, in relation to the right to cultural participation and the risks of exclusion linked to technological ableism.

To achieve these objectives, a literature review is conducted that constitutes the theoretical framework of this study and provides the foundation for the analysis, along with an examination of the online experiences derived from the virtual tours of the Museo Nacional del Prado, Museo Nacional Centro de Arte Reina Sofía, Museo Nacional Thyssen-Bornemisza, Museo Arqueológico Nacional and the Galería de las Colecciones Reales.

3. Theoretical Framework

The incorporation of digital technologies expands the possibilities of access to the museum experience, although it can also reproduce dynamics of exclusion when designs respond to a normative user and fail to consider functional diversity. Based on a literature review, disability is analysed from the social model and the human rights model, as well as the evolution of digitalisation in the museum field. Finally, the regulatory framework for the analysis of digital accessibility is examined in order to identify the most appropriate instrument for evaluating online museum experiences.

3.1. Disability: From the Social Model to the Human Rights Approach

“Disability is part of the human condition” (World Health Organization [WHO] and World Bank, 2011, p. 27). This statement, with which the World Report on Disability opens, summarises a paradigm shift in the understanding of this phenomenon: the transition from conceptions centred on individual disability towards structural approaches that locate barriers in the social, cultural and technological environment.

The social model of disability, which emerged in the 1970s from the Independent Living Movement, holds that disability does not have a strictly biological origin, but is produced by cultural, economic and environmental barriers that generate disadvantages for this minority group (Oliver and Barnes, 2010; Palacios, 2008). Unlike the medical model, which is oriented towards the rehabilitation of the individual, this approach proposes transforming environments to guarantee equality and inclusion (Victoria, 2013). As Guzmán et al. (2010) point out, the social model introduces “important paradigm shifts” from an ethical perspective (p. 52).

The human rights model, consolidated with the Convention on the Rights of Persons with Disabilities (United Nations and OHCHR, 2014), expands this approach by establishing that States have the responsibility to eliminate discriminatory barriers and guarantee full participation on an equal basis. This regulatory framework shifts the conception of persons with disabilities from passive recipients of assistance to their recognition as rights-holders, promoting their autonomy and independence. Both models —social and human rights— coexist today alongside earlier approaches (United Nations and OHCHR, 2014, p. 19) and constitute the conceptual framework from which digital accessibility is analysed in this study.

In the European context, the current stage is characterised by an approach of effective equality (Barriga, 2008), driven by milestones such as the European Year of Persons with Disabilities (2003), which reinforced institutional commitment to the rights and visibility of the group. This evolution is particularly relevant in an increasingly «phygital» context (BeRepublic, 2024), where the convergence between the physical and the digital generates new barriers that require specific analysis, particularly in interactive cultural environments such as museums.

3.2. The Museum in the Digital Transition

The incorporation of digital technologies in museums has not been a homogeneous or linear process but rather has undergone an evolution through multiple phases associated with technological, institutional and cultural transformations. Below, the digital evolution experienced by the museum sector is examined, and how accessibility guidelines have been considered in accordance with current regulations is analysed.

3.2.1. Physical Museums and the Digital Environment

Between the 1960s and 1990s, the first implementations of information and communication technologies in museums were primarily oriented towards internal tasks such as registration, cataloguing and research on collections (Nikolaou, 2024). During this period, technology was conceived as a support for management and specialised knowledge, rather than as a means to enhance the public’s experience (Yap et al., 2024). Towards the end of the 20th century, projects for the digitisation of collections began to become widespread, laying the foundations for the subsequent opening of content to the digital environment (Pavlovic, 2022).

From the beginning of the 21st century, museums entered a stage marked by the incorporation of the web and forms of interactivity (Pavlovic, 2022). The development of institutional websites, digital audio guides and mobile devices made it possible to link physical exhibitions with online content, with the aim of extending the visit and reinforcing its educational dimension. However, interaction remained limited and predominantly unidirectional, with technology functioning as a complement to the in-person visit (Furferi et al., 2024).

The COVID-19 pandemic led to lockdown measures on a global scale (Ballena et al., 2021), which required a rapid digital transition to ensure the continuity of museums (Markopoulos et al., 2021; Meng et al., 2022; Noehrer et al., 2021) and favoured the rise of digital museums (Jingjing et al., 2024). This context accelerated the adoption of digital transformation technologies and the exploration of new strategies to attract remote audiences.

