heritage

MDPI

Article

Accessibility, Natural User Interfaces and Interactions in Museums: The IntARSI Project

Eva Pietroni [1,*], Alfonsina Pagano [1], Luigi Biocca [1] and Giacomo Frassineti [2]

[1] CNR ISPC, Reseacrh Area Rome 1, via Salaria km 29,300, 00015 Monterotondo, Italy; alfonsina.pagano@ispc.cnr.it (A.P.); luigi.biocca@cnr.it (L.B.)
[2] Venue in Rome, IULM University, via Marco Minghetti 17, 00187 Rome, Italy; giacomo.frassineti@gmail.com
* Correspondence: eva.pietroni@cnr.it; Tel.: +39-06-90672349

Abstract: In a museum context, people have specific needs in terms of physical, cognitive, and social accessibility that cannot be ignored. Therefore, we need to find a way to make art and culture accessible to them through the aid of Universal Design principles, advanced technologies, and suitable interfaces and contents. Integration of such factors is a priority of the Museums General Direction of the Italian Ministry of Cultural Heritage, within the wider strategy of museum exploitation. In accordance with this issue, the IntARSI project, publicly funded, consists of a pre-evaluation and a report of technical specifications for a new concept of museology applied to the new Museum of Civilization in Rome (MuCIV). It relates to planning of multimedia, virtual, and mixed reality applications based on the concept of "augmented" and multisensory experience, innovative tangible user interfaces, and storytelling techniques. An inclusive approach is applied, taking into account the needs and attitudes of a wide audience with different ages, cultural interests, skills, and expectations, as well as cognitive and physical abilities.

Keywords: technologies for museums; accessibility; universal design; natural interaction interfaces; tangible user interfaces; art and culture

Citation: Pietroni, E.; Pagano, A.; Biocca, L.; Frassineti, G. Accessibility, Natural User Interfaces and Interactions in Museums: The IntARSI Project. *Heritage* **2021**, *4*, 567–584. https://doi.org/10.3390/heritage4020034

Academic Editor: Nicola Masini

Received: 26 January 2021
Accepted: 1 April 2021
Published: 4 April 2021

1. Introduction: Scope of the Action and General Context in Which It Has Been Started

1.1. Premises

From more than twenty years of research, the Virtual Heritage Lab (VHLab) of the Italian National Research Council, Institute of Heritage Science (CNR ISPC) has been involved in shaping, developing, and implementing multifaceted virtual museum environments through technological installations, communicative strategies, and layout design; the general aim has always been to enhance cultural contents and storytelling to educate and emotionally involve museum visitors.

Recently, the VHLab team has developed a Universal Design (UD)–oriented strategy to shape technology, interfaces, and contents, taking into account a larger potential audience of visitors with differentiated needs and expectations.

The Italian Ministry of Cultural Heritage (MIBACT) has established a long-term strategy [1] for the revitalization of the national museums' network and exploitation of various cultural contexts for the benefit of a wider audience. Within this strategy, some relevant museums were funded to redesign their spaces' layout, including digital and technical installations, in order to make exhibits more attractive to an extended audience. One of the museums that took advantage of such a renovation is the Museum of Civilization in Rome (MuCIV). Recently it has been opened to the public after a long process of aggregation of four previous institutions (Early Middle Ages Museum, Popular Arts and Traditions Museum, Ethnographic Museum, Eastern Art Museum). The new museum is very rich in content, but unfortunately it is located in a marginal tourist area of Rome with plenty of offices rather than tourist attractions, but with great potentialities. The museum is defining new promotional strategies aimed at reaching a new public: not a mass one,

but focused on specific targets. It has a multicultural vocation, represented by artifacts and intangible heritage related to dominant or fragile anthropological contexts, aristocratic and popular, and coming from all over the world. Consistent with this vocation, the choice to connote itself as a museum grounded on the ethical principles of social inclusiveness and accessibility seems a promising perspective.

1.2. Goal of the Contribution

On occasion of the IntARSI project, funded by the Lazio region, the VHLab team encouraged and supported the new museological approach based on physical and multimedia inclusivity and accessibility; it was involved by MuCIV to design several multimedia solutions in order to enhance collections along the exhibition pathway.

Our proposal is based on theoretical background and practical guidelines we have evolved along more than twenty years of research and concrete experience in museum studies and virtual heritage projects (communicative media for cultural heritage, new forms of storytelling and paradigms of interaction, user experience design), supported by the results of surveys carried out on thousands of European museums visitors [2–6].

Beside, the project also involved very experienced consultants in museum communication for people with visual, hearing, and motor disabilities. Indeed, accessibility experts have oriented our contribution towards the adaptation of our methodologies and ideas to the principles of UD. Thus, the solutions proposed here are the result of a broad cooperation validated on the basis of everyone's previous know-how. We believe that the process of innovation of this contribution springs from the merge of so many experiences, resulting in a holistic approach, where the whole result is greater than the sum of the parts.

This paper illustrates the approach, the developed content, and the outputs based on the initial criteria and scope. The research presented here is the first step of a wider process, which focuses on the pre-evaluation, design, and technical specifications. Hopefully, it shall continue in the future with the concrete execution of works (second step) and with the user experience evaluation (third step).

1.3. Structure of this Contribution

In Section 1 we present the goal of this research, its background in terms of competencies involved, general context in which it has been started, and its innovative value.

In Section 2 we present the topic of multimedia accessibility in museums, introducing some guidelines to enrich the experience as much as possible for a wider audience, favoring collective and individual dimensions. We also introduce Universal Design principles, discussing how they have been evolved and applied in the European and Italian contexts, and how they can be integrated in the general user experience design.

Section 3 presents the IntARSI project, venues and collections interested in the project, and methodological approach.

Section 4 illustrates a couple of proposed solutions, showing how new technological devices can meet the public's expectations as well as cognitive needs. The focus is mainly on tangible interface applications that would be ideal for all users, especially people with physical diseases, and natural interaction interfaces.

Section 5 concludes the contribution proposing future improvements and announcing the realization phase of the IntARSI project, as well as suggesting the application of a user-centered approach in designing inclusivity for museum contexts.

2. Accessibility of Multimedia Contents in Museums

The main challenge to be faced today in cultural venues is to create a closer synergy and interconnection between (a) real collections, (b) digital contents, (c) storytelling, and (d) audiences, in order to create new scenarios related to the cultural experience (Figure 1).

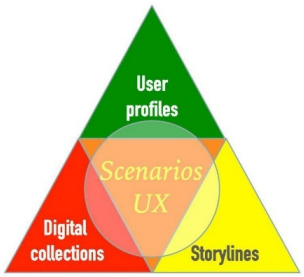

Figure 1. The connection between collections, users, and stories must be encouraged in museums to create new scenarios of user experience.

Multimedia communication is probably the most efficient way to address this challenge. Indeed, the main goal of translating a physical cultural object into a virtual one is not merely the creation of a digital replica of the real object. This process does not pertain to objectivity, to the object's description, or quantity; rather, it is the creation of a dynamic space of narratives, relationships, and interactions [7]. What matters is the experience, what we do with the digital content, the simulation of a multiple and open past. The feedback we get from the virtual context modifies our behavior and critical sense, and stimulates understanding and the process of attribution of meaning. Thus, the process of knowledge is constructed and consolidated [8].

This process of contextualization and attribution of meaning to the cultural heritage is therefore diachronic, evolving through various cycles of interaction, through variation and redundancy, and is different from era to era, from person to person. Many factors contribute to the design of a good experience within the exhibition pathway [4]:

- quality of the information and harmonious integration between real and virtual contents
- configuration of the spaces, visitors' flow and viability
- layout
- lighting
- noisiness of the environment
- possibility for the audience to pause comfortably, to sit or stand still during the interaction with the contents
- balance between free interaction and guided experience
- duration of the narrative units and their distribution along the visit path
- communicative rhythm, harmonic coherence of words, images and sounds

But how can we shape up the exhibition's layout, the presentation of real and multimedia content, and the interaction interfaces as inclusively as possible? How can we make it attractive and accessible to different audiences, including those with specific needs?

