

***Redefining the Museum Experience: Modeling as a Mechanism for
Sensory Perception and Heritage Interpretation for the Blind***

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Abstract:

The safety and security of artifacts in museums hinge on the principle of non-contact; repeated handling can lead to their permanent loss. However, this poses a significant challenge for visitors with special needs, particularly the blind, whose primary means of understanding and imagining objects is through touch.

Museum modeling offers a powerful solution to this dilemma. By utilizing techniques and tools to create physical or virtual experiences that simulate or simplify museum content, modeling can significantly enhance visitor engagement. This includes providing 3D printed replicas for tactile exploration, incorporating digital modeling and virtual reality (VR), and adopting a user-centered design approach. These methods create an inclusive educational and recreational environment, allowing People with visual impairments visitors to experience and connect with artifacts in a meaningful way, all while ensuring the preservation of the original pieces.

Keywords: Museum Accessibility; People with Disabilities; 3D Printing; Virtual Reality; Modeling.

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ملخص:

تعتمد سلامة وأمن القطع الأثرية في المتاحف على مبدأ عدم التلامس؛ حيث يمكن أن يؤدي التداول المتكرر إلى فقدانها بشكل دائم. ومع ذلك، يمثل هذا تحديًا كبيرًا للزوار من ذوي الاحتياجات الخاصة، وخاصة المكفوفين، الذين تُعد حاسة اللمس وسيلتهم الأساسية لفهم وتصوير الأشياء.

تقدم النمذجة المتحفية حلاً قويًا لهذه المعضلة. فمن خلال استخدام التقنيات والأدوات لإنشاء تجارب مادية أو افتراضية تحاكي أو تبسط محتوى المتحف، يمكن للنمذجة أن تعزز بشكل كبير من تفاعل الزوار. ويشمل ذلك توفير نُسخ مطبوعة ثلاثية الأبعاد للاستكشاف اللمسي، ودمج النمذجة الرقمية والواقع الافتراضي (VR)، واعتماد منهجية تصميم تتمحور حول المستخدم.

تخلق هذه الأساليب بيئة تعليمية وترفيهية شاملة، مما يتيح للأشخاص ذوي الإعاقة البصرية تجربة القطع الأثرية والتواصل معها بطريقة هادفة، مع ضمان الحفاظ على القطع الأصلية في الوقت ذاته.

كلمات مفتاحية: إمكانية الوصول للمتاحف، ذوي الإعاقة، الطباعة ثلاثية الأبعاد، الواقع الافتراضي، النمذجة.

- Introduction:

Museums are essential cultural and civilizational spaces, housing humanity's heritage and providing platforms for education and contemplation. However, the principle of preserving artifacts from damage due to physical interaction has long presented a challenge to achieving full visitor inclusivity, particularly for individuals with special needs. While sight is the primary sense for exploring museum exhibits, The blind individuals frequently encounter traditional barriers that prevent them from direct interaction with original artifacts, thereby excluding their crucial sense of touch in forming perceptions and understanding. This contradiction between the necessity of preservation and the right to access poses a systematic challenge for museums striving to offer a rich and accessible experience for all.

In this context, advancements in modeling technologies emerge as a promising solution, enabling museums to overcome these obstacles without compromising the integrity of precious exhibits. Modeling is no longer just a tool for creating miniature representations; it has evolved to include 3D printed replicas, virtual reality (VR), and user-centered digital design, opening new avenues for effectively engaging the people with visual impairments. This article aims to explore how modeling can bring about a qualitative transformation in the museum experience for the blind visitors, overcoming traditional challenges. The research will present specific examples of innovative display methods that leverage modeling to enhance sensory interaction, while also highlighting the current problems faced by the blind in museums, and how modeling can offer sustainable solutions that contribute to building more accessible and equitable museums.

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1- Modeling in Museums

1.1- The Modeling

Modeling is defined as the process of identifying, discovering, encoding, and building the capacity to replicate, transfer, or demonstrate attributes, skills, practices, and abilities. It also involves embodying and visualizing ideas to make them easier to understand and modify. In this context, it refers to what stimulates the emergence of new ideas.

Modeling is a crucial process for transforming abstract concepts and ideas into tangible forms. This aligns with the fundamental definition of modeling as a mechanism for embodying ideas to make them easier to grasp. Consequently, museum institutions apply the principles of modeling when presenting history, culture, and science through physical exhibits. These exhibits convert complex information into sensory experiences that simplify visitor understanding and stimulate their intellectual curiosity.

The role of this process isn't limited to merely showcasing historical records; it also serves as a means of transmitting knowledge and sparking new ideas, making museums dynamic environments for learning and discovery.

Thus, modeling can be described as the visual representation of an item's characteristics, qualities, and abilities, simplified, condensed, and abstracted to express the original item.¹

1.2- The Use of Modeling in Museums

The application of modeling in contemporary museums is evident through the adoption of advanced digital tools and techniques that translate cultural ideas and concepts into tangible experiences. Among the most prominent of these tools are 3D printing, virtual reality, augmented reality, interactive screens, and holographic technology. These innovations have enabled museums to present rich and interactive content that goes beyond the limits of traditional display, enhancing visitors' understanding of the exhibited material, including those with visual impairments.

1.2.1. 3D printing using a printer

3D printing: is an additive manufacturing method that appeared in 1980 and was called rapid prototyping technology. It allows a three-dimensional, tangible

كفاية سلمان أحمد، وآخرون، الواقع الافتراضي والعرض الرقمي كوسيلة لتوثيق الأزياء¹ n.d.، التراثية، مجلة التصميم الدولية، المجلد 7، العدد 4، أكتوبر 2017، ص 462

product to be created by designing it on a computer and then printing it (manufacturing it) with a 3D printer.²

One of the most significant advantages of 3D printing is its ability to produce highly complex shapes, including hollow parts or those with internal lattice structures designed to reduce weight. It's important to note that a prerequisite for the printing process is the availability of a 3D digital model.

In the context of museums, 3D printing is utilized in two distinct ways. Firstly, it's used in the restoration of damaged archaeological or architectural artifacts. Here, damaged parts are reproduced using matching models based on digital data, allowing for precise reconstruction of the artifact or building. Secondly, 3D printing is employed to create 3D digital models of artifacts for display in public squares or to provide replicas of artifacts for sale in museum shops.³

Additionally, some museums resort to displaying identical replicas of rare or fragile artifacts whose direct exhibition might lead to their original condition deteriorating. This is achieved through 3D printing techniques. An example of this is what the Naturalis Biodiversity Center in Leiden, Netherlands, did. They used 3D printing to replace a missing part of the T-Rex dinosaur skeleton known as "Trix." Since the skeleton was missing some bones, the project's organizers decided to print the upper part of the left leg using a model matching the right leg, instead of using bones taken from other individuals.⁴

The use of this technology isn't limited to protecting original artifacts; it also extends to replicating tangible models specifically for blind and visually impaired individuals. This significantly enhances their access to museum content and enriches their sensory experience.