From a longitudinal perspective, the academic literature interprets this evolution as a process of progressive transformation linked to institutional development, rather than as an abrupt change (Tham

et al., 2025; Yap et al., 2024). Theoretical models highlight gradual adaptation, with episodes of acceleration such as that provoked by the pandemic but supported by pre-existing structures. In this process, digital technologies have transcended the administrative sphere to become integrated into key areas such as exhibitions, education, audience analysis, economic sustainability and the emergence of new professional profiles linked to the digital domain.

3.2.2. Accessibility, Rights and Universal Design in the Museum Context

At present, numerous organisations are developing initiatives aimed at promoting social awareness of equal opportunities and universal accessibility, such as the celebration of world days, awareness campaigns, actions on social media and greater representation of persons with disabilities in the media. Together, these efforts favour progressive changes towards greater understanding and social sensitivity regarding functional diversity (Devotta et al., 2013).

In this context, the report *Ley General de Derechos de las Personas con Discapacidad y de su Inclusión Social. Versión en lectura fácil* (General Law on the Rights of Persons with Disabilities and their Social Inclusion. Easy-to-Read Version) (García Muñoz, 2015) includes, in its “Additional and Final Provisions”, various proposals to strengthen accessibility in different areas. Among these, the National Accessibility Plan promoted by the Government stands out, along with the plan for the prevention of deficiencies and worsening of disabilities, the improvement of infrastructure to reduce architectural barriers, and the incorporation of subjects on universal accessibility in vocational and university training (p. 55).

Complementarily, Article 14 of Royal Decree 193/2023, of 21 March, establishes the basic conditions of accessibility and non-discrimination in access to and use of public goods and services, obliging natural and legal persons to ensure that information directed to the public is accessible and appropriate to the needs of persons with disabilities, regardless of the channel used.

Likewise, Law 11/2023, transposing European Directive 2019/882, known as the European Accessibility Act, broadens the approach to accessibility by extending its requirements to services and certain products, with the aim of guaranteeing autonomy in everyday life. This legislation applies, among others, to products linked to computer systems and to services related to audiovisual communication, transport, banking services, e-commerce, basic utilities and social networks (AIS Certificación, 2023), promoting the harmonisation of accessibility criteria across the European Union.

In parallel with regulatory developments, the concept of “Universal Design” acquires a central role in reflections on accessibility. Initially formulated by Ronald L. Mace (1985, as cited in Sánchez, 2013) and expanded in the 2004 Stockholm Declaration of the European Institute for Design and Disability (EIDD), this approach holds that “good design empowers, bad design disables” (EIDD, n.d., para. 1) and seeks to guarantee equal opportunities through inclusive designs applicable to the urban environment, services, culture and information.

On the other hand, the American Alliance of Museums identifies seven basic principles —equitable use, flexibility, simplicity, perceptible information, tolerance for error, low physical effort and adequate size— (Arma, 2023), which translate into multiple forms of access to information and more comprehensible and equitable environments.

Finally, the integration of digital accessibility technologies in museum exhibitions contributes to eliminating barriers that hinder full participation in cultural content (Jinling et al., 2024). However, as Carrillo (2020) points out, accessibility should not be limited to physical barriers, but should also encompass information, communication and participation. This view aligns with that expressed by Fortuna et al. (2023) and Cano (2017), who emphasise the importance of a universal design approach centred on the user from the initial phases of projects.

3.2.3. Digital Practices and Online Experiences as a Complement to the Museum

The notion of the virtual museum has been used to describe collections of digitised objects accessible through digital environments, viewable from any location and allowing flexible interaction with collections (Deloche, 2003; McKenzie, 1997, as cited in Vélez, 1999; Talens and Hernández, 1997). Since its emergence in the mid-1990s, linked to the development of the “information superhighways”, this concept has evolved significantly in its uses and meaning (Vélez, 1999). Today, the virtual museum is not conceived as an autonomous entity, but as part of an ecosystem of digital experiences that extend traditional museum mediation.

In this sense, it is more appropriate to understand these initiatives as digital or online museum experiences, conceived as extensions of the physical museum rather than as its replacement. From this perspective, the comparison between physical and virtual museum loses relevance, since both offer complementary benefits. As Reigosa (2019) points out, the digital experience does not replace the in-person visit, but rather prolongs it, anticipates it or reconfigures it, thereby expanding the possibilities of access to collections. The contemplation of the work of art, which emerges as a space of encounter, remains irreplaceable.

One of the main features of digital museum experiences is their potential for accessibility, particularly in terms of continuous availability and the overcoming of spatial barriers. Moreno (2005) highlights that permanent access to content, subject to an internet connection, makes it possible to overcome the geographical limitations of the physical museum. Likewise, these experiences facilitate alternative access from the home and acquire relevance for people with physical or intellectual disabilities.