According to ISO 9241-11:2018 [9], the term "accessibility" refers to the extent to which products, systems, services, environments, and facilities can be used by people in a population with the widest range of user needs, characteristics, and capabilities, to achieve an identified goal in an identified context of use.

As a public place of education and culture, the museum encourages collective communication, sharing, and social exchange. The approach in the representation of contents, languages, and technologies must be chosen to involve groups of people, even heterogeneous. This happens, for example, with a video projection or an interactive installation on a large screen, accessible to several users at the same time: here each of them can enjoy audio-visual content and can choose to play an active role, taking control of the system, or to attend as a passive spectator. It is recommended that interactive technologies facilitate simple and immediate alternation between active and passive participation, so that the public feels encouraged to switch the roles without being inhibited by technology. In this way it is possible for users to start socializing and exchanging ideas around that specific topic. Additional attributions of social and cultural values can arise from visitors' interaction [10].

It is also important that the experience, lived by the passive audience, is sufficiently rewarding in terms of perceptual and narrative involvement, although inevitably conditioned by the quality of the "performance" played by the user who is taking the active control of the system. These factors largely depend on conceptual and interaction design.

Alongside the social dimension, it is important to convey moments of intimate and personal reflection inside the museum, favoring a deep contact with the artwork. The space, the contents, and the languages adopted in this case are modeled on visitors aiming to establish an inner dialogue with the cultural object, seeking the depth to get to the essence. Another fundamental criterion to reach various types of audiences is multichannel communication, which is the ability to convey content through different media, languages, and technologies intended for users of various cultural backgrounds, origins, age, or with specific needs. A multisensory approach is also necessary to favor the experience and the contact with the cultural object, since it is able to convey information, perceptions, and sensations that can stimulate cognitive and emotional processes. Thus, a multisensory approach generates embodiment [11], making the users feel part of that world [12].

The research presented here, related to the design of the IntARSI project, is shaped on these criteria of museology, and it tries to improve the connection among collections, stories, and audiences, enhancing multicultural, collective, and reflective dimensions.

2.1. Universal Design (UD) Principles

The seven principles of UD were first developed in 1997 by a working group of American architects, product designers, engineers, and environmental design researchers. Their purpose was to define a framework of best practices to increase the usability of physical spaces, products, and communication systems, making them accessible to the largest user categories with different abilities, without special or separate design. The main benefit of UD is that addressing the divergent needs of special populations increases usability for everyone. The seven principles are: (1) equitable use; (2) flexibility in use; (3) simple and intuitive use; (4) perceptible information; (5) tolerance for error; (6) low physical effort; (7) size and space for approach and use [13].

In December 2019 a new version of the European guideline "accessibility requirements for Information and Communication Technologies (ICT) products and services" (EN 301549) [14] was published to specify functional accessibility requirements applicable to ICT products and services, to be used in public procurement in Europe. This standard, compliant with ISO/IEC 17007:2009 (i.18) [15], has been drawn up under the competence of the authority federated to "Ente Italiano di Normazione" (UNI),—"Tecnologie informatiche e loro applicazioni" (UNINFO), and became part of the Italian national legislation on 17 December 2020. The document is suitable for web-based technologies, non-web technologies, and hybrid technologies using both. It includes software, hardware, and services. Most parts of the principles here established are addressed to improve the accessibility and usability of multimedia applications, and comfort of use, by blind and deaf people, or by visitors with limited abilities in vision and hearing, visitors in wheelchairs, and persons with cognitive disabilities. However, they can improve the experience of all users, generating ease in use and well-being, in accordance with the UD principles. The proposed general solutions are based on multisensory and multichannel approaches in communication. This means that information has to be delivered not only by means of a unique media/sensory solicitation, but more than one. Thus, visitors at the same time can touch, read, listen to, and look at the same content and, even if one of their senses is not working well, they can access information using an alternative sensory approach. Some criteria must be respected, of course, in creating such alternatives. For instance:

1. Users should be able to autonomously set subtitle layout (position, font size, contrast, synchronization, background, length).
2. Audio descriptions of visual content (useful for visually impaired persons) should be well designed in terms of selection of meaningful content and absence of interference

with other audio solicitations, possibility to be activated by the user on a predefined specific audio channel of the device.

3. International Sign (IS) language (and national versions) and lip reading should take advantage of the right size and framing of the human translator, from the background, from possible subtitle concurrence, and from the right speed of gestures and synchronization.
4. Users should be able to customize enlargement of images.
5. Contrast and brightness regulation should be available functions for visually impaired visitors.
6. The presence of Braille translations needs to respect specific standards of size and distance among lines and relief.
7. The physical layout of the communicative systems (spaces, distances, heights, position of the interaction interfaces and screens) should be ergonomically designed to allow access of users in wheelchairs.
8. Lights, lines or colors, and patterns in relief can be useful to mark the perimeters of interactive areas where users have to focus their attention on interaction interfaces, making them easier to be identified, especially by visually impaired persons, but certainly they are useful for everybody.
9. Tangible user interfaces are of course fundamental in several cases [16,17], and we are going to discuss them in the following sections of the paper, in relation to the IntARSI project.
10. Hardware systems should support specific sensory disabilities, like assistive listening devices.

In conclusion, new integrated technological solutions and a multisensory and multichannel approach provide an opportunity to revolutionize the way art and culture are experienced, breaking down the architectural and perceptive barriers that still prevent them from being a truly universal language [18].

2.2. State of the Art of Accessibility of Museum Content, the Italian Experience

Despite the principles of UD, the focus of institutions, designers, and architects was initially mostly on users with physical difficulties and in wheelchairs, thus the legislation was mainly addressed to measures and prescriptions of space sizes rather than to "solutions for all".

Gradually, a growing awareness of a better inclusion of larger users' needs took place, also extending to different sensorial and cognitive difficulties. Design and solutions started to encompass additional sectors and human activities as well as building types and environments. The recent European regulation, just discussed, adopted also by national laws, is a demonstration of this evolution: the focus is now on the individual's levels of ability to perform certain tasks in daily life.

In museums and exhibitions, whose mission is cultural and social growth, accessibility is not an easy issue to deal with. Indeed, recently they have been transforming in multifaceted and dynamic contexts, more conditioned by quick but uneven changing realities, and also in terms of funding, offers, and audience capacity attractiveness.

Thus, the relevance of the visitors' expectations and needs has been gradually taking prevalence on some preservation criteria that were traditionally limiting larger visits to the monumental areas.

Thus, solutions for accommodating the widest range of users' needs are strictly linked to the museum performance evaluation [19–22].

One of the forms in which multimedia and art intertwine is represented by tangible user interfaces (TUIs) [23]. A TUI is a form of technology aimed at improving users' involvement, active participation, and accessibility in cultural heritage venues. These interfaces, in their multiple and different forms, can be used by a wide variety of users of all ages and needs.

