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Co-designing Cultural Heritage Experiences for All with Virtual Reality: a Scenario-Based Design approach

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Abstract

The use of digital technologies for enhancing the accessibility of cultural heritage sites is an emerging field of research with relevant design challenges. Research in this field highlights the potential of virtual reality (VR) to guarantee access to and enjoyment of cultural heritage to visitors with disabilities. This paper aims to advance knowledge on the design of visitor-centric VR solutions for enhancing cultural heritage accessibility, presenting the process, tools and findings of a user experience design research for the development of a compensatory VR solution for visitors with mobility impairments. For this research, the Scenario-Based Design method (SBD) is applied within a User-Centered Design approach to identify user requirements of the VR solution. Based on this method, different personas and corresponding scenarios are designed to represent the needs, motivations and behaviors of the main user groups of the digital solution. Further, the SBD is used in the prototyping phase as a tool for the co-design activity, which involved users, designers and other stakeholders to identify the experiential and functional requirements for the VR solution. The paper presents the findings of the co-design process and discusses the implications of the use of SBD for developing digital solutions for cultural heritage accessibility.

L'uso delle tecnologie digitali per migliorare l'accessibilità dei luoghi della cultura è un campo di ricerca emergente che presenta rilevanti sfide di design. La ricerca in questo campo evidenzia il potenziale della realtà virtuale (RV) per garantire l'accesso e la fruizione del patrimonio culturale ai visitatori con disabilità. Il presente lavoro intende contribuire all'avanzamento delle conoscenze sul design di soluzioni RV *visitor-centric* per migliorare l'accessibilità del patrimonio culturale, presentando il processo, gli strumenti e i risultati di una ricerca di user experience design finalizzata allo sviluppo di una soluzione compensativa per i visitatori con disabilità motorie. La ricerca impiega il metodo dello Scenario-Based Design (SBD) nell'ambito di un approccio di User-Centered Design per identificare i requisiti utili allo sviluppo della soluzione RV. Attraverso questo metodo, diversi *personas* e i corrispondenti scenari sono stati progettati per rappresentare bisogni, motivazioni e comportamenti dei principali gruppi di utenti. Lo SBD è stato inoltre utilizzato nella fase di prototipazione come strumento per l'attività di co-design che

ha coinvolto utenti, designer e altri stakeholder allo scopo di identificare i requisiti esperienziali e funzionali per l'efficace sviluppo della soluzione. L'articolo presenta i risultati del co-design e discute le implicazioni dell'uso di questo approccio per lo sviluppo di soluzioni digitali per l'accessibilità del patrimonio culturale.

Introduction

According to the World Health Organization, about 15% of the world's population (over 1 billion people) is estimated to experience disability and this number is growing due to increases in chronic health conditions and population ageing, among other causes ([44]). Making cultural heritage accessible to people with disabilities is an imperative for the development of inclusive societies and accessible tourism for all ([45]). Promoting accessibility represents a crucial aspect of contemporary management of cultural heritage to create participative and inclusive spaces where culture is collectively created through the experiences of the audience ([32]).

The accessibility of cultural heritage sites is a complex challenge that needs to be addressed in relation to all aspects of the visitor experience ([36]) and to every stage of the tourist journey, starting from travel planning and decision making ([30]). The concept of accessibility of cultural heritage is multi-dimensional and refers to the tangible, intangible and digital barriers that can represent an obstacle to the fruition based on individual interactions and /or context ([10]). In recent years, several projects in the cultural heritage context have been aimed at removing physical, sensorial and intellectual barriers to achieve pilot schemes for a "Universal Accessibility" in line with universal design principles ([32];[9]).

The application of digital technologies in relation to cultural heritage accessibility is a primary issue of investigation, also in the light of the growing application of augmented and virtual reality technologies for enhancing cultural visitors' experiences ([7];[21];[6]). On one hand, research is concerned with making augmented and virtual contents and interaction accessible to all ([18];[31]); on the other hand, projects address the potential of technologies to compensate full or partial inaccessibility of heritage sites providing access to the broadest audience of visitors ([1];[2]).