Furthermore, digital environments enable forms of engagement with works that are difficult to reproduce in traditional exhibition spaces, such as non-linear tours and personalised explorations. In these contexts, the visitor gains greater control over their experience, establishing a more autonomous relationship with the collections (Carreras, 2005).

In the current context, these experiences materialise in practices such as virtual tours, digital exhibitions and online collections integrated into institutional strategies (Biedermann, 2021; Yang et al., 2024). However, their capacity to broaden access depends on the accessibility conditions of the digital environments, which can generate new barriers if inclusive criteria are not incorporated from the design stage (Ding et al., 2024; Nikolaou, 2024).

3.3. Regulatory Framework for the Analysis of Digital Accessibility

In the European context, the digital accessibility of products and services is articulated through various complementary normative and technical frameworks. Firstly, the European Accessibility Act (EAA) establishes the legal obligation to ensure the accessibility of certain products and services, defining its scope and the obliged parties, but without detailing the technical mechanisms for its implementation. For its part, the Web Content Accessibility Guidelines (WCAG 2.2), developed by the World Wide Web Consortium (W3C), provide an international set of technical guidelines that specify how to design and evaluate accessible web content, structured around four fundamental principles: perceivability, operability, understandability and robustness. Within this framework, the EN 301 549 standard serves as the European technical reference by incorporating and adapting the WCAG to the European regulatory context and extending its criteria to other ICT products and services. In this way, while the EAA defines the legal requirement for accessibility, the WCAG specify the technical criteria, and EN 301 549 enables the operationalisation and evaluation of compliance in digital environments, such as online museum experiences.

The interconnection between the EAA, WCAG 2.2 and EN 301 549 creates a coherent regulatory ecosystem. The EAA establishes the legal framework, EN 301 549 defines the specific technical requirements, and the WCAG serve as the basis for web content. By complying with UNE-EN 301549, companies automatically align with the legal obligations of the EAA (Insuit, 2025, para. 23).

From an institutional perspective, according to the Asociación por la defensa del derecho a la accesibilidad web (Association for the Defence of the Right to Web Accessibility, ADDAW, n.d.), the objective of the EN 301 549:2022 standard is to ensure that products are usable by all people, including individuals with disabilities. This standard is the result of a review of the previous version, UNE-EN 301549:2019, and takes into account technological advances and current user needs.

However, recent data reveal a significant gap between the regulatory framework and its practical application. According to the Web Accessibility Barometer 2025, produced by InSuit in collaboration with Tech4access, “98% of large private companies in Spain fail to comply with the European Accessibility Act (EAA)” (para. 1). Furthermore, one in four websites does not meet the minimum requirements of an accessibility audit, and the most frequent errors —identified as “insurmountable barriers for users”— include the absence of alternative text in images, insufficient colour contrast (which must achieve a minimum ratio of 4.5:1), forms without appropriate labels, confusing hierarchical structure resulting from an illogical ordering of headings, and exclusive dependence on JavaScript (InSuit, 2025; Tech4access and InSuit, 2025).

In this context, a particularly relevant element of UNE-EN 301549 is its functional performance approach, which shifts attention from the technology to the user experience. This approach considers scenarios such as use without vision, without hearing, with limited mobility or with reduced cognitive capacities, and proves particularly suitable for evaluating accessibility from a disability perspective. In contrast to evaluations focused exclusively on technical compliance, the functional performance approach allows analysis of whether a digital experience can be used effectively by people with diverse needs and abilities.

4. Methodology

The present research analyses five museum institutions located in Madrid: the Museo Nacional del Prado, the Museo Nacional Centro de Arte Reina Sofía, the Museo Nacional Thyssen-Bornemisza, the Museo Arqueológico Nacional and the Galería de las Colecciones Reales. The sample selection is based on museological, methodological and statistical criteria to ensure the internal coherence of the study, the comparability of the data and its scientific validity.

Firstly, all the selected institutions meet the definition of a museum established by the International Council of Museums (ICOM), as they are permanent entities, open to the public, non-profit, that acquire, conserve, research, communicate and exhibit cultural heritage for educational and social purposes (ICOM, 2022). Likewise, they possess stable collections, consolidated curatorial structures and regular museographic programming, which allows their analysis from a rigorous museological perspective.