TUIs have so far been deployed in multiple museums and cultural heritage sites: some examples are the interfaces from the MIT Tangible Media Group (tangible.media.mit.edu), which can be considered the arch-types for all TUIs and a beta-test for this kind of technology; the TUIs developed by Gagarin (www.gagarin.is, site accessed on the 3 April 2021) a company based in Iceland, used in museums all over the world to make the exploration of the space, physical and virtual, a real and creative experience; or the "Espositore for All" in Turin, Italy, which allows people with physical disabilities to experience works of art otherwise inaccessible to them (https://italiapost.it/torino-venaria-espositore-for-all/, site accessed on the 3 April 2021). A great contribution to the improvement of TUIs in Italy comes from the Omero National Tactile Museum in Ancona city (www.museoomero.it, site accessed on the 3 April 2021) [24], with its great collection of printed reproductions of artworks and maps. The Tactile Museum of Varese (www.museotattilevarese.it/, site accessed on the 3 April 2021) is an excellent example of accessibility too: it exhibits a collection of tactile wooden models that reproduce aspects of the landscape, architecture, art, archeology, and design. Tactile models have a dual function: didactic and emotional; in addition to the models, the museum hosts multisensory itineraries and installations, capable of combining fun with an interest in experimentation. The Civic Museum of Natural Science of Bergamo (www.museoscienzebergamo.it, site accessed on the 3 April 2021) also promotes a multisensory and inclusive pathway to discover its collections: it is possible to touch samples of the skin and skeleton of some vertebrates, to manipulate stones and minerals, discover the fossilization process with the hands, experience the physical properties of minerals, and listen to the songs of different bird species. The ancient domus of Via dell'Abbondanza of Pesaro (www.pesaromusei.it/area-archeologica-via-dellabbondanza/, site accessed on the 3 April 2021) promotes an inclusive approach: the three-dimensional reconstructions of the ancient rooms of the domus are projected, allowing visitors to imagine how daily life took place and to immerse themselves in the atmosphere of the Pisaurum of the Roman era. The visit path of the archaeological area is enriched with Braille panels and tactile models for visitors with special needs. In 2020, three tactile and multisensory itineraries were created in the museums of Belgiojoso Palace in Lecco (www.comune.lecco.it, site accessed on the 3 April 2021): the Archaeological Museum, the Historical Museum, and the Natural History Museum. Various stations have been conceived with tactile maps, captions in Braille, and enlarged characters for the visually impaired, with faithful reproductions and original pieces. Each tactile station is equipped with an electronic signal, which activates self-descriptions of the museum hall and of the elements on display through a specially designed reproducer, delivered to each visitor. The goal of the IntARSI project is to amplify the impact of multimedia in museums adopting a multichannel approach in order to involve different audiences in the experience at the same time. Indeed, the project tries to design an integrated solution to communication, built on the coexistence of several sensory stimuli in the experience of an artifact, or a group of artifacts: visual, auditive, tactile. Each kind of sensorial solicitation is provided through integrated solutions as far as possible. From one side, in the experience design, we adopt the multi-layered paradigms of virtual museums in terms of high quality of images and sounds, sensory immersion, advanced storytelling techniques, virtual reality and embodiment, playfulness, and possibility to deepen the content. On the other side we implement many communication channels that can sometimes cooperate, other times work as alternative systems based on synaesthesia principles: touching (instead of looking at) and exploring a scale model, a replica, or the real object and receiving back properly designed audio-visual content. Technologies and interfaces are in most cases the same for all the users, according to UD criteria. Of course, head-mounted displays are not for blind users, but tangible interfaces can be enjoyed by everyone if following specific criteria. Content format can be interactively customized by users according to their needs, in the same installation, as explained at the end of Section 2.1. In most cases interfaces and solutions for visitors with disabilities are translated into facilities for a wide public (aged persons, children).

In conclusion, with this project we try to encourage the involvement and cooperation among users around a similar experience without isolating the different targets or impoverishing the perceptive and emotional impact of the multimedia experience for any of them. We expect that this will favor social exchange and individual growth.

2.3. TUI Basic Requirements

TUIs, as well as all forms of technology aimed at improving users' ways of experiencing cultural content, need to respect some basic principles:

- Digital interfaces and physical buttons of the TUI need to be easily recognizable, accessible, and their uses need to be understandable by all users;
- the main feature of TUIs are the cultural objects, not the technology used for the system interaction, so their design must be driven by the content to be transmitted;
- the presence of TUIs needs to be well integrated into museum spaces, without interfering with visitors' experience and without appearing as alien elements, but effectively camouflaging into the context in which they are located.

The general use of a TUI is the following: the user is able to touch a replica, or in some cases the original version, of a specific item presented on the TUI; this action causes a system modification in status which recognizes the touch and conveys the information via video, sound, subtitles, or all of them. Depending on the object and its complexity, touching a specific part of it will cause the system to convey the corresponding information, while touching another part will activate another content related to it. This behavior is common in most of the TUIs. In terms of structure and composition, a TUI is usually composed of:

- a surface onto which the object is placed, or better fixed, to avoid dangerous uses;
- the object—that can be touched and activated;
- a hardware infrastructure, composed of sensors (placed into the object and allowing the system to recognize users' touch and manipulation, which causes the corresponding audio and/or video information to be transmitted), and other computing elements, such as a Raspberry or Arduino system;
- a screen or TV through which visual information is conveyed (if present);
- an audio system;
- an appropriate illumination system.

2.4. User Experience Design in Museums

It is not easy to create content and experiences that will satisfy a diverse museum audience. Therefore, it is important to study the museum audience in advance: where they come from, how culturally and technologically literate they are, what age group they are, and whether they participate primarily in guided tours or alone, in order to design the best types of museum experience.

Nevertheless, how is a user experience conceived? It comes from observation, participation, and interaction with a specific "sphere of life" [25], in a precise moment.

Experience is made up of non-predictable processes, influenced by a series of conditions and variables, both objective and subjective [26]. For this reason, experience does not have the same value for each individual and does not produce the same effects in all users. Likely, experience includes:

- all actions and reactions of the user that occur before, during, and after the use;
- objective aspects raised out of the usage such as usability, effectiveness, visibility, and efficiency of the system and user interface;
- subjective aspects raised out of the usage such as motivation, critical processing, memorization, and interpretation.

Experience is the basis of the process of the user's identity construction, which turns to be individual but still collective (sociality) [25]. Therefore, it is very important to understand how, within cultural venues, audiences experience culture.

3. The IntARSI Project

3.1. Goals, Venues, Target

The IntARSI project stands as a new opportunity for CNR ISPC and the Museum of Civilization in Rome (MuCIV, main proponent), the Museum of Toys in Zagarolo, and the Archaeological Park of Ostia Antica (all of them are in Italy, Lazio region), to cooperate in order to establish virtual and physical connections among intercultural contexts, cultural objects, and urban and regional contexts. This cooperation has been supported by an initiative financed by the Lazio region aiming at empowering a network of cultural sites sharing strategies, innovative design and, possibly, audiences, thus incrementing their cultural offer, attractiveness, and educational impact on local and foreign communities. As mentioned, CNR ISPC, in collaboration with MuCIV, is primarily responsible for the design and planning of multimedia content, which has been recently completed; the next phase will be the development of the digital applications. The sites interested by the project are:

1. MuCIV, in Rome, specifically referring to the Opus Sectile decoration located in the Early Middle Ages section of the museum; the contemporary African collection, exhibited in the Prehistoric-Ethnographic section of the museum; and the Figure Theater objects exhibited in the Popular Arts and Traditions section of the museum;
2. Archaeological Park of Ostia Antica, specifically referring to the archaeological remains of the Porta Marina building, and the artifacts exhibited in the Ostiense Museum;
3. Museum of Toys, in Zagarolo, specifically about the collection of puppets and marionettes.