² Ali Hamood Twaij, Imad Hamood Abdulhussein, and Zahraa Hussein Alioue, The Effect of Using 3D Printer in Implementation of Pottery Sculpture Designs, *بحوث الفنون* العدد36 الاصدار1-2020, n.d., مجلة لارك للفلسفة و اللسانيات و العلوم الاجتماعية Edition.

³ سيد عبده أحمد ، أسامة يوسف محمد، عمر بنعبد العزيز مخلص ، إحياء المباني والتحف الأثرية والحفاظ عليها باستخدام المسح ثلاثي الأبعاد وتكنولوجيا الواقع المختلط مجلة العمارة والفنون والعلوم الإنسانية - المجلد السابع - العدد الحادي والثلاثون، نيناير 2022، n.d. ص 775

⁴ el_pedrodude, '3D-printed T-Rex fossil reconstruction at Naturalis, Leiden', Reddit Post, R/3Dprinting, 30 December 2022
<https://www.reddit.com/r/3Dprinting/comments/zz6gsb/3dprinted_tr_ex_fossil_reconstruction_at_naturalis/> [accessed 23 June 2025].

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A prime example in this field is the Louvre Museum in Paris. The Louvre provides tactile models of artistic and historical works within dedicated routes for blind and visually impaired visitors, allowing them to interact directly with exhibits in an inclusive and sensory manner. The museum places great emphasis on enabling this group to engage with its collections through specialized spaces and experiences. The museum applied this methodology by creating a Tactile Gallery where visitors can touch plaster or resin casts of original sculptures, accompanied by an audio guide and workshops titled "Touching to See." Furthermore, the museum opened a new space called "La Petite Galerie," which includes a special tactile strip, a tactile book, and a downloadable audio-described tour with samples of materials that can be explored during the visit, further enhancing visitors' sensory perception.⁵

These examples clearly show that 3D printing is one of the most effective modeling tools for enhancing blind visitors' understanding of museum content. It does this by creating tangible representations of artistic and architectural elements. Its use goes beyond merely protecting original pieces or providing educational replicas; it also acts as a sensory bridge, enabling blind visitors to interact with cultural heritage in a direct and inclusive way. This integration of technology and human-centered design reflects the modern museum's shift towards more inclusive and diverse visitor experiences.

1.2.2. Virtual Reality and Augmented Reality

Virtual Reality (VR) represents a convergence of three key technologies: communication systems, 3D computer graphics, and modern media.⁶

It is a digital technology for representing objects, people, and their environment, allowing for full immersion and interaction between them and humans.⁷

This is an immersive 3D environment designed by computer programs. Virtual reality surrounds the user, drawing them into a simulated world that appears

⁵ 'Musée du Louvre', n.d. <https://accessible.net/paris/musee-art/musee-du-louvre_3894> [accessed 23 June 2025].

⁶ فتيحة محمدي، 'السياحة الافتراضية كبديل استراتيجي للسياحة التقليدية في ظل أزمة 3.2 (2021) جائحة كورونا(كوفيد-19)'، مجلة معالم للدراسات الاعلامية و الاتصالية، pp. 93–124.

⁷ علياء عاطف عطية علي، 'المتاحف الافتراضية ما بين التسويق الرقمي و رقمنة التراث'، 5.3 (2022)، المجلة العلمية للسياحة والفنادق والتراث، pp. 235–54, doi:10.21608/sis.2022.175254.1106.

realistic. This virtual world can be entirely fictional or a detailed recreation of actual reality. Interaction within this virtual environment occurs through the responses and sensory feedback exchanged between the virtual setting and the user's senses.⁸

For museums, virtual reality is an effective way to increase visitor numbers and reach a wider audience.⁹

This technology has emerged as a transformative solution in the sector, offering the potential to create immersive and interactive environments that transcend physical and spatial barriers through the simulation of realistic and engaging experiences.¹⁰

Additionally, this technology has demonstrated its potential in responding to the challenges of authenticity and the shift towards a new museology, making it an effective tool that enhances the museum's educational and interactive role. In this context, the most prominent uses of this technology are as follows:

Bridging the Authenticity Gap: Virtual reality helps reduce the gap between original and non-original experiences by creating virtual environments perceived as real, thus reshaping the concept of authenticity within the museum context.

Enhancing Immersive Experiences: It boosts the museum's ability to offer immersive experiences, where visitors feel a genuine presence within virtual displays. This elevates the level of personal interaction with the exhibited content.

Balancing Education and Entertainment: It serves as an effective tool for striking a balance between educational and entertainment functions, allowing visitors to learn cultural and historical concepts in an enjoyable and engaging manner.

Supporting New Museology Trends: It supports contemporary trends in new museology by focusing on the visitor as a central element in the reception process, rather than merely showcasing valuable collections.

⁸ محمدي, 'السياحة الافتراضية كبديل استراتيجي للسياحة التقليدية في ظل أزمة جائحة كورونا(كوفيد-19).

⁹ Yingru Qian, 'Virtual Reality and Modern Visitor in the Museum', 29 November 2021, pp. 290–94, doi:10.2991/assehr.k.211120.053.

¹⁰ Mohamed A. Mohamed Hassan, Henar Abo El-Magd Ahmed Kalefa, and Mohamed Hosny Sabet Mohamed, 'Enhancing Museum Engagement through Virtual Reality A Case Study of the Egyptian Museum in Cairo', International Journal of Engineering and Applied Sciences-October 6 University, published online 1 January 2025, doi:10.21608/ijeasou.2025.344546.1018.

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Enabling Personalized Experiences: It allows for the design of customized visitor experiences that align with their interests and needs, thereby elevating the quality of the museum experience on an individual level.

Expanding Access to Exhibits: It broadens the reach of exhibits, especially those difficult to display physically due to geographical constraints or the preservation of artifacts.

Reviving Lost or Inaccessible Sites: It contributes to bringing back to life sites and exhibits that no longer exist or are inaccessible, by offering realistic simulations that integrate historical and technical dimensions.¹¹

A pioneering example in this field is "Mona Lisa: Beyond the Glass" – The Louvre Museum, Paris. Developed in 2019 in partnership with HTC Vive Arts and Emissive, this interactive experience coincided with the major preparatory exhibition of Leonardo da Vinci's works.

This approximately seven-minute experience offers visitors an immersive journey, re-presenting the Mona Lisa in a 3D digital environment. It allows them to view the painting away from the crowds and the protective glass that typically separates them from the original artwork. Using HTC Vive Cosmos virtual reality headsets, participants can virtually approach the painting, observe its intricate details, and listen to an audio commentary explaining the work's artistic and historical significance.¹²

¹¹ Hyunae Lee and others, 'Experiencing Immersive Virtual Reality in Museums', *Information & Management*, 57.5 (2020), p. 103229, doi:10.1016/j.im.2019.103229.

¹² Hannah McGivern, 'Reality Check: Is VR Set to Revolutionise Museums?', 17 December 2019

<<https://www.theartnewspaper.com/2019/12/17/reality-check-is-vr-set-to-revolutionise-museums>> [accessed 23 June 2025].