Secondly, the selection is supported by verifiable quantitative criteria, as all five museums exceed 500,000 annual visitors according to official statistics. In the case of the Museo Arqueológico Nacional, the data come from the Estadística de Museos y Colecciones Museográficas of the Ministry of Culture (Ministerio de Cultura, 2025). For the Galería de las Colecciones Reales, the figures are based on the institutional statistics of Patrimonio Nacional, published annually (Patrimonio Nacional, 2026). For their part, the Prado, Reina Sofía and Thyssen-Bornemisza museums disseminate their figures through institutional statements and official reports, widely reported by public bodies and cultural agencies (Ministerio de Cultura, 2025). Therefore, museums with high visitor numbers were chosen, considering that such attendance justifies their social relevance and the availability of resources to implement accessibility measures aimed at people with disabilities. Within this quantitative criterion, the Museo del Real Madrid (“Tour Bernabéu”) and the Palacio Real de Madrid were excluded, since although both could be considered to meet the aforementioned criteria (the proposed museum definition and the annual number of visitors), the visitor experience in both cases introduces structural biases that prevent direct comparison with museums in the strict cultural sense.

The combination of state-owned museums, foundation museums and those under Patrimonio Nacional finally allows the analysis of high-attendance institutions with different management models, while maintaining a common museological and statistical framework. This strategy strengthens the internal validity of the study, avoids comparisons between non-equivalent categories and guarantees the replicability and scientific robustness of the analysis.

For the analysis of accessibility strategies in the virtual tours of the selected museums, the “Accessibility indicators for online exhibitions and museums”, presented in Table 1 and developed by Marinho and Norberto (2022), were used. According to the authors, this tool is based on international guidelines, the Web Content Accessibility Guidelines (WCAG 2.1) and the academic literature on accessibility in digital and museum environments. The authors note that, although numerous automatic tools exist for evaluating web accessibility, these often present inconsistencies and errors, a point supported by Dubois et al. (2014) and Vigo et al. (2013). Likewise, it is highlighted that such tools do not allow evaluation of attitudinal and communicative aspects, as their application is limited to the technical structure of web development.

The tool is structured around three indicators, each composed of differentiated attributes. The first, “Design and navigability”, refers to the structure of the digital platform and the navigation actions within the online exhibition. The second, “Attitudinal”, alludes to the institution’s efforts to promote policies of diversity, equity and inclusion, including people with disabilities. The third, “Communicative”, focuses on the informative and instructional aspects, both internal and external, of online exhibitions. Together, the three indicators break down into a total of 35 items, which constitute a reference for the creation, updating and evaluation of online exhibitions, with the aim of improving access to museums and education for diverse audiences.

The analysis was conducted independently by the three researchers signing the study. In an initial phase, a pilot test was carried out with the Museo Nacional del Prado in order to compare interpretations, unify registration criteria and resolve discrepancies in the application of the items. Subsequently, each researcher evaluated the five museums independently. The assessments were compared through a double-coding session, and discrepant cases were resolved by reasoned consensus among the three coders. This procedure strengthened inter-coder reliability and minimised interpretive biases.

Access to the virtual tours and the application of the indicators took place between 2 and 19 January 2026. The date of each observation session for each museum was recorded, given the dynamic nature of web content. The URLs for access to the virtual tours were documented and verified at the beginning and end of the data collection period.

For each of the 35 items proposed by Marinho and Norberto (2022), a three-level classification system was established: full compliance (CT), when the criterion is fully and verifiably satisfied; partial compliance (CP), when the criterion is observed with limitations, implicitly, or without explicit specification by the institution; and non-compliance (NC), when no observable evidence of the criterion is identified or the institution does not communicate information in this regard. This ordinal scale makes it possible to capture relevant nuances that a binary record would not reflect, while offering a systematic framework for inter-institutional comparison. The results are presented in Table 2.