The title of the project, intARSi, is inspired by the ancient marble intarsia technique that characterizes one of the main artworks: the Opus Sectile decoration, at MuCIV, originally found in the domus of Porta Marina in Ostia Antica. The project partners intend to recall, metaphorically, the idea of how pieces of precious materials, carved in different forms, can be skillfully assembled to create something new that, as a whole, enhances the potentialities of the individual components. IntARSI pertains n.12 multimedia and virtual productions, based on the concept of "augmented" and multicultural experience, built on multisensory, immersive, multichannel solutions, aiming at stimulating an emotional impact on users. In designing the technological applications an inclusive approach has been applied, which takes into account the needs and attitudes of an audience differentiated by age groups, cultural interests, skills, and expectations, as well as cognitive and physical abilities. Systems and contents are conceived in order to be accessible, both in terms of usability and comprehensibility. Moreover, they are shaped and transmitted not only according to typically didactic communication methods, but also according to a playful and dramatized approach in storytelling (following the practice of learning-by-doing [27–30]). Technology naturally integrates with the collections and their spatiality, recreating a "dramaturgy" around the exhibited objects and reconstructing their sensory and symbolic dimension and context of usage, according to a new museological perspective. Four main targets have been considered (Italian and foreign tourists; children and teenagers; experts, professionals, amateurs; and people with different specific needs), conceiving installations able to work with different targets, according to the UD approach. In this way, the museum partners could guarantee a democratic access to shared, inclusive, and in-depth experiences. For the same reason, the type of experience enabled by intARSi is twofold: passive, for those who want to simply attend a show; and active, for those who want to be engaged in the first person.

3.2. Preliminary Study at MuCIV: Self-Assessment Phase

Along with the consideration in Section 2.4, for the IntARSI project we decided to first analyze what happened inside one of the major museums involved, the MuCIV, before starting the design of multimedia and layout interventions. On one side, we studied the museum visiting paths, considering how clear the presentation of contents and the communicative apparatus was, what visitors could find, and what they were allowed to

do from the moment they entered until the moment they left the museum. On the other side, we investigated who the visitors were, where they came from, how often they visited the museum, and what their interests, needs, and expectations were. Finally, we studied if the museum was able to manage users with specific needs (like sick or elderly persons, or children as well as people with disabilities).

Observations, questionnaires, and interviews supported this initial study—the so-called self-assessment phase. We limited the survey to MuCIV because (a) it is the main proponent and thus it will host several and different multimedia applications; (b) it has the greatest potentialities in terms of audience development and strategies because it was born very recently from the fusion of four previous museums and its vocation is to be a cultural aggregator; and (c) it has already settled few actions in favor of visually impaired visitors; therefore, there is a sincere interest in increasing UD principle in the museum. On the 3rd of November 2019, we conducted interviews directed towards visitors and, when possible, museum staff, on a day of heavy public presence in the museum rooms. This was done in order to understand which sections were the most visited, the strengths and weaknesses of the MuCIV, and to get a general idea on the composition of the visitor base. A summary of the main results is provided below, based on 38 anonymous and voluntary interviews:

- the audience of the museum is composed of 76% adults (ranging from 26 to 60 years old);
- the audience comes mainly from Rome, with a small percentage coming from other parts of Europe (5%);
- 15% of visitors are composed of teachers and university students interested in specific parts of the museum;
- 45% of the users visit the museum with their family;
- 73% are familiar with technologies in general;
- 86% would be interested in a more multimedia and technological experience of the museum.

It was not possible to meet people with any kind of impairment, but we collected information from the museum's staff, who periodically organize visits especially addressed to blind persons in very small groups (1 or 2 persons with companions) supported by expert guides. The only dedicated physical supports in the museum are Braille panels installed on some showcases. Apart from these short descriptions, narration of the pieces is totally entrusted to the human operators. The evaluation allowed us to draft *user personas*, fictional characters useful to anticipate the target identification, the user experience roadmap inside the museum, and if and how the different target groups would probably approach the solutions imagined for IntARSI.

3.3. First Basic Recommendations for the Accessibility to the Museum's Contents

Within such a general vision, we identified some initial and basic recommendations regarding pathways, signs, and overall organization of contents. We summarize here the main ones:

- Paths and spaces must be flat or with minimal level differences and obstacles, easily identifiable and recognizable, with comfortable transit also by wheelchairs, with contrast colors to highlight room's change or steps—also for visually impaired people. This is an existing condition inside the museum. In addition, we proposed to integrate tactile paving indicators to guide blind users to the multimedia installations placed in different parts of the museum. These indicators can be useful for all visitors, in order to orientate their visit towards the intARSi contents.
- Communication systems should have a clear hierarchy and identification/recognition through short, legible, and easily understandable messaging, and signage with proper choice of colors and contrasts, type, and font size.
- Signs must not be hidden by obstacles, neither they can be an obstacle to visibility and mobility; appropriate legibility from long and closer distance with no lighting interference and reflection to visitors' sight; proper height installation of signs are

between 1.30 m and 1.70 m (in particular, signs in Braille must be easily reachable without effort and without excessively raising the arms); general information panels should use large font sizes, with a correct graphical balance between background and text; when necessary they must include a QR code to access their audio version; inappropriate supports (reflective surfaces like glass, shiny metals, mirrors, etc.) must be avoided.

- Assistance to visitors by trained staff must be guaranteed to complement the overall users' accommodation.
- A catalogue addressed to impaired visitors could be created to be consulted at the entrance of the museum, including a tactile guide towards the accessible installations spread throughout the museum.

4. The IntARSI Technological Proposals

The second phase of the IntArsi project consisted of conceptualizing and designing some technological solutions which respected the UD principles and the above-mentioned recommendations. CNR ISPC identified, among several proposals, three of them as the most innovative and inclusive:

- Applications and TUI for the Opus Sectile decoration exhibited in one of the MuCIV rooms (see Section 4.1);
- Holographic showcase and its integration with TUI technology for the African section of MuCIV (see Section 4.2);
- Holographic theatre and its integrations with natural interaction (NI) interfaces (mid-air gestures) [31] for the Figure Theater of the MuCIV and the Museum of Toys in Zagarolo (see Section 4.3).

4.1. Applications and TUIs: The Case of the Opus Sectile Decoration

The Opus Sectile is a formidable piece of early Roman art (IV A.D.) found in the archeological site of Ostia Antica, and transferred to the Museum of the Middle Ages (MuCIV) in 2006 [32]. It is a wide marble inlay decoration, extending on three walls and on the floor, and it is the best preserved of the Roman ancient world. A room is completely dedicated to its exhibition, approximately repeating the volume and measures of the original environment.

Inside this museum's room for the first time, the public will be able to see the extraordinary marble decoration virtually contextualized in the original environment of the Porta Marina building in Ostia Antica, thanks to a single user-immersive experience of virtual reality that will be enjoyed through a head-mounted display. The idea is to alternate the detailed vision of the original artwork in the present room and its virtual contextualization. Throughout this process of redundancy and variation, comprehension and knowledge grow up. In the same room, projection mapping can be periodically started, for a collective experience, on the surface of the marble inlay, synchronized to an audio surround. The purpose of such a projection mapping is to animate the decorative context, tell its interpretations of iconographies, the execution technique, and the story of its conservation. Always in the same room a TUI has been designed, useful in particular for single user experience of blind people. It consists of a physical scale model of the room and its inlay decoration, with the main lines characterizing the figures in relief, useful to understand the grandiosity and the dislocation of the decorative cycle on the walls and on the floor. Additional tactile drawings of the main scenes and Braille panels (Figure 2) support the experience, as they help users to perceive specific contents/figures [33]. In this case, no additional multimedia has been associated to avoid an overload of technologies.

Figure 2. Opus Sectile room, with all the types of intervention: projection mapping, immersive Virtual Reality, tactile experience for blind people.

Beside, a tangible path of "introduction" to the theme of the Opus Sectile has been planned along the corridor leading to the Opus room, with four tangible and interactive "stations" that can be used by different groups of users. These TUI stations have been conceived as completely accessible.