Figure 1. Still from Mona Lisa Beyond the Glass

Additionally, the National Museum of Science and Technology in Milan...¹³ also adopted leveraged virtual reality to present "The Last Supper" experience. Due to the fragility of Leonardo da Vinci's "The Last Supper" mural, visitors are only allowed to view it for a few minutes. To overcome this time constraint, the museum developed a virtual reality experience. This allows for an extended, interactive engagement with the artwork by virtually displaying and explaining its symbols, setting, and characters within an immersive environment, all while preserving the integrity of the original masterpiece.¹⁴

¹³ 'The Vision of Leonardo', n.d.

<https://www.museoscienza.org/en/project/the-vision-of-leonardo?utm_source=chatgpt.com> [accessed 23 June 2025].

¹⁴ 'LAST SUPPER INTERACTIVE - Franz Fischnaller - FRANZ FISCHNALLER', n.d. <<https://franz-fischnaller.com/last-supper-interactive-by-franz-fischnaller/>> [accessed 23 June 2025].

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Figure 2. Last Supper Interactive (LSI) by Franz Fischnaller in Deep Space 8K at Ars Electronica. Photo: Magdalena SickLeitner. Gigapixel image of the Last

Following these two examples, many other international museums are launching similar initiatives targeting diverse community groups, including those with visual impairments. For instance, the Statens Museum for Kunst in Copenhagen introduced an interactive virtual reality experience designed to empower blind and visually impaired visitors to engage with artworks through audio descriptions and haptic feedback. This significantly enhances their understanding of the artistic content.

In this vein, Chen et al. (2025) conducted a study titled "EnVisionVR: A Scene Interpretation Tool for Visual Accessibility in Virtual Reality." The survey included 12 participants who were blind or visually impaired. The study's results showed a 41.7% improvement in identifying the locations of elements within the virtual environment, along with a 33.3% increase in the effectiveness of interacting with them. This underscores the viability of using virtual reality

technologies to improve the museum experience for individuals with visual impairments.¹⁵

Especially if it's accompanied by precisely descriptive explanations. In this way, virtual reality technology helps blind visitors achieve museum accessibility in an experience that breaks traditional barriers.

Augmented Reality (AR)

Augmented Reality (AR) technology relies on the integration of the real world with a virtual one.¹⁶ This technology is interactive, participatory, and synchronous. It integrates virtual objects and information (digital data) by projecting them into the user's real-world environment to provide additional information. This enhances real-world perception through digital elements and data, including sound, images, interactive 3D graphics, and videos.¹⁷

Augmented Reality (AR) technologies can identify visitor activity to unlock information about exhibits, providing instant access by combining hybrid physical and digital artifacts. This can enable visitors to follow tasks and allow for close exploration of artifacts, their characteristics, and context—for example, the uses and functions of artifacts, information about the restoration of damaged pieces, spatial characteristics, and so on. It can also activate audio and visual effects. Ultimately, AR facilitates the interpretation of exhibits and the understanding of their meaning.¹⁸

This is achieved by adding digital layers of information, such as animations, videos, audio clips, or interactive quizzes. Visitors can use augmented reality glasses or mobile devices to scan QR codes or markers on exhibits and access the enhanced content.¹⁹

¹⁵ Junlong Chen and others, 'EnVisionVR: A Scene Interpretation Tool for Visual Accessibility in Virtual Reality', arXiv:2502.03564, preprint, arXiv, 5 February 2025, doi:10.48550/arXiv.2502.03564.

¹⁶ 'علي', 'المتاحف الافتراضية ما بين التسويق الرقمي و رقمنة التراث'.

¹⁷ محمدي, 'السياحة الافتراضية كبديل استراتيجي للسياحة التقليدية في ظل أزمة جائحة كورونا(كوفيد-19)'.

¹⁸ Stella Sylaiou and others, 'Leveraging Mixed Reality Technologies to Enhance Museum Visitor Experiences', 2018 International Conference on Intelligent Systems (IS), September 2018, pp. 595–601, doi:10.1109/IS.2018.8710530.

¹⁹ 'Top 5 Use Cases for AR and VR for Museums', n.d.

<<https://www.takeaway-reality.com/post/top-5-use-cases-for-ar-and-vr-for-museums>> [accessed 24 June 2025].

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In this regard, the Smithsonian National Museum of Natural History developed the "Skin and Bone" experience, which allowed visitors to virtually reconstruct the form of extinct creatures, including joint and muscle movement.

The same museum also introduced Aira technology, which assists visually impaired individuals by providing free verbal descriptions. Visitors can choose to use their smartphone cameras or smart glasses for this purpose. Aira leverages augmented reality and artificial intelligence to connect visitors with a remote agent who observes the visitor's location and can see what's in front of them. This "guide" can help the visitor navigate museum exhibits and also provide practical information about where to find various museum facilities.²⁰

For blind visitors, Augmented Reality (AR) can provide additional audio layers that interpret the exhibited items. This makes them easier to understand within a sensory and auditory context, supporting the inclusivity of the museum experience and ensuring knowledge is accessible to all visitors, regardless of their visual abilities.

Interactive Screens:

Interactive screens are among the most significant tools used in museums. Visitors engage with the information displayed on these screens, which incorporate sound, animated images, diagrams, graphics, and more. This technology is characterized by its ability to attract visitors, who interact with it either through touch or remotely (via gestures).²¹

Based on observations of museum experiences, it's clear that interactive screen technology is being effectively used to engage visitors. For instance, the Museum of Art and History in Tlemcen, Algeria, utilizes interactive screens that allow visitors to engage with exhibited content via touch. Similarly, during a visit to the Museum of Islamic Art in Cairo and the National Museum of Egyptian Civilization, a comparable adoption of this technology was noted, enabling

²⁰ Fariza Ahmadova, 'Keeping Museums Inclusive for People with Disabilities', UN Today, 29 February 2024

<<https://untoday.org/keeping-museums-inclusive-for-people-with-disabilities/>> [accessed 24 June 2025].

²¹ سميرة بودرع، عائشة حنفي، أهمية تصميم عرض تفاعلية بالمتاحف الجزائرية المتحف الوطني العمومي للتاريخ والفن بتلمسان انونجا، مجلة هيردوت للعلوم الإنسانية والاجتماعية، المجلد 06، العدد 02، 2022، ص 1116 n.d.

visitors to explore exhibits interactively through touch. This significantly enhances their understanding and engagement with the displayed content. These technologies can be further developed to include dedicated audio descriptions, allowing people with visual impairments individuals to comprehend the exhibition's content without relying on sight. When interactive screens are designed with both auditory and haptic feedback, they empower blind visitors to access and interact with information at the same level as sighted visitors. This boosts the museum experience's inclusivity and ensures knowledge reaches a broader segment of society.



Figure4 . Interactive Screen at the Museum of Islamic Art in Cairo



Figure3 . Interactive screen at the Museum of Art and History in Tlemcen

Hologram Technology

Holography is an advanced 3D imaging technique that uses laser beams. This technology achieves artistic awe in all its elements.²²

For example, the Natural History Museum in London applied this technology to display a moving 3D dinosaur, offering visitors a vivid, lifelike viewing experience. Similarly, during our visit to the National Museum of Egyptian

²² 'علي, 'المتاحف الافتراضية ما بين التسويق الرقمي و رقمنة التراث

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Civilization, we observed the use of holographic technology to present collection of holdings in a 3D format.