Table 1. Accessibility indicators for online exhibitions and museums

Indicator	Design and navigability
<i>Attribute</i>	<i>Comfort, security and flexibility of navigation.</i>
Analysis factor	1. Visits can be made via desktop computers and mobile devices, in both portrait and landscape mode.
	2. Navigation is compatible with different input devices, such as a mouse and keyboard.
	3. Navigation and interaction are consistent throughout the activity, and clear instructions are provided in case of change.
	4. Navigation instructions or section titles can be accessed using assistive technology.
	5. It is possible to navigate between modules in any order and at any time during the visit, and the mechanisms can be accessed using assistive technology.
	6. Textual information is displayed in text format, not as text images.
	7. Sections can be visited without a predefined time limit or, if there is one, the timer can be disabled.
	8. Sections can be visited without automatic screen movement or, if there is, the movement can be interrupted.
	9. The visit is free of visual stimuli with flashing lights.
Indicator	Design and navigability
<i>Attribute</i>	<i>Flexibility of access, handling and presentation</i>
Analysis factor	10. The visit does not contain elements that open or appear automatically when focused on with input devices.
	11. The tour does not contain sounds that start automatically.
	12. Textual information can be customised in size and contrast without loss of content or functionality.
	13. All links can be identified by text alone, regardless of context.
Analysis factor	14. All textual and visual content, except decorative elements, is displayed with good contrast between background and foreground elements.
	15. Professionals with disabilities are part of the institution's staff and participate in the development of online exhibitions, and this is mentioned during the visit.
	16. Information is provided on institutional programmes that promote the inclusion of people with disabilities in online activities.
	17. Visitors are provided with different means of contact (e.g. email, social media, institutional telephone numbers) with accessible communication.
Analysis factor	18. Accessible mediated activities are offered for the online exhibition.
	19. Accessibility and inclusion are part of the institutional mission and are mentioned in institutional documents.

	20. Online activities and resources are or will be adapted to the international parameters proposed by the W3C through the most up-to-date WCAG.
	21. Promotion of institutional activities related to online and physical accessibility among staff is reported.
	22. Appropriate and respectful ways of referring to persons with disabilities are reported.
	23. Professional and/or financial support to promote employee training in accessibility is reported.
	24. Information is provided on the resources available to develop, evaluate and implement actions that promote accessibility.
	25. Information is provided on periodic institutional evaluation actions regarding accessibility in online activities.
Indicator	Communicative
<i>Attribute</i>	<i>Communication and dissemination to a wide audience</i>
Analysis factor	26. Communication on websites and/or social media is accessible according to the specific characteristics of each platform.
	27. The accessibility features of the exhibition are reported on the communication channels.
	28. Instructions and/or demonstrations on how to navigate the platform with the same accessibility are provided.
<i>Attribute</i>	<i>Diverse media and resources for pluralistic communication</i>
Analysis factor	29. The use of language is consistent throughout the exhibition and foreign words are translated.
	30. Uncommon words, expressions specific to the content of the presentation, and abbreviations are accompanied by a definition and/or explanation.
	31. Instructions are presented with at least two types of sensory stimulus, such as visual, textual, or auditory.
	32. Alternative media accompany all video and audio content with equivalent information.
	33. All audio content has equivalent captions or transcripts.
	34. Sign language interpretation is provided for audible content and automatic sign language translation software for textual content.
	35. All visual information is accompanied by alternative text and/or audio descriptions.

Note. Adapted from "The development of an accessibility indicator framework for analysing online exhibitions: a pathway for social inclusion in museums' activities", by L. Marinho and J. Norberto, 2022, in Proceedings: II International Congress on Museums and Digital Strategies. UPV.

It is important to note that the evaluation has focused exclusively on virtual tours or digital resources that enable remote exploration of the collection, in accordance with the definition of virtual visit provided by El-Said and Aziz (2022), taking into account the observable user experience and the information explicitly communicated by the institutions in the relevant sections. No technical accessibility features have been inferred when these were not declared or clearly verifiable through use of the resource. The absence of information has been considered a result. The analysis of the 35 items is based on the virtual tours as they are integrated and presented on the museums' official websites, without analysing the complete institutional website or the general accessibility policies of the site unless they are explicitly applied to and mentioned in relation to the virtual tours.

On the other hand, it should be pointed out that the five museums employ different technological solutions for their digital experiences. While four of them offer immersive 360° virtual tours, the Galería de las Colecciones Reales (GCR), inaugurated in July 2023, presents its collection through the "Explorar" section of its institutional website. The GCR therefore does not provide a web-based 360° virtual tour, but it does offer a mobile application (GVAM Guías interactivas) and an on-site immersive experience called El Cubo. For the present study, the "Explorar" section of its website has been analysed. It should also be noted that the information obtained from the Museo Arqueológico Nacional via mobile phone was not extracted through its website, but from its official application. This is because accessing MAN Virtual from a mobile device requires the use of that application.

Therefore, it is necessary to emphasise that the technological diversity of the platforms employed — Second Canvas (Prado and Thyssen), Google Arts & Culture (Reina Sofía), MAN Virtual (Arqueológico Nacional) and institutional website (GCR)— constitutes a relevant factor in the interpretation of the results, since accessibility capabilities (keyboard navigation, screen reader compatibility, responsive design) depend in part on the underlying technological infrastructure.

5. Analysis and Results

Below, a summary table is first presented with the results for each item and each museum. Subsequently, a summary of the findings obtained is provided, accompanied by a description of the relationships established between them. These are detailed in an organised manner according to the three indicators established in the analysis framework.