4.1.1. TUI Features

The TUIs designed for the project follow general guidelines regarding the infrastructure: they will have the same dimensions, i.e., a size varying between 120 × 90 cm and 150 × 100 cm, with a top surface placed at 75 cm from the ground to allow the wheelchair accommodation and an easier accessibility to tangible content. Each TUI will follow the same usability logic in order to keep a consistency in the user experience roadmap. They will be composed of:

- an inclinable monitor placed at 90° respective to user's point of view (size 46–55 inches);
- 3D print of the digital replica—or the original—artifact(s) placed and fixed on a slightly (13–15°) inclined surface;
- informative panels of different dimensions (A0, A4, A5, and A3) printed with letters and superimposed in Braille, useful for (a) general introduction (A0); (b) tactile drawings or Braille text put inside a lateral pocket for alternative accessibility to contents (A3 and A4); (c) captions under the interfaces on the table (A5);
- directional audio systems and magnetically induced amplifier. Directional audio is required since each of the TUIs will be placed in the same corridor in close proximity, and a normal audio system would produce conflicting audio sources;
- tactile paving systems to guide users to the TUIs;
- ad hoc illumination system, useful to mark each interactive area/interface and make them more recognizable;
- sensors' interaction system.

Definitively, six TUIs have been designed for the IntARSI project: five of them will be located inside the Museum of the Early Middle Ages, a section of MuCIV; they will introduce the Opus Sectile decoration and the context of prevenience (Porta Marina building); the sixth one will be located in the Ostiense Museum in the Archaeological Park of Ostia Antica (Figure 3). Each one will present a particular topic accessible by users through tactile input on 3D-printed surfaces or objects; the latter will trigger an audiovisual narrative in the frontal 46′ screen, creating a touch-mediated multimedia experience.

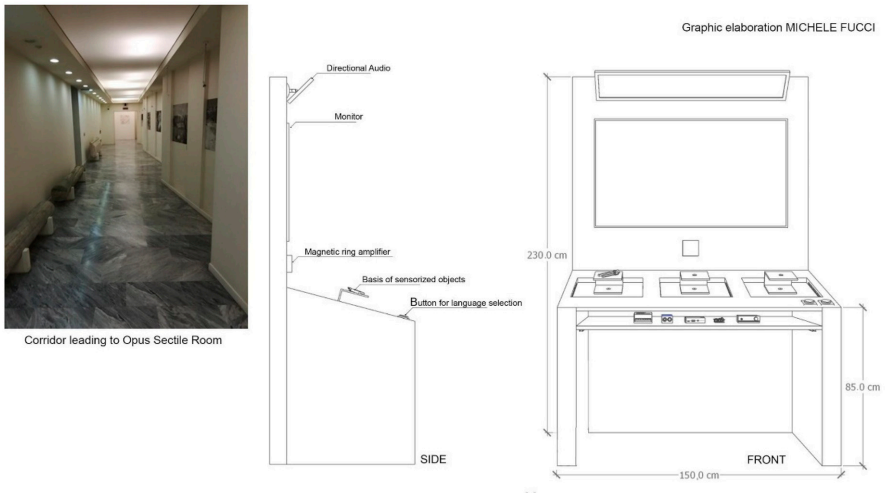

Figure 3. On the left: the corridor leading to the Opus Sectile Room where TUIs will be located. On the right: the standard configuration of a TUI (graphic and technical elaboration in collaboration with Michele Fucci).

4.1.2. Usability and User Experience Roadmap

With reference to usability, the user approaching the TUI will need to understand immediately and clearly what he/she can do and how to interact with the tangible elements. Instructions will firstly be issued on the A0 panel placed next to the workstation where only information to let the system start will be indicated (as the choice of language). As soon as the language is selected on the table (ITA/EN), by two buttons, a simplified explanation in infographics will start explaining: (a) welcome to the workstation, (b) introduction to the topic, (c) what to do and how to access the multimedia contents (start/end/restart), and (d) timing of use/waiting/timeout. Infographics will be similar in style in all the workstations, but different in content according to each TUI. It will be a video in 2D graphics, accompanied by audio and Italian Language Sign (LIS)/International Sign (IS) [33].

In each TUI station, the activation and interaction with the narrative content will take place through the manipulation of real, 3D objects (tangible interface), also perceivable by people with visual impairments. Each of these objects will be fixed to the top surface (but raised to be touched and perceived tactilely in their whole volume, 360°). Where it will not be possible to use the original objects, 3D prints or handmade replicas will be created, with tactile translations (patterns) making understandable figures, decorative motifs, and color variety, where necessary. Touching the tangible objects will allow them to display, on the screen located above, the related narration in audiovisual form. The latter will be supported by subtitles written in the same language and sign language—LIS if in Italian, IS if in English—to facilitate access to deaf people. Each narrative unit will last about 1 min, so as not to tire the user.

Audio will be transmitted through directional speakers, so as not to create sound interferences in the environment that will host multiple multimedia installations and/or not to disturb visitors who are not experiencing that specific TUI station. If some visitors want to passively enjoy the content, they will have to stand next to the active user, in the axis with the directional audio. For people with cochlear implants and/or sound amplifiers, a magnetic induction amplifier will be included to enhance listening and isolate background noise.

4.1.3. Contents, Languages, and Style

The user will be guided through a journey from the original location of the marble (which will be narrated through the tools used to excavate and shape the materials), to the decoration of Porta Marina (where the user can interact through a puzzle game, reconstructing the figures of the Opus Sectile), to the enigmatic personage of a bearded

human figure with a halo (which will be proposed, in a simplified way, as a tangible 3D-printed object) to, finally, a 3D reconstruction of the building and urban settlement in Ostia Antica.

In terms of language and style, it is necessary to capture the essential meaning of the message to convey. It is also important to calibrate well the duration of sentences, their logical structure, and correctly formulate the form and the expressive register of the narrative. For this reason, the aid of accessibility experts has been crucial in this preliminary phase of the project, and it will be necessary during the realization phase.

The duration of a video in LIS/IS is comparable to its version in spoken language. The text in LIS is not a translation of the text in the spoken language, but it is a new text that has its own sequential structure; therefore, according to the experts it will be convenient to start from a text conceived in LIS and then transposed into the spoken language, rather than the opposite [34].

The narration that works for LIS should also be effective for the blind or visually impaired users: the audio should also help the visually impaired person to understand what is happening on the monitor, describing the shapes, their constituent elements, and their location in space (audio description). It will therefore be necessary to give precise spatial references, for example: "the animal you see in the center, the flower you see on the left, etc.". This same audio will also be useful to deaf users (in the form of LIS), providing more descriptive information on what is being explained.

It is also necessary to specify in the text, whenever it occurs, noises and sounds as to ensure an augmentative sensory experience and a complete understanding of the content for deaf users. Graphics should be essential and uncrowded. Overlapping of different elements has to be avoided (e.g., writing on photographs, etc.). For texts, the background can be dark with light characters or vice versa. There is not a univocal solution since there are many types of visual impairments. The images that will be placed alongside the narrator in video need to correspond to (and be synchronized with) the story he/she is telling; they may consist of drawings, photographs, animations, and videos. The tactile drawings will be translated according to the rules of good tactile reading in order to create useful aids for the recognition of images by the visually impaired users [23].

Finally, each TUI station has one or more tangible objects on the table, each of which will determine the start of a single narrative fragment. The order of activation of the various narrative fragments is not univocal; therefore, the narrative units will be autonomous although related.

4.2. Holographic Showcase and Its Integration with TUIs

In the African section of the MuCIV, a holographic showcase will be set up integrated in a larger projection wall [5]. Inside the showcase, two original objects will be exhibited, a *Baulé Male Statue* and a *Lega Mask*. The virtual contents will be visible sometimes inside the showcase, in the form of a hologram, and sometimes outside the showcase, expanding themselves on the surrounding projection wall.