Although holography is primarily a visual technology, it can be integrated with audio and haptic technologies to make its content comprehensible for blind individuals within multi-sensory museum environments. Through this integration, blind visitors can enjoy inclusive museum experiences, expanding their access to cultural content and enhancing their engagement.



Figure .5 Hologram Display at the National Museum of Egyptian Civilization

3. Individuals with Special Needs (Visually Impaired) in the Museum Space

3.1. Individuals with Special Needs (Visually Impaired Category)

Before delving into the concept of visual impairment, let's first clarify the term "individuals with special needs." This term refers to individuals whom "God Almighty has afflicted by depriving them of some of their abilities or senses, or who have become unable to carry out their affairs due to old age, illness, disability...etc."²³ This segment represents a category of society that suffers from one or more types of disabilities, such as visual impairment, hearing impairment, speech impairment, physical disability, or intellectual disability, all of which negatively impact them.²⁴ They have become unable to move, work, and contribute like others, which has made them in need of special care and attention from their relatives and the society in which they live.²⁵

3.2. The Blind Individuals

Based on this, a blind person is defined as an individual unable to read, even with the aid of glasses. They're also understood as someone who must learn and live using senses other than sight.²⁶

From a medical perspective, a blind person is identified as someone whose visual acuity is less than 6/60 or 20/200. Educationally, an individual is considered blind if they're unable to acquire knowledge through their visual system²⁷.

3.3. Problems Faced by Blind Individuals During Museum Visits

The World Health Organization (WHO) estimates that 2.2 billion people suffer from near or distant vision impairment.²⁸

²³ عمار سليم عب، وآخرون، أهم المشكلات التي تواجه ذوي الاحتياجات الخاصة والرؤية المستقبلية دراسة نظرية تحليلية ن مجلة جامعة بابل للعلوم الإنسانية، المجلد 28، العدد 1، 2020، n.d. ص 62

²⁴ عزة فاروق جوهري، خدمات المعلومات لذوي الاحتياجات الخاصة (الإعاقة البصرية) n.d.، بجامعة الملك عبد العزيز شطر البنات دراسة في مدى الإتاحة والإفادة والجودة، ص 7

²⁵ عمار سليم عب، وآخرون، أهم المشكلات التي تواجه ذوي الاحتياجات الخاصة والرؤية المستقبلية دراسة نظرية تحليلية ن مجلة جامعة بابل للعلوم الإنسانية، المجلد 28، العدد 1، 2020. ص 62

²⁶ احمد سيد احمد، ابداع المكفوفين مجلة بحوث الشرق الأدنى، العدد التاسع والتسعون - 2024، مايو، n.d. ص 259-260

²⁷ عزة فاروق جوهري، خدمات المعلومات لذوي الاحتياجات الخاصة (الإعاقة البصرية) بجامعة الملك عبد العزيز شطر البنات دراسة في مدى الإتاحة والإفادة والجودة، ص 7

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According to the World Blind Union, the number of blind people worldwide is approximately 39 million. Additionally, there are 285 million visually impaired individuals globally, meaning those with a limited degree of vision in one or both eyes.²⁹

For a person with a visual impairment, exposed museum objects may not hold much significance. Therefore, improving museum accessibility means thinking outside the box and utilizing all available tools to make the experience more engaging for those whose disabilities make their visit challenging.³⁰

Referring to the professional definition of a museum, widely recognized and promoted by the International Council of Museums (ICOM) since 2007, it's clear that museums should provide all members of society with access to knowledge and culture. However, visually impaired visitors still encounter many limitations when visiting these spaces. This is largely because museum exhibitions remain primarily designed to be visually appealing. The "centrality of the eye in museums

²⁸ 'Blindness and Vision Impairment', n.d.

<<https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment>> [accessed 24 June 2025].

²⁹ 'جسور بوست « اليوم العالمي لـ "برايل" .. لغة أضاءت ظلام حياة المكفوفين حول العالم', n.d.

<https://jusoorpost.com/ar/posts/16332/%D8%A7%D9%84%D9%8A%D9%88%D9%85_%D8%A7%D9%84%D8%B9%D8%A7%D9%84%D9%85%D9%8A_%D9%84%D9%80%D8%A8%D8%B1%D8%A7%D9%8A%D9%84_%D9%84%D8%BA%D8%A9_%D8%A3%D8%B6%D8%A7%D8%A1%D8%AA_%D8%B8%D9%84%D8%A7%D9%85_%D8%AD%D9%8A%D8%A7%D8%A9_%D8%A7%D9%84%D9%85%D9%83%D9%81%D9%88%D9%81%D9%8A%D9%86_%D8%AD%D9%88%D9%84_%D8%A7%D9%84%D8%B9%D8%A7%D9%84%D9%85> [accessed 24 June 2025].

³⁰ Fariza Ahmadova, 'Keeping Museums Inclusive for People with Disabilities', UN Today, 29 February 2024

<<https://untoday.org/keeping-museums-inclusive-for-people-with-disabilities/>> [accessed 24 June 2025].

and exhibitions" makes non-visual engagement with art and artifacts almost impossible in all but the most innovative institutions.³¹

In this context, when we consider the experiences of blind and visually impaired individuals during their museum visits, it's easy to find examples of accessibility shortcomings that negatively impact their participation. For one, this can begin with physical accessibility and the orientation limitations they might face. On the other hand, there are often restrictions on touching exhibits or replicas, and barriers to intellectual access for their interpretation—all of which are concerning issues.³²

Based on the foregoing, the challenges faced by visually impaired visitors during museum visits can be summarized as follows:

Absence of Braille Signage: This prevents them from reading available information about the exhibits.

Lack of Audio Guides: The insufficient provision of audio guides, which could offer accurate and comprehensive descriptions of artifacts, poses an additional barrier to their understanding of the displayed content.

Difficulty Comprehending Exhibits due to Lack of Visual Access: This is a fundamental challenge in their experience, as the museum experience remains heavily reliant on sight without effective compensation through other senses.

Inadequate Pathway Design: The design of pathways within the museum can impede the movement of visually impaired visitors, especially when using a white cane, if the design is not suited to their specific mobility needs.

³¹ Roberto Vaz, Paula Odete Fernandes, and Ana Cecília Rocha Veiga, 'Designing an Interactive Exhibitor for Assisting Blind and Visually Impaired Visitors in Tactile Exploration of Original Museum Pieces', *Procedia Computer Science*, CENTERIS 2018 - International Conference on ENTERprise Information Systems / ProjMAN 2018 - International Conference on Project MANagement / HCist 2018 - International Conference on Health and Social Care Information Systems and Technologies, CENTERIS/ProjMAN/HCist 2018, 138 (2018), pp. 561–70, doi:10.1016/j.procs.2018.10.076.

³² Roberto Vaz, Diamantino Freitas, and António Coelho, 'Blind and Visually Impaired Visitors' Experiences in Museums: Increasing Accessibility through Assistive Technologies', *The International Journal of the Inclusive Museum*, 13.2 (2020), pp. 57–80, doi:10.18848/1835-2014/CGP/v13i02/57-80.