Table 2. Compliance with the 35 accessibility items in the virtual tours of the museums analysed

No.	Evaluation item	PR	TH	RS	MAN	GCR
<i>I. Design and navigability</i>						
1	Device access and guidelines	●	●	●	●	●
2	Input device compatibility	●	●	●	●	●
3	Consistency in navigation and instructions	●	●	●	●	●
4	Access through assistive technologies	○	○	○	○	○
5	Freedom of order on the route	●	●	●	●	●
6	Presentation of textual information	○	○	○	○	●
7	Time limit	●	●	●	●	●
8	Automatic screen movement	●	●	●	●	●
9	Intermittent visual stimuli	●	●	●	●	●
10	Automatically opening elements	●	●	●	●	●
11	Automatic sound	●	●	●	●	●
12	Text and contrast customisation	○	○	○	●	○
13	Textual identification of links	●	●	○	●	●
14	Visual contrast	●	●	●	●	●
<i>II. Attitudinal</i>						
15	Participation of professionals with disabilities	○	○	○	○	○
16	Online inclusion programmes	○	○	○	○	○
17	Accessible means of contact	●	●	●	●	●
18	Online accessible mediation	○	●	○	●	●
19	Accessibility in the institutional mission	●	●	●	●	●
20	Reference to WCAG standards	●	●	●	●	●
21	Internal promotion of accessibility	○	○	○	○	○
22	Respectful language	●	●	●	●	●
23	Accessibility training	○	○	○	○	○
24	Specific accessibility resources	○	○	○	○	○
25	Periodic assessment	○	○	○	○	○
<i>III. Communicative</i>						
26	Accessible communication	●	●	●	●	●
27	Accessibility information	○	○	○	○	○
28	Accessible instructions	●	●	●	●	●
29	Language and languages	●	●	●	●	●
30	Definition of terms	○	○	○	○	○
31	Multisensory instructions	●	●	●	●	●
32	Alternatives to audiovisuals	●	●	○	●	○
33	Subtitles and transcripts	○	○	○	○	○
34	Sign language	○	○	○	○	○
35	Audio description or alternative text	○	○	○	○	○
● Full compliance (n)		9	10	9	9	8
● Partial compliance (n)		10	10	9	11	13
○ Does not comply (n)		16	15	17	15	14
% Total compliance		25.7	28.6	25.7	25.7	22.9

Note. ● = full compliance (CT): the criterion is fully satisfied; ● = partial compliance (CP): the criterion is observed with limitations or without explicit specification; ○ = non-compliance (NC): absence of the criterion or no observable evidence. PR = Museo Nacional del Prado; TH = Museo Nacional Thyssen-Bornemisza; RS = Museo Nacional Centro de Arte Reina Sofía; MAN = Museo Arqueológico Nacional; GCR = Galería de las Colecciones Reales. Websites analysed: museodelprado.es/visita-virtual-coleccion-2023; museothyssen.org/thyssenmultimedia/visitas-virtuales; artsandculture.google.com/partner/museo-reina-sofia; manvirtual.es; galeriadelascoleccionesreales.es/explore

5.1. Indicator 1. Design and Navigability

In relation to access to and use of the virtual tours, all museums allow entry from computers and mobile devices—in the case of the Museo Arqueológico Nacional, downloading the application is required—and they impose no time limits for completing the tour. The experiences are primarily designed for large screens and do not communicate specific adaptations for screen orientation. Interaction relies systematically on the use of a mouse and touch devices, without prior indication of compatibility with keyboard navigation or other alternative input devices.

Navigation is consistent in all cases, although instructions for use are not presented explicitly but depend on visual and iconographic conventions. None of the museums specifies compatibility of the virtual tours with assistive technologies such as screen readers. The structure of the tour is predominantly free, allowing the user to move without a predefined order, with the exception of those visits that incorporate guided, sequential tours, as in the case of the Museo Thyssen.

Textual information is integrated, in most museums, directly into the visual interface of the tour, without detailing its semantic accessibility. Only in one case does the use of structured web text predominate as the primary means of conveying information. Regarding the dynamic behaviour of the interface, some museums incorporate automatic camera movement during the visit, while in others movement depends exclusively on user action. No intermittent visual stimuli were identified in any of the resources analysed.

The Museo Arqueológico Nacional offers options for customising text size when accessing the visit. None allows additional control of visual contrast during the virtual tour. Interactive elements are identified predominantly through icons, with occasional cases combining icons and text, or prioritising textual links. In general, the visual contrast between the background and content is adequate, although no technical criteria or adjustment options are provided.