The internal hologram will be related to the form, to the constitutive elements of the object, its details, and relative meanings. In the showcase, an effect of mixed reality (MR) will thus be produced, relying on the Pepper's ghost technique, born with photography in the XV century, diffused in theaters in the XIX century, and today enhanced by digital technologies [35].

External contents, projected on the surrounding wall, will be related to the context of production and use of such objects in Africa, documented and shown through photographs and archive footage: ceremonies, rituals, dances and music, and contexts of production of these artifacts. These *repertoires* cannot be displayed in the holographic showcase, which needs a specific visual grammar.

Indeed, a hologram is an illusion of reality [36]. Its use is not only aimed at arousing amazing reactions in visitors, thanks to its magical effect. Through the hologram, in fact, it is possible to create a better integration between real and virtual dimensions: if we

include the real artifact inside the holographic showcase, the attention still remains focused on the real artifact. Not its virtual replica, but the original one, is the center of our attention during the experience: the virtual animations and the story fragments come out of the real figures, creating a mixed reality experience. The holographic showcase is conceived as a small theatrical stage equipped with controls for the direction and synchronization of each scenic device: lights, audio speakers, scenery, projections. Everything will be managed by ad hoc software.

The structure of the installation is designed according to the rules of the Pepper's ghost technique: a monitor is mounted on the top of the showcase to close its ceiling, in a hidden position; the images transmitted by the monitor are reflected by a transparent mirror positioned at 45° (invisible to the public because of its transparency) and are projected, by effect of an optical illusion, on a projection plane on the back, corresponding with the position of the real objects. Elements such as (a) integration of real and digital content, (b) structure, (c) materials, (d) interior design, (e) lighting, (f) audiovisual grammar, and (g) narrative approach and dramatization are designed as a whole, and combine to constitute an "expressive unity" [5]. The holographic showcase, in such a configuration, has been firstly conceived and realized by our team in occasion of the CEMEC project [5] (Connecting Early Medieval European Collections), within the Creative Europe framework (2015–2019), presented in several European museums during an itinerant exhibition and tested on more than 600 visitors. A huge amount of data has been collected regarding its attractiveness, educational impact, usability, and sustainability. The IntARSI project has been the occasion to evolve this format to embrace UD criteria, most probably for the first time, without renouncing its magic.

The selection of contents and the interaction is done through TUI on a table/surface placed frontally, leaning on the showcase. Most probably this is the first example of a holographic showcase which takes care of UD criteria. On the table, two replicas of the objects are positioned at the extremities, and can be touched by visitors in order to be perceived and better identified (especially by blind visitors). Between them there are four buttons for language selection (Italian, English, LIS, and IS). In this case, LIS or IS versions are not automatically integrated with the spoken languages, but must be activated intentionally if needed, because the figure of the translator in video could interfere a little bit with the magic of the hologram that comes (also) from the graphic essentiality. On the bottom of the table, some A5 panels are printed with normal fonts and overlapping Braille: they indicate the function of the buttons above, and the captions of the two replicas (Figure 4).

The installation will be equipped with a lateral pocket containing Braille text and tactile drawings, dealing with the main contents of the narrative. These auxiliary supports will be in A3 format. Panels, interfaces, audio systems will be similar to the ones implemented for the other TUIs.

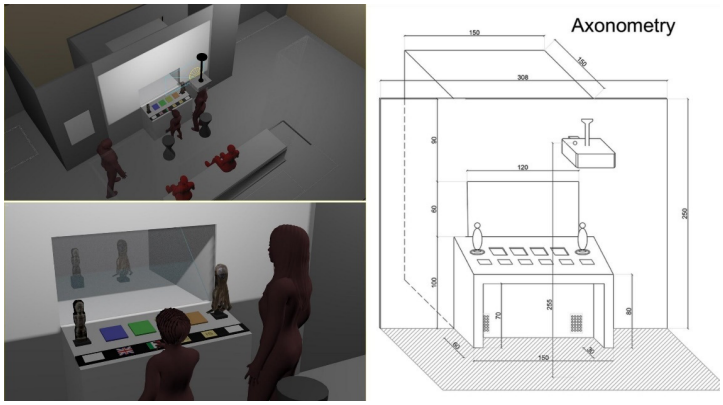

Figure 4. Holographic showcase with TUIs. On the left: rendering showing the main components of the interface. On the right: frontal axonometric projection with measures. In collaboration with Enzo d'Annibale, CNR ISPC.

4.3. Holographic Theatre and Its Integration with Gesture-Based Interaction

In the rooms dedicated to the Figure Theater of the MuCIV and in the Museum of Toys in Zagarolo, demo-ethno-anthropological assets will be brought back to life, in their intangible value, as evidence of customs and cultural traditions. Through the creation of a holographic theater, some marionettes (that are physically exhibited in the surrounding showcases) will be virtually animated. Again, the holographic theater will be based on the technique of Pepper's ghost (Figure 5). VHLab has a long-standing experience (since 2011) with natural (mid-air gesture based) interaction applied to virtual reality environments. This modality of interaction is not mediated by traditional devices like a mouse, joystick, etc., resulting indeed clearer for everyone. The experience is configured as a progression of physical as well as cognitive actions. Numerous surveys have been carried out to evaluate the user experience related to such VR applications [37–39]. Hundreds of visitors were observed and interviewed in the different venues, taking into account both active and passive users. What has been found is that interacting with a VR application through body gestures, in the center of a "performative" space, immediately generates in the visitor the impression of being involved in a playful situation, unusual inside a museum, and it encourages socialization and alternation between active and passive roles. Therefore, the experience is done with enthusiasm, like a game, in most of the cases. This is particularly evident for those visitors under 20 and over 60, while the intermediate age group shows a greater self-control that can lead to shyness and any other social and psychomotor inhibition [6].

3D digital replicas of some puppets will be realized, visualized inside the holographic theater and contextualized in a virtual scenography. At the beginning of the show they will explain to the public their history, their typical gestures and expressions, and their origin, character, and context of use; after a while, they will become "movable" thanks to visitors' gestures, and a game will start, as a single user or in a team. The gestures and the mime of the virtual marionette can be performed by visitors through gesture-based interaction interfaces, made possible by sensors for full-body motion capture, like Kinect or a similar device. While the marionette will tell a typical story, vocally interpreting its role, the user will move in front of it, giving expression to its body and completing the performance. Thus, the visitor will play the role of puppeteer, as his/her movements are transferred to the virtual marionettes, but the visitor himself/herself will become a marionette in front of a mirror.

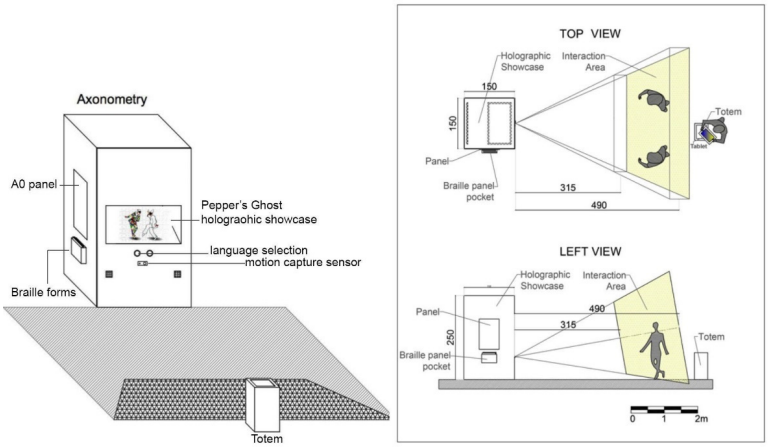

Figure 5. Setup of the holographic theatre and interactive area. In collaboration with Enzo d'Annibale, CNR ISPC.