4. The Role of Modeling in Enhancing the Museum Experience for Visually Impaired Individuals

Modeling is a central tool for improving museum accessibility for visually impaired individuals. It achieves this by transforming visual content into forms that can be perceived through alternative senses like touch and hearing. These models help reshape the visually impaired visitor's experience from that of a passive recipient to an active, exploratory one based on sensory and cognitive interaction.

As per the new definition approved by the International Council of Museums (ICOM) at the Prague conference in 2022, "A museum is a permanent, non-profit institution in the service of society that researches, collects, conserves, interprets, and exhibits tangible and intangible heritage. Open to the public, accessible and inclusive, museums foster diversity and sustainability. They operate and communicate ethically, professionally, and with the participation of communities, offering varied experiences for education, enjoyment, reflection, and knowledge sharing."³³

The transformation in the concept of the contemporary museum reflects a shift towards enhancing accessibility. A museum's value is no longer solely determined by its content, but by how it is presented to ensure the participation of visitors from all segments of society, especially the visually impaired.

Museums now recognize, more than ever, the importance of integrating and welcoming this group into their spaces, exhibitions, and programs. A testament to these institutions' genuine commitment as agents of change is the theme of International Museum Day 2020: "Museums for Equality: Diversity and Inclusion." This theme

³³ Alberto Garlandini, 'Standing Committee for the Museum Definition – ICOM Define Final Report (2020-2022)', Hybrid Format: In Person at the Prague Congress Centre, Prague (Czech Republic) and Online (Agora), 24 August 2022.

underscored museum institutions' dedication to making culture accessible to all societal groups, including people with visual impairments, through initiatives that ensure diversity and ease of access.³⁴

Here, we'll outline some key recommendations from the United Nations Convention on the Rights of Persons with Disabilities, ratified by Germany in 2008 and the European Union in 2010. The Convention includes a comprehensive set of recommendations, and the broader their implementation, the more independently blind and visually impaired individuals can benefit from museums. It's best to consider these recommendations from the initial planning stages, though they can also be implemented gradually later, in conjunction with maintenance or restoration work when needed.

In this context, the most prominent recommendations can be summarized as follows:

- **Agreement on Planning and Involving the Target Group in Project Implementation:** Specialists or accessibility coordinators should be involved from the earliest stages of museum and exhibition planning and installation.
- **Providing Information about the Institution/Exhibition:** Museum information should be provided through accessible means, such as an accessible website, Braille, large print, or audio discs (with additional information for blind and visually impaired individuals).
- **Ensuring Access to Outdoor Areas:** The museum or exhibition grounds should be easily accessible by public transport. The path from the nearest station to the entrance should also be marked with tactile guidance lines.

³⁴ 'International Museum Day 2020: President's Message', International Council of Museums, n.d.
<<https://icom.museum/en/news/international-museum-day-2020-presidents-message/>> [accessed 24 June 2025].

- **Ensuring Access to Indoor Areas – Lobby and Exhibition Halls:** This includes building entrances, doors, stairs, a tactile or visually contrasting guidance system, as well as signage and any written information that should be provided for each exhibition.
- **Displays and Exhibits:** Miniature or magnified replicas should be provided for exhibits that are too small or too large to touch, or those that are not allowed to be touched for other reasons.
- **Guided Tours:** Dedicated guided tours for blind and visually impaired individuals are an important addition to any museum, but they are not a substitute for comprehensive accessibility.
- **Miscellaneous:** This primarily relates to audio guides and interactive information devices.³⁵

Building on these recommendations, we can identify several applied models that museums have effectively adopted. These models embody the role of modeling in facilitating the experience for visually impaired individuals, enabling them to engage with exhibits sensually and cognitively.

Given the lack of a standardized or detailed classification of modeling patterns for this group in existing literature, a systematic division based on the nature of interaction and technologies used has been adopted. This distinguishes three main categories of models: tactile modeling, auditory modeling, and interactive modeling. This classification is based on a content analysis of existing museum experiences. Below, we'll highlight prominent applied models adopted by various museums, categorized according to this proposed division,

³⁵ Ahmed Mohammed M. Abdelrazik, 'Accessible Museums' Facilities for Visually Impaired Visitors : Applicable Project in the Museum of Islamic Art in Cairo', 6.2 *مجلة العمارة و الفنون و العلوم الإنسانية*, (2021), pp. 1900–12, doi:10.21608/mjaf.2020.46902.2016.

focusing on how each category contributes to improving the experience for blind visitors through different modeling tools.

4.1. Tactile Modeling

Tactile modeling helps visually impaired visitors recognize the dimensions and physical characteristics of artifacts or artworks. This is achieved through 3D models that match the original in overall shape and proportions. This allows individuals to form an accurate mental image of the piece, which is impossible in traditional, vision-dependent exhibitions. Researchers and organisations advocate that providing tactile experiences to people with visual impairments is very important, since visitors can then explore the objects more deeply, and, not being dependent on oral or written descriptions provided by others, may perceive more details and confirm the information obtained during the exploration of the object. These strategies are of great value because of the opportunity they offer to people with visual impairments to perceive the shape, texture, weight and other properties of objects more accurately. There has been some debate about the approaches to adopt in museum touch tours. Visitors who have visual impairments may be allowed to touch objects belonging to the museum exhibition, or, if the safety of the objects is at risk, the opportunity for touching replicas may be offered.³⁶

Internationally, there are many pioneering experiences in this area. Among the most prominent is the Louvre Museum's expansion of its Tactile Gallery initiatives, gradually integrating tactile tours into various wings. The Department of Islamic Arts was the first to adopt this approach, creating a tactile tour consisting of ten educational stations. These stations highlight the diversity of Islamic ornamentation (vegetal, figurative, geometric). Each station provides a miniature replica of the piece, with a visual interpretation of the content, alongside Braille texts, large print, and samples of the original materials.³⁷

The rooms in the Decorative Arts department, specifically those dedicated to 18th-century furniture, have also benefited from a similar tactile tour. These tools are set to be gradually implemented across all permanent collections in the

³⁶ Susana Mesquita and Maria João and Carneiro, 'Accessibility of European Museums to Visitors with Visual Impairments', *Disability & Society*, 31.3 (2016), pp. 373–88, doi:10.1080/09687599.2016.1167671.

³⁷ 'Musée du Louvre'.

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museum. This will contribute to enhancing universal accessibility for all visitors, especially those with visual impairments.³⁸

In a similar vein, the Prado Museum in Madrid, Spain, created a 3D exhibition of paintings titled "Touching the Prado," where blind visitors can explore and enjoy the collections. Visitors are invited to touch and examine classic artworks by Goya and Velázquez, zooming in and out to see the paintings in full detail. The project meticulously identified which details to emphasize and how to best optimize them for the hands of blind individuals. Additionally, the museum provides Braille guides and audio commentaries alongside the artworks.