5.2. Indicator 2. Attitudinal

The results relating to the attitudinal indicator reveal a generalised absence of explicit references to inclusion and digital accessibility in the design and development of the virtual tours. The tours do not communicate the participation of professionals with disabilities in these processes, nor the existence of specific inclusion programmes linked to online activities.

Although all the museums provide institutional contact channels on their websites, in no case is their accessibility or suitability for different communicative needs during the visit specified. The virtual tours incorporate various types of digital mediation—general, informative or guided in nature—, although none of them is described as accessible or explicitly adapted for people with disabilities.

Accessibility is mentioned in the institutional policies of all the museums analysed—through accessibility statements, Universal Design strategies or references to regulatory standards such as UNE-EN 301549—, but without any direct link to the virtual tours. In references to web accessibility regulatory standards, in general terms, their application to the virtual tours is also not detailed. No explicit actions are identified that are communicated in relation to staff training in digital accessibility, the allocation of specific resources or the periodic evaluation of the accessibility of these contents.

5.3. Indicator 3. Communicative

In the communicative domain, the virtual tours of the five museums are presented through clear and comprehensible communication, although they do not explicitly incorporate criteria of communicational accessibility. No specific information is provided regarding the accessibility of the digital contents or the conditions of use for different functional abilities.

The instructions for using the virtual tours are implicit and, in all cases, rely on visual elements. The language employed is consistent and the contents are available in several languages, but systematic definitions of specialised terms or resources to support comprehension are not included.

Multisensory communication is limited. Although some tours optionally incorporate auditory elements, consistently across all museums there is no a priori provision of alternatives to audiovisual contents that include subtitles, transcriptions, sign language interpretation, audio description or structured alternative texts, which restricts autonomous access for people with sensory disabilities.

6. Discussion

The results reveal that the virtual tours of the analysed museums have been conceived primarily as immersive visual experiences in which digital accessibility is not integrated in a systematic or explicit manner. Although the resources allow broad access in technological terms (multi-device compatibility and no time limits), this accessibility is fundamentally limited to basic technical aspects and does not extend to users' functional diversity.

The high degree of homogeneity observed across the museums suggests the existence of a virtual tour model centred on visual exploration and interaction through iconography, which reproduces in the digital environment barriers similar to those present in the physical space when universal accessibility measures are not implemented. This finding is consistent with similar studies conducted in other geographical contexts (Bogdanova et al., 2021; Li et al., 2022).

Particularly noteworthy is the absence of information regarding compatibility with assistive technologies, the lack of non-visual alternative navigation, and the non-existence of sensory accessibility resources (subtitles, audio description, sign language). These shortcomings directly affect people with visual and hearing disabilities, limiting their autonomy in accessing the virtual tours. This reveals a gap between policies of physical and digital inclusion.

An additional factor in interpreting the observed differences is the technological heterogeneity of the platforms employed. For example, the Prado and Thyssen use Second Canvas technology (Madpixel), whereas the Reina Sofía hosts its tours on Google Arts & Culture, an external platform that natively incorporates accessibility standards from the Google ecosystem (semantic labelling, keyboard navigation, screen reader support). This circumstance may help explain certain differences in technical items such as navigation or semantic structure. Nevertheless, the results show that the Reina Sofía does not stand out in full compliance (25.7%), suggesting that the platform's native advantages do not automatically translate into greater overall accessibility of the resource. It is the Thyssen-Bornemisza that achieves the highest rate of full compliance (28.6%), possibly associated with the combination of multisensory instructions and a coherent interface in its guided tours, albeit with limitations in other areas, such as textual presentation. For its part, the MAN employs a proprietary platform developed in collaboration with Samsung (2017), while the GCR offers an informative web experience without an immersive 360° component.

The case of the GCR is particularly illustrative: inaugurated in July 2023, it is the most recently created institution in the sample and yet does not offer an online 360° virtual tour, unlike museums whose digitisation (with virtual tours) dates back to 2017 (Museo Arqueológico Nacional, 2017) or 2022 (Museo Nacional del Prado, n.d.). Its choice of a mobile app and on-site immersive experience (El Cubo) suggests a different digitisation model, oriented towards in-situ mediation rather than remote accessibility.