The game can be played in a team, with players moving other puppets or selecting, through a peripheral device, proper digital scenographies to be visualized, as background, in the holographic showcase. The player/team who best interprets the character and context of the puppets will be the winner of the game.

5. Conclusions

Improving the physical and virtual worlds for people with specific needs in terms of physical, cognitive, and emotional abilities, allows the museum experience to live in a more intense and profitable way. Especially for art and culture, technology can change the way people communicate and interact within museum spaces, translating the accessibility concept into concrete actions to make the environment truly smart [40].

Within the IntARSI project we carried out the first, essential step toward a wider strategy for museums' valorization based on the concepts of user-centered approach, multisensory and multichannel communication, accessibility, tailored interfaces and tools, multicultural inclusion, storytelling, emotional solicitation, and technological innovation.

Beyond European guidelines and national rules for accessibility of ICT products, an extended application of these criteria in common museums is very rare. Interventions in favor of multimedia accessibility are often circumscribed to specific actions: museums entirely dedicated to blind people; guided tours in sign language managed by physical professionals; applications created in research laboratories and temporarily tested in cultural venues; tactile paths for blind users, often limited to the possibility of touching copies of the original objects, with little possibility of deepening. These are important and praiseworthy initiatives, but they are not always effective examples of inclusive experiences for all the people. The current contribution tries to establish coherent, profitable, and feasible solutions for a permanent and inclusive museum fruition, without renouncing to the technological boost, while allowing playful dynamics, attractive solutions usable by all the public, adopting multichannel communication strategies.

Our partners were MuCIV (Rome), Ostia Antica Archaeological Park (Ostia), and the Museum of Toys (Zagarolo). All of them are in the Lazio region (Italy) which funded this initiative. MuCIV was interested in embracing new cultural, ethical, and social issues, retaining specific targets, like experts, foreign communities (also of immigrants), and impaired persons. Thus, we tried to open our previous and long experience in the field of virtual heritage and museums to the UD issues, involving accessibility experts and communication scientists. In the following phase of the project, we intend to involve African communities living in Rome for the creation of multimedia contents to be implemented in the TUIs about contemporary Africa, where some representative objects of their culture will be surely integrated.

In the context of IntARSI, we learned how to adapt previously developed solutions (e.g., the holographic showcase realized in the context of the recent European CEMEC project) to make them accessible to impaired persons, introducing tactile interaction and sign language, even in those situations where this seemed unsuitable. Single user or multiplayer installations, interactive or passive, and dynamic or contemplative experiences have been designed, dealing with topics representing popular or aristocratic, ancient and contemporary cultures and regional, national, or international contexts [41–44].

The innovative value of the current contribution stands in the whole design process that required cooperation and know-how transferring among experts coming from different research fields: museums designers, digital curators, storytellers, technicians, engineers, interface and user experience designers, acoustics engineers, and experts of visual and hearing disabilities, including external communities, allowing a co-creation process to take place. This encounter is not common in Italian and foreign museums, despite the guidelines, rules, and recommendations in terms of ICT accessibility and social inclusion introduced by Europe and adopted by national laws. Typically, museums had been poorly funded for renovation, digitization, maintenance, and marketing. Restrictions on budgets and monuments' preservation had often led to partial and incomplete solutions for few or limited application areas. However, there have been some excellent cases of Italian museums dedicated to specific disabilities that were a basis for identifying appropriate technical specifications, as mentioned in Section 2.2.

The IntARSI project wants to integrate several aspects of communication: attractiveness, accessibility, usability, educational impact, emotional and multisensory engagement,

storytelling, and gaming strategies in a unified vision. We hope that the work conducted within this project can be seen as a first milestone for integrating a wide range of actions that can improve the accessibility for larger user groups, according to a more comprehensive and unitary perspective for the museum development and management. A wider strategy for museums, in general, is needed: for instance, the presence of a staff, specifically trained and dedicated to welcome and support impaired persons, mediating their approach with the environment and the technologies; training or recruiting staff who can speak sign language; and staff who are themselves disabled would be important next steps. An access audit should include a review of all communication issues and marketing, for example, ensuring that images of the museum on posters and on the website include images of disabled visitors.

In conclusion, we are confident that the next steps of this process (and project) can be based on deep cultural interactions between real and virtual environments, museum staff, and visitors' participation.

Author Contributions: Conceptualization, E.P.; methodology, E.P., A.P., G.F.; validation, E.P.; formal analysis, E.P. and A.P.; investigation, E.P., A.P., L.B. G.F.; resources, E.P., A.P.; data curation, E.P., A.P., G.F.; writing—original draft preparation, E.P., A.P., L.B., G.F.; writing—review and editing, E.P., A.P., G.F., L.B.; supervision, E.P.; project administration, E.P.; funding acquisition, E.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by MuCIV, CUP: F34E19000070003. Agreement MuCIV-CNR ISPC prot. N. 0000566 del 20/09/2019.

Data Availability Statement: Data supporting reported results can be found in the Technical Dossier of the IntARSI Multimedia project developed by CNR ISPC (ex ITABC) delivered to MuCIV, including links to archived datasets generated during the study (prot. N. 1489/2020).

Acknowledgments: The authors would like to thank the MuCIV, in particular the Filippo Maria Gambari, Francesca Manuela Anzelmo, Ilenia Bove, Gaia Del Pino; the Archaeological Park of Ostia Antica, in particular Clauda Tempesta and Alberto Tulli; the experts in accessibility Cristiana Carlini (Museo Omero) and Carlo Di Biase for their precious support; Michele Fucci for helping us with the technological system integration; the colleagues of CNR ISPC-Virtual Heritage Lab who collaborated in the design of technologies and in the archaeological research; our colleague Nicolò Paraciani who supported us in the topic of accessibility; finally, Lazio Innova who financed the project.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Council of Europe (CoE). Council of Europe (CoE). Council of Europe Framework Convention on the Value of Cultural Heritage for Society. In *Faro Declaration of the Council of Europe's Strategy for Developing Intercultural Dialogue*; Council of Europe: Strasbourg, France, 2005.
2. Falk, J.H. *Identity and the Museum Visitor Experience*; Left Coast Press: Cambridge, MA, USA, 2009.
3. Falk, J.H.; Dierking, L.D. *The Museum Experience Revisited*; Routledge: London, UK, 2012.
4. Pietroni, E. Experience Design, Virtual Reality and Media Hybridization for the Digital Communication Inside Museums. *Appl. Syst. Innov.* **2019**, *2*, 35. [CrossRef]
5. Pietroni, E.; Ferdani, D.; Forlani, M.; Pagano, A.; Rufa, C. Bringing the illusion of reality inside museums—A methodological proposal for an advanced museology using holographic showcases. *Informatics* **2019**, *6*, 2. [CrossRef]
6. Pietroni, E.; Pagano, A.; Poli, C. Tiber Valley Virtual Museum: User Experience Evaluation in the National Etruscan Museum of Villa Giulia. In Proceedings of the 24th International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision WSCG 2016, Plzen, Czech Republic, 30 May–3 June 2016; Skala, V., Pan, Z., Eds.; UNION Agency: Plzen, Czech Republic, 2016; pp. 97–106, ISSN 2464–4625 (CD-ROM)ISSN 2464–4617 (print).
7. Bateson, G. *Steps to an Ecology of Mind*; University of Chicago Press: Chicago, IL, USA, 1972.
8. Forte, M. About Virtual Archaeology: Disorders, Cognitive Interactions and Virtuality. In *Virtual Reality in Archaeology*; Barceló, J.A., Forte, M., Sanders, D.H., Eds.; British Archaeological Reports; Archeopress: Oxford, UK, 2000.
9. ISO 9241-11:2018. Ergonomics of Human-System Interaction—Part 11: Usability: Definitions and Concepts. Available online: https://www.iso.org/standard/63500.html (accessed on 3 April 2021).
10. Pescarin, S. Video Games, Ricerca. In *Patrimonio Culturale*; Franco Angeli Editore: Milano, Italy, 2020; ISBN-13: 9788835103004.
11. Mellet-d'Huart, D. A model of (en)action to approach embodiment: A cornerstone for the design of virtual environments for learning. *Virtual Real.* **2006**, *10*, 253–269. [CrossRef]