In a unique experience, the Azerbaijan National Carpet Museum, the first inclusive museum in Azerbaijan, uses technology to help blind visitors experience artworks through Braille dot printing. As part of this social project, weavers in the museum's traditional techniques department created miniature samples of ten carpets from the permanent collection, which can now be touched by hand. This approach allows visually impaired individuals to feel the different Azerbaijani carpets and distinguish between various weaving techniques. Each sample is also accompanied by a note in both English and Azerbaijani Braille.³⁹

On a national level, the National Museum of Modern and Contemporary Art of Algiers has recently begun developing 3D models of certain modern Algerian artworks. These models are specifically designed for tactile interaction by visually impaired individuals, as part of educational programs aimed at directly involving this group in the museum experience.

4.2. Audio Modeling

Auditory modeling is one of the most effective ways to enable visually impaired individuals to cognitively interact with museum content. It serves as a suitable

³⁸ ‘Quelles sont les aides à la visite pour une personne avec un handicap visuel ?’, Musée du Louvre, 12 May 2024
<<https://contact.louvre.fr/hc/fr/articles/16948945505821-Quelles-sont-les-aides-%C3%A0-la-visite-pour-une-personne-avec-un-handicap-visuel>> [accessed 24 June 2025].

³⁹ Fariza Ahmadova, ‘Keeping Museums Inclusive for People with Disabilities’, UN Today, 29 February 2024
<<https://untoday.org/keeping-museums-inclusive-for-people-with-disabilities/>> [accessed 24 June 2025].

alternative for conveying information when touch alone cannot provide full detail or context for exhibits.

Research in this area emphasizes the importance of utilizing non-visual senses for engaging with museum collections. As one study noted:

"Museum managers should explore the potential for visitors with visual impairments to use these other senses to interact with museum collections. There is a wide range of interpretative techniques that offer audio interpretations about museum holdings that people with visual impairments can use..." (Heatherington, 2002; MCC, 2007; RNIB & Vocaleyes, 2003; Snyder, 2005).

This highlights different types of these technologies: either fixed audio pillars located at specific points in museums, or portable audio guides that visitors can carry throughout the museum.

Audio guides are typically interactive systems where visitors press buttons when they want to hear information about specific objects. An audio guide suitable for visitors with visual impairments includes precise descriptions. There are also some audio guides where the audio explanation is activated automatically as visitors pass certain objects, using systems that rely, for example, on infrared sensing. These latter systems are particularly important for people with visual impairments, as they simplify the identification of exhibit locations and allow them to use their canes freely.⁴⁰

These efforts are expanding to include advanced initiatives that integrate sound with other senses in multi-sensory experiences. One notable example is:

The Abraham Lincoln Presidential Library and Museum in Springfield, United States, recently hosted an exhibition called "Lincoln: Sight, Sound & Touch." This exhibit integrates touch with sounds to provide an interactive experience for visually impaired individuals. It features tactile models of a sculpture from the Lincoln Memorial, Lincoln's face and hands, and a Lincoln medal. Touch sensors trigger audio descriptions of the object, while buttons on each panel allow visitors



Figure 6. An advertising poster featuring Abraham Lincoln is reimaged with dimension so those with impaired vision who visit Abraham Lincoln Presidential Library and Museum can more fully experience the “Lincoln: Sight, Sound & Touch” display.

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to hear interpretations of the history and significance of each element.⁴¹

In Europe, the "Blind Museum Tour" application was developed for the Lighthouse for the

Blind Museum in Greece and other national museums. This application, available on Android smartphones, offers audio tours, emergency options, and return options, providing descriptions of exhibits as visitors approach them. The app uses Bluetooth Low Energy (BLE) beacons as proximity sensors within exhibits to update the user's location and deliver audio descriptions.⁴²

While some museums rely on smart applications and digital audio guides to provide descriptive content for the people with visual impairments, the Smithsonian American Art Museum adds a more inclusive element through its "InSight" tours, conducted twice monthly. Trained guides lead small groups of blind and visually impaired visitors on a tour of the museum.

These tours are interactive, inviting participants to experience exhibits through vivid descriptions. Unlike a standard audio guide, visitors can pause, ask questions, and clarify points. The tours move slowly through the museum, giving people a chance to absorb the artworks at their own pace. Some visitors are inspired by the tour guide's words to paint their own mental picture. Others use personal magnification equipment. Some pieces are even available for touch.

⁴¹ 'Lincoln Museum Opens "tactile" Exhibit for Those with Impaired Vision', n.d.

<<https://www.myjournalcourier.com/news/article/lincoln-museum-opens-tactile-exhibit-impaired-20342623.php>> [accessed 24 June 2025].

⁴² Roberto Vaz, Diamantino Freitas, and António Coelho, 'Perspectives of Visually Impaired Visitors on Museums: Towards an Integrative and Multisensory Framework to Enhance the Museum Experience', Proceedings of the 9th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-Exclusion (New York, NY, USA), DSAI '20, 9 June 2021, pp. 17–21, doi:10.1145/3439231.3439272.

The guides create rich imagery with their words, speaking about colors, smells, and sounds that might be present in a scene. The tours engage visitors' other senses to help paint a mental picture.⁴³

4.3. Interactive Modeling

Recent advancements in digital simulation technologies demonstrate how interactive modeling can redefine the museum experience for blind individuals. Virtual touch interfaces and haptic feedback have opened up new possibilities for interacting with cultural heritage without needing to touch original artifacts. This ensures the protection of fragile collections while simultaneously enhancing inclusivity.

This type of modeling relies on advanced devices such as haptic pens, smart gloves, and mid-air haptic systems, which recreate the sensation of a surface's texture and shape. This provides the user with a sensory experience that closely mimics reality, without the need to touch the original piece.⁴⁴

Among the examples that have implemented this technology, we highlight the Manchester Museum's pioneering initiative to improve access for blind and partially sighted visitors to artifacts that cannot be physically touched. This was achieved through the development of a Haptic Interactive interface, funded by the Stavros Niarchos Foundation and in collaboration with a specialized technology provider.

This technology is based on a 3D digital system that allows users to explore detailed archaeological models using a special pen. This pen generates sensations of touch, friction, and resistance, giving the user a tangible feeling of the object's surface within a virtual space.

A group from the Henshaws Society for Blind People participated in the design and development of this experience from its inception. They selected three artifacts (a Greek jug, a predynastic hippopotamus vessel, and a faience shabti) to be scanned and converted into 3D models. Audio elements were also added to

⁴³ Manual Charr, 'Best Practice in Making Museums More Accessible to Visually Impaired Visitors', MuseumNext, 8 December 2024
<<https://www.museumnext.com/article/making-museums-accessible-to-visually-impaired-visitors/>> [accessed 21 June 2025].

⁴⁴ Raymond Agarwal, 'Haptic Feedback in Museums: Can You Really "Touch" History?', The Museum Of The Future, 16 May 2025
<<https://themuseumofthefuture.com/haptic-feedback-in-museums/>> [accessed 24 June 2025].

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explain the physical and historical properties of the objects, along with grooved rings that guide the user within the virtual space.