Regardless of the technological solution adopted, the results suggest the existence of a structural tension between technological immersion and universal accessibility. The analysed virtual tours prioritise an aesthetic and visually enveloping experience based on panoramic tours, high-resolution photographs and iconographic interfaces, which, while appealing to a normative audience, constitutes an exclusionary model for users with functional diversity. This logic corresponds to what might be termed an aestheticisation of the digital experience, in which visual quality and the sense of immersion take precedence over inclusive functionality. Such an approach implies that accessibility may come to be regarded as an element that could compromise the aesthetic experience, rather than being conceived as a principle compatible with it and even capable of enriching it.

This tension acquires a particularly relevant institutional dimension when considered in the light of the current regulatory context. The European Accessibility Act (EAA), transposed in Spain through Law 11/2023, establishes legal obligations for the accessibility of digital products and services which, although not explicitly mentioning museum virtual tours, configure a framework of responsibility applicable to digital services offered by public institutions. The five institutions analysed are public entities with significant budgets and considerable technical resources. The systematic absence of accessibility criteria in their virtual tours cannot therefore be attributed to resource limitations but rather reveals a strategic prioritisation that relegates digital accessibility in favour of other objectives such as dissemination, international projection or technological innovation.

This disconnection is clearly manifested in the results for items 19 and 20: all the analysed museums have institutional accessibility statements and references to regulatory standards, but these policies are

not operationally translated into the virtual tours, which lack the specific adaptations that such statements presuppose.

In this sense, the results directly challenge the digital cultural policies of public institutions. If museums aspire to fulfil their social function —as established by the ICOM definition (2022)—, accessibility cannot be limited to the physical space or treated as an additional layer but must be integrated as a transversal principle across all dimensions of the museum experience, including the digital one. The observed gap between frequently visible and communicated physical accessibility policies and the accessibility of virtual tours suggests that the digital transformation of museums has inadvertently reproduced dynamics of exclusion that current legislation precisely seeks to correct.

Overall, the study highlights the need to advance towards a universal design approach applied to museum digital environments, in which accessibility is not an afterthought but a structural principle in the design of virtual tours. Integrating criteria of communicational, sensory and cognitive accessibility would make it possible to broaden potential audiences and enrich the digital museum experience from an inclusive and sustainable perspective.

7. Conclusions and Future Research Lines

The main contribution of this study lies in the systematic application of a framework of accessibility indicators specifically designed for digital museum environments —that proposed by Marinho and Norberto (2022)— to the virtual tours of five high-attendance museums in Spain, within the context of the European regulatory framework (EAA, WCAG, EN 301 549). Unlike previous research, which has addressed digital museum accessibility in a partial manner or in different geographical contexts (Bogdanova et al., 2021; Li et al., 2022), the present work offers a comprehensive comparative analysis that encompasses the technical, attitudinal and communicative dimensions of accessibility, applied to leading public institutions with specific regulatory obligations. Likewise, the adoption of a three-level assessment scale (full compliance, partial compliance and non-compliance) makes it possible to move beyond the usual binary records and provide a diagnosis with greater analytical resolution.

The Universal Design approach, which promotes inclusive environments from their conception, proposes more accessible, diverse and user-centred digital experiences. Online museum experiences — such as virtual tours and digital collections— expand access and overcome spatial barriers, although their effectiveness depends on the proper application of accessibility criteria set out in the European regulatory framework.

The analysis carried out shows that the virtual tours developed by the studied museums primarily prioritise the visual dimension and the sense of immersion, while digital accessibility does not constitute a transversal axis of their design. Although these initiatives broaden access from a technological perspective, they do not sufficiently consider the diversity of users' abilities, thereby limiting their inclusive reach and consolidating their role as a complementary resource to the in-person experience. Likewise, the similarity in the approaches adopted by the different institutions suggests the existence of a common model that transfers to the digital environment barriers analogous to those in the physical space, particularly due to the limited integration of assistive technologies and strategies oriented towards sensory accessibility, and which, in some cases, contrasts with the accessibility policies declared by the institutions themselves and even applied in certain areas of their online sites.

This research opens future lines of work. One of these would be the comprehensive analysis of the accessibility information that these and other museum institutions provide on their websites. In this regard, it is particularly relevant to examine the easy-to-read contents and tours that numerous museums already incorporate, including some of those analysed here. In these, we can find clear explanations, formulated in simple words, about the works, their artists or the artistic movements to which they belong, as well as their transcription in sign language.

For all these lines of research, it seems pertinent to conduct in-depth interviews with the teams responsible for these areas in order to gain a more detailed understanding of their Diversity, Equity and Inclusion (DEI) policies. Similarly, the establishment of focus groups with people with disabilities would make it possible to understand first-hand their navigation and use experience of the resources available from these institutions and to establish relevant recommendations for the development of an inclusive museum experience, both in the physical and digital environments.

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