12. Wagner, R.W. Edgar Dale: Professional. *Theory Pr.* **1970**, *9*, 89–95. [CrossRef]
13. Betsy, J.; Case, P.H.D. Universal Design, Policy Report, June 2003, by Pearson Education, Inc. or Its Affiliate(s). Available online: http://images.pearsonassessments.com/images/tmrs/tmrs_rg/UniversalDesign.pdf (accessed on 27 December 2020).
14. Accessibility Requirements for ICT Products and Services. EN 301549. Available online: https://www.etsi.org/deliver/etsi_en/301500_301599/301549/02.01.02_60/en_301549v020102p.pdf (accessed on 3 April 2021).
15. ISO/IEC 17007:2009. 2018-Conformity Assessment—Guidance for Drafting Normative Documents Suitable for Use for Conformity Assessment. Available online: https://www.iso.org/standard/42635.html (accessed on 3 April 2021).
16. Baykal, G.E.; Veryeri Alaca, I.; Yantaç, A.E.; Göksun, T. A Review on Complementary Natures of Tangible User Interfaces (TUIs) and Early Spatial Learning. *Int. J. Child-Comput. Interact.* **2018**, *16*, 104–113. [CrossRef]
17. Billinghurst, M.; Grasset, R.; Seichter, H. Chapter 11—Tangible Interfaces for Ambient Augmented Reality Applications. In *Human-Centric Interfaces for Ambient Intelligence*; Aghajan, H., Delgado, L.C., Augusto, J.C., Eds.; Academic Press: San Diego, CA., USA, 2010; pp. 281–302. ISBN 9780123747082. [CrossRef]
18. Grassini, A. *Toccare la Bellezza—Catalogo Mostra*; Corraini: Mantova, Italy, 2020; pp. 11–17.
19. Macdonald, S. Interconnecting: Museum visiting and exhibition design. *CoDesign* **2007**, *3*, 149–162. [CrossRef]
20. Bedford, L. *The Art of Museum Exhibitions: How Story and Imagination Create Aesthetic Experiences*; Left Coast Press: Walnut Creek, CA, USA, 2014.
21. Bogle, E. *Museum Exhibition Planning and Design*; AltaMira Press: Landham, MA, USA, 2013.
22. Decker, J. (Ed.) *Technology and Digital Initiatives: Innovative Approaches for Museums*; Innovative Approaches for Museums; Rowman & Littlefield Publishers: Lanham, MD, USA, 2015.
23. AA.VV. A cura di Museo Tattile Statale Omero. L'arte a portata di mano. Verso una pedagogia di accesso ai Beni culturali senza barriere. In Proceedings of the Atti del Convegno, Armando, Roma, Italy, 21–23 October 2004.
24. Grassini, A. I ciechi e le arti plastiche. In *Le dispense del Museo Omero*; Museo Omero: Ancona, Italy, 2004.
25. Hassenzahl, M. The thing and I: Understanding the Relationship between User and Product. In *Funology*; Blythe, M.A., Overbeeke, K., Monk, A.F., Wright, P.C., Eds.; Human-Computer Interaction Series; Springer: Dordrecht, The Netherland, 2003; Volume 3, pp. 31–42.
26. Veneziani, M. Experientia. Lessico Intellettuale Europeo. In Proceedings of the X Colloquio Internazionale, Roma, Italy, 4–6 January 2001; Olschki: Firenze, Italy, 2002. ISBN 9788822251435.
27. DuFour, R.; DuFour, R.; Eaker, R.W.; Many, T.; Mattos, M. *Learning by Doing: A Handbook for Professional Learning Communities at Work*, 3rd ed.; Solution Tree: Bloomington, IN, USA, 2016.
28. Moon, J.A. *A Handbook of Reflective and Experiential Learning: Theory and Practice New York*; Routledge: London, UK, 2004.
29. Dewey, J. *Experience & Education*; Kappa Delta Pi: New York, NY, USA, 1938.
30. Kolb, D. *Experiential Learning: Experience as the Source of Learning and Development*; Prentice Hall: Englewood Cliffs, NJ, USA, 1984.
31. Baraldi, S.; Bimbo, A.D.; Landucci, L.; Torpei, N. Natural Interaction. In *Encyclopedia of Database Systems*; Liu, L., Özsu, M.T., Eds.; Springer: Boston, MA, USA, 2009. [CrossRef]
32. Arena, M.S. *l'Opus Sectile di Porta Marina*; Soprintendenza per i Beni Archeologici di Ostia: Roma, Italy, 2005.
33. Caselli, M.C.; Maragna, S.; Volterra, V. *Linguaggio e Sordità*; Il Mulino: Bologna, Italy, 2006; pp. 38–40.
34. Di Biase, C. Accessibilità e Lingua dei segni. In *Quaderni della valorizzazione. Nuova Serie 4—Edited by Direzione Generale Musei*; MiBACT: Rome, Italy, 2017.
35. Porta, J.B. *Natural Magick*; NuVision Publications: Canton, MA, USA, 2003; ISBN 9781595472380.
36. Dawson, P. The Visual Language of Holograms. In *Advanced Holography-Metrology and Imaging*; Naydenova, I., Ed.; IntechOpen Limited: London, UK, 2011; ISBN 978-953-307-729-1.
37. Carvalho, D.; Bessa, M.; Magalhães, L.; Carrapatoso, E. Performance evaluation of gesture-based interaction between different age groups using Fitts' Law. In *Proceedings of the XVI International Conference on Human Computer Interaction (Interacción '15)*; Association for Computing Machinery: New York, NY, USA, 2015; Article 5; pp. 1–7. [CrossRef]
38. Carvalho, D.; Bessa, M.; Magalhães, L. Different interaction paradigms for different user groups: An evaluation regarding content selection. In Proceedings of the XV International Conference on Human Computer Interaction—Interaccion'14, Puerto de la Cruz, Tenerife, Spain, 10–12 September 2014; p. 40.
39. Khalaf, A.S.; Alharthi, S.A.; Dolgov, I.; Toups, Z.O. A Comparative Study of Hand Gesture Recognition Devices in the Context of Game Design. In Proceedings of the 2019 ACM International Conference on Interactive Surfaces and Spaces, Daejeon, Korea, 10–13 November 2019; pp. 397–402.
40. Convention on the Rights of Persons with Disabilities. Available online: https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html (accessed on 3 April 2021).
41. Davidson, L.; Pérez Castellanos, L. *Cosmopolitan Ambassadors: International Exhibitions, Cultural Diplomacy and the Polycentral Museum*; Vernon Press: Wilmington, DE, USA, 2018.
42. Pitman, B.; Hirzy, E. *Ignite the Power of Art: Advancing Visitor Engagement in Museums*; Yale University Press: New Haven, CT, USA, 2011.
43. Roppola, T. *Designing for the Museum Visitor Experience*; Routledge: London, UK, 2014.
44. Simon, N. *The Art of Relevance*; Wordpress: Santa Cruz, CA, USA, 2016.