This interface provided a comprehensive sensory and cognitive experience that doesn't replace direct touch but enhances and enriches it, contributing to a deeper and more inclusive interaction with the exhibits. By developing a portable version of the system, the museum aims to expand its reach and benefit a wider audience, making this experience a promising model for integrating sensory technology into the display of cultural heritage.⁴⁵

Similarly, the British Museum adopted "Ultrasonic Mid-Air Haptics" in one of its projects. This technology allowed visitors to "feel" the surface of cuneiform tablets without actual physical contact, through a digital simulation based on ultrasonic waves.⁴⁶

As further examples of interactive modeling applications within museums, we can point to what the Louvre Museum implemented in one of its 16th-century wings. Here, a sensory station was created adjacent to the original artwork, allowing visitors, particularly the visually impaired, to interact with a decorative element through three integrated units:

A tactile map to identify the location and historical context.

An embossed model of a decorative helmet, enabling recognition of its shape and size through touch.

Accompanying audio effects, along with texts available in Braille.⁴⁷

This station exemplifies a model for integrating the senses in museum displays, not solely relying on digital technology, but rather through thoughtfully designed on-site modeling that considers both tactile and auditory perception.

From this, it's clear that interactive modeling in museums isn't limited to a virtual technical dimension. Instead, it encompasses a wide range of solutions that

⁴⁵ Adrian Murphy, 'Haptic Interactive Technology Brings Visitors Closer to Museum Collections', *Museums + Heritage*, 28 February 2013 <<https://museumsandheritage.com/advisor/posts/haptic-interactive-technology-brings-visitors-closer-to-museum-collections/>> [accessed 24 June 2025].

⁴⁶ Agarwal, 'Haptic Feedback in Museums'.

⁴⁷ 'The Louvre Museum's Salle Des Verres - Tactile Studio', n.d. <<https://tactilestudio.co/achievements/salle-des-verres-musee-louvre-architectural-model-sensory-device/>> [accessed 24 June 2025].

activate multiple senses simultaneously. In many applications, interactive modeling forms overlap, integrating various senses—like touch, sound, and even movement—to provide a more comprehensive and profound experience for visually impaired visitors.



Figure 6. The original work is next to the sensory station

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Figure 7. This sensory station allows visitors to discover a decorative element of the old palace through a tactile and sonic exploration

5. Conclusion:

The Transformative Role of Modeling in Inclusive Museum Experiences

This research demonstrates that modeling, in all its forms—tactile, auditory, and interactive—is a pivotal tool for creating an inclusive museum experience for blind individuals. It compensates for the absence of sight through alternative senses, granting them full sensory and cognitive interaction with exhibits. Furthermore, advanced technological applications, such as 3D printing, virtual reality, and augmented reality, extend beyond mere visual spectacle. They are reshaping the philosophy of museum display towards inclusivity and equitable access to knowledge.

Both local and global experiences have proven that modeling can transform a museum from a closed visual space into a multi-sensory

environment. This new approach considers human diversity and ensures the right to culture for everyone. With increasing international calls for more inclusive cultural access, integrating visually impaired individuals through modeling solutions must be a strategic choice, not an exception.

Therefore, it's recommended that museum institutions adopt a participatory approach when designing their experiences. This approach should consider the needs of this demographic from the earliest stages, aligning with the modern concept of the museum as an educational, recreational, and contemplative space all at once.

Reference:

Abdelrazik, Ahmed Mohammed M., 'Accessible Museums' Facilities for Visually Impaired Visitors : Applicable Project in the Museum of Islamic Art in Cairo', 6.2 *مجلة العمارة و الفنون و العلوم الإنسانية*, (2021), pp. 1900–12, doi:10.21608/mjaf.2020.46902.2016

Agarwal, Raymond, 'Haptic Feedback in Museums: Can You Really "Touch" History?', *The Museum Of The Future*, 16 May 2025 <<https://themuseumofthefuture.com/haptic-feedback-in-museums/>> [accessed 24 June 2025]

Ahmadova, Fariza, 'Keeping Museums Inclusive for People with Disabilities', *UN Today*, 29 February 2024 <<https://untoday.org/keeping-museums-inclusive-for-people-with-disabilities/>> [accessed 24 June 2025]

——, 'Keeping Museums Inclusive for People with Disabilities', *UN Today*, 29 February 2024 <<https://untoday.org/keeping-museums-inclusive-for-people-with-disabilities/>> [accessed 24 June 2025]

——, 'Keeping Museums Inclusive for People with Disabilities', *UN Today*, 29 February 2024 <<https://untoday.org/keeping-museums-inclusive-for-people-with-disabilities/>> [accessed 24 June 2025]

Alberto Garlandini, 'Standing Committee for the Museum Definition – ICOM Define Final Report (2020-2022)', *Hybrid Format: In Person at the Prague Congress Centre, Prague (Czech Republic) and Online (Agora)*, 24 August 2022

Ali Hamood Twaij, Imad Hamood Abdulhussein, and Zahraa Hussein Alioue, *The Effect of Using 3D Printer in Implementation of Pottery Sculpture*

Redefining the Museum Experience: Modeling as a Mechanism for Sensory Perception and Heritage Interpretation for the Blind

مجلة لارك للفلسفة و اللسانيات, n.d., العدد36 الاصدار1-2020 بحوث الفنون, Designs, Edition و العلوم الاجتماعية

‘Blindness and Vision Impairment’, n.d. <<https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment>> [accessed 24 June 2025]

Charr, Manual, ‘Best Practice in Making Museums More Accessible to Visually Impaired Visitors’, MuseumNext, 8 December 2024 <<https://www.museumnext.com/article/making-museums-accessible-to-visually-impaired-visitors/>> [accessed 21 June 2025]

Chen, Junlong, and others, ‘EnVisionVR: A Scene Interpretation Tool for Visual Accessibility in Virtual Reality’, arXiv:2502.03564, preprint, arXiv, 5 February 2025, doi:10.48550/arXiv.2502.03564

Hassan, Mohamed A. Mohamed, Henar Abo El-Magd Ahmed Kalefa, and Mohamed Hosny Sabet Mohamed, ‘Enhancing Museum Engagement through Virtual Reality A Case Study of the Egyptian Museum in Cairo’, International Journal of Engineering and Applied Sciences-October 6 University, published online 1 January 2025, doi:10.21608/ijeasou.2025.344546.1018

‘International Museum Day 2020: President’s Message’, International Council of Museums, n.d. <<https://icom.museum/en/news/international-museum-day-2020-presidents-message/>> [accessed 24 June 2025]

‘LAST SUPPER INTERACTIVE - Franz Fischnaller - FRANZ FISCHNALLER’, n.d. <<https://franz-fischnaller.com/last-supper-interactive-by-franz-fischnaller/>> [accessed 23 June 2025]

Lee, Hyunae, and others, ‘Experiencing Immersive Virtual Reality in Museums’, Information & Management, 57.5 (2020), p. 103229, doi:10.1016/j.im.2019.103229

‘Lincoln Museum Opens “tactile” Exhibit for Those with Impaired Vision’, n.d. <<https://www.myjournalcourier.com/news/article/lincoln-museum-opens-tactile-exhibit-impaired-20342623.php>> [accessed 24 June 2025]

- McGivern, Hannah, ‘Reality Check: Is VR Set to Revolutionise Museums?’, 17 December 2019 <<https://www.theartnewspaper.com/2019/12/17/reality-check-is-vr-set-to-revolutionise-museums>> [accessed 23 June 2025]
- Mesquita, Susana, and Maria João and Carneiro, ‘Accessibility of European Museums to Visitors with Visual Impairments’, *Disability & Society*, 31.3 (2016), pp. 373–88, doi:10.1080/09687599.2016.1167671
- Murphy, Adrian, ‘Haptic Interactive Technology Brings Visitors Closer to Museum Collections’, *Museums + Heritage*, 28 February 2013 <<https://museumsandheritage.com/advisor/posts/haptic-interactive-technology-brings-visitors-closer-to-museum-collections/>> [accessed 24 June 2025]
- ‘Musée du Louvre’, n.d. <https://accessible.net/paris/musee-art/musee-du-louvre_3894> [accessed 23 June 2025]
- Qian, Yingru, ‘Virtual Reality and Modern Visitor in the Museum’, 29 November 2021, pp. 290–94, doi:10.2991/assehr.k.211120.053
- ‘Quelles sont les aides à la visite pour une personne avec un handicap visuel ?’, Musée du Louvre, 12 May 2024 <<https://contact.louvre.fr/hc/fr/articles/16948945505821-Quelles-sont-les-aides-%C3%A0-la-visite-pour-une-personne-avec-un-handicap-visuel>> [accessed 24 June 2025]
- Sylaiou, Stella, and others, ‘Leveraging Mixed Reality Technologies to Enhance Museum Visitor Experiences’, 2018 International Conference on Intelligent Systems (IS), September 2018, pp. 595–601, doi:10.1109/IS.2018.8710530
- ‘The Louvre Museum’s Salle Des Verres - Tactile Studio’, n.d. <<https://tactilestudio.co/achievements/salle-des-verres-musee-louvre-architectural-model-sensory-device/>> [accessed 24 June 2025]
- ‘The Vision of Leonardo’, n.d. <https://www.museoscienza.org/en/project/the-vision-of-leonardo?utm_source=chatgpt.com> [accessed 23 June 2025]
- ‘Top 5 Use Cases for AR and VR for Museums’, n.d. <<https://www.takeaway-reality.com/post/top-5-use-cases-for-ar-and-vr-for-museums>> [accessed 24 June 2025]

Redefining the Museum Experience: Modeling as a Mechanism for Sensory Perception and Heritage Interpretation for the Blind

- Vaz, Roberto, Paula Odete Fernandes, and Ana Cecília Rocha Veiga, 'Designing an Interactive Exhibitor for Assisting Blind and Visually Impaired Visitors in Tactile Exploration of Original Museum Pieces', *Procedia Computer Science*, CENTERIS 2018 - International Conference on ENTERprise Information Systems / ProjMAN 2018 - International Conference on Project MANagement / HCist 2018 - International Conference on Health and Social Care Information Systems and Technologies, CENTERIS/ProjMAN/HCist 2018, 138 (2018), pp. 561–70, doi:10.1016/j.procs.2018.10.076
- , Diamantino Freitas, and António Coelho, 'Blind and Visually Impaired Visitors' Experiences in Museums: Increasing Accessibility through Assistive Technologies', *The International Journal of the Inclusive Museum*, 13.2 (2020), pp. 57–80, doi:10.18848/1835-2014/CGP/v13i02/57-80
- , Diamantino Freitas, and António Coelho, 'Perspectives of Visually Impaired Visitors on Museums: Towards an Integrative and Multisensory Framework to Enhance the Museum Experience', *Proceedings of the 9th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-Exclusion* (New York, NY, USA), DSAI '20, 9 June 2021, pp. 17–21, doi:10.1145/3439231.3439272
- احمد سيد احمد، ابداع المكفوفين مجلة بحوث الشرق الأدنى، العدد التاسع والتسعون - مايو 2024، ص260-259، n.d.
- ‘جسور بوست» اليوم العالمي لـ"برايل".. لغة أضاءت ظلام حياة المكفوفين حول العالم', n.d. <https://jusoormapost.com/ar/posts/16332/%D8%A7%D9%84%D9%8A%D9%88%D9%85_%D8%A7%D9%84%D8%B9%D8%A7%D9%84%D9%85%D9%8A_%D9%84%D9%80%D8%A8%D8%B1%D8%A7%D9%8A%D9%84_%D9%84%D8%BA%D8%A9_%D8%A3%D8%B6%D8%A7%D8%A1%D8%AA_%D8%B8%D9%84%D8%A7%D9%85_%D8%AD%D9%8A%D8%A7%D8%A9_%D8%A7%D9%84%D9%85%D9%83%D9%81%D9%88%D9%81%D9%8A%D9%86_%D8%AD%D9%88%D9%84_%D8%A7%D9%84%D8%B9%D8%A7%D9%84%D9%85> [accessed 24 June 2025]

سميرة بودرع، عائشة حنفي، أهمية تصميم عرض تفاعلية بالمتاحف الجزائرية المتحف الوطني العمومي للتاريخ والفن بتلمسان انودجا، مجلة هيردوت للعلوم الإنسانية والاجتماعية، المجلد 06، العدد 02، 2022، ص 1116 n.d.

سيد عبده أحمد ، أسامة يوسف محمد، عمر بنعبد العزيز مخلص ، إحياء المباني والتحف الأثرية والحفاظ عليها باستخدام المسح ثلاثي الأبعاد وتكنولوجيا الواقع المختلط مجلة العمارة والفنون والعلوم الإنسانية - المجلد السابع - العدد الحادي والثلاثون، يناير 2022، ص 775 n.d.

عزة فاروق جوهرري، خدمات المعلومات لذوي الاحتياجات الخاصة (الإعاقة البصرية) بجامعة الملك عبد العزيز شطر البنات دراسة في مدى الاتاحة والإفادة والجودة، ص 7 n.d.

علي، علياء عاطف عطية، 'المتاحف الافتراضية ما بين التسويق الرقمي و رقمنة التراث'، المجلة العلمية 54-235 pp. (2022)، للسياحة والفنادق والتراث، 5.3
doi:10.21608/sis.2022.175254.1106

عمار سليم عب، وآخرون، أهم المشكلات التي تواجه ذوي الاحتياجات الخاصة والرؤية المستقبلية دراسة نظرية تحليلية ن مجلة جامعة بابل للعلوم الإنسانية، المجلد 28، العدد 1، 2020، ص 62 n.d.

كفاية سلمان أحمد، وآخرون، الواقع الافتراضي والعرض الرقمي كوسيلة لتوثيق الأزياء التراثية، مجلة التصميم الدولية، المجلد 7، العدد 4، أكتوبر 2017، ص 462 n.d.

محمدي، فتيحة، 'السياحة الافتراضية كبديل استراتيجي للسياحة التقليدية في ظل أزمة جائحة كورونا(كوفيد-19)', (2021) pp. 93-124، مجلة معالم للدراسات الاعلامية و الاتصالية، 3.2