In the last years, several cultural sites around the world have been virtually reconstructed through VR technologies for improved accessibility ([19];[13];[34];[35]). Among the most renowned VR applications is the virtual tour created for the fragile site of the Lascaux Caves in France, which were permanently closed to the public in 1963 for conservation issues: the alternative experience with VR allows visitors to be immersed in the original caves to admire the masterpiece of the Upper Paleolithic and interact with other visitors with avatars. In 2018, the National Gallery of Prague launched the VR experience 'Touching Masterpieces' that allows visually impaired visitors to touch through haptic gloves the 3D models of some famous sculptures, such is the bust of Nefertiti (in the Neue Museum, Berlin) and Michelangelo's David (in the Gallerie dell'Accademia, Florence) ([16]). VR technologies have been increasingly used to provide access to archaeological sites or museums that are not fully accessible to people with reduced mobility due to physical barriers that cannot be eliminated ([19];[25]). Pérez et al. ([37]) developed a VR application for one of the most important archaeological sites in Spanish Protohistory to provide

people in wheelchairs with the most realistic sensations while virtually touring the site. VR was used at the UNESCO World heritage site of Geevor Tin Mine Museum (UK) to provide an accessible experience for visitors who cannot access the underground mines ([24]). The analysis of elderly visitors' perceptions of this VR experience of the museum by tom Dieck et al. ([42]) provided evidence of the positive impact of VR on these visitors' experiences. Overall, previous research highlighted the potential role of VR for cultural heritage accessibility from an experiential perspective in relation to: visitors' better understanding of the cultural value according to a broad meaning of accessibility beyond physical and perceptual barriers ([1];[35]); development of a personal, emotional connection with cultural assets ([1];[2]); avoiding marginalizing situations through a single support for all ([2]); enhancing the sensory experience of heritage ([37]) and the social experience during the visit with family and companions ([42]).

Notwithstanding the significant progress on the use of immersive VR technologies in the cultural heritage sector, several design challenges remain in the development of VR solutions for providing universally accessible heritage experiences, including:

- designing for cultural experiences, which relates to the need to take fully into account the different motivations of cultural visitors ([1];[12]);
- designing for user empowerment that concerns the need to go beyond design for accessibility and pursue "the strongest form of human-centered design" ([26]);
- designing for customer-centric visitor experiences, which implies the need to fully understand the needs along the different stages of the visitor journey to design meaningful experiences with VR ([21]);
- designing for personalized cross – domain assistive solutions to address the accessibility and usability needs of people with disabilities ([36]).

In the light of these design challenges, this paper aims to contribute to advance knowledge on the design of visitor-centric VR solutions for enhancing the accessibility of cultural heritage. It presents the process and findings of a design research aimed to develop a VR solution for improving cultural heritage accessibility for visitors with mobility impairments. The research is conducted through User-Centered Design (UCD) ([23]) in line with the foundations of tourism experience design ([43]) and the principles of Design for All. Specifically, the paper provides insights into the application of the Scenario Based Design (SBD) method to identify user requirements for the VR solution through the involvement of users in the design cycle, from the concept generation to the prototype design.

Background

Research supports UCD as a preferred approach for the development of immersive solutions for cultural heritage ([4];[5];[40]), in line with the principles of Design for All ([2];[17]) in the context of the pervasive use of ubiquitous computing to mediate and support cultural heritage experiences. This approach is also at the basis of design for user empowerment ([26]), where users with disabilities are engaged in every stage of the design cycle.

Among the UCD methods, SBD ([38]) is useful to engage users, designers and other stakeholders in collaborative design processes, as an effective bridge between designers and the end users ([29]). It allows to visualize a case of use in a narrative (i.e., a storyboard) of a typical situation in which the end user interacts with the digital solution: this facilitates the user to imagine possible difficulties or advantages in using the digital application and designers to adequately consider the contextual and social factors for its sustainability. In this sense the scenario becomes a 'design object' ([29]) that can be modified, enriched, extended in the co-designing activities in parallel to the technological implementation.

Described by Carrol ([8]) as a method for envisaging and developing new technology-based systems for work or leisure, SBD is used in cooperative design and the application of ethnography for system design. Recently, it has been used in the design and development of new technological systems in different domains, including technology-enabled experiences of embodied computer games ([41]). In these experiences, scenarios are effective tools for users, stakeholders and designers to visualize a real situation in interacting with technologies and SBD offers a significant and unique approach to address some of the most typical and difficult challenges in design. The possibility to represent a real situation with all the potential social and technical constraints and informed with needs, goals, activities and context is for both designers and users a great resource to understand the real application of a new digital solution. Together with scenarios, personas are the tools borrowed from UCD to make visible and personalized a typical situation. Personas, as fictional users that encapsulate distinct sets of behavior patterns ([14]), are used in all the studies we refer to in the present project.

Recent research supports the use of SBD in design processes of digital solutions in tourism and cultural heritage. For instance, McCabe et al. ([29]) use SBD to engage diverse city stakeholders in developing innovative, technology-based tourism services with scenarios. In the cultural heritage context, Hall and Bannon ([20]) highlight the usefulness of SBD in the process for the creation of successful interactive museum exhibitions for children. The work by Ciasullo et al. ([11]) supports the use of SBD as an effective methodology in the development of customized technologies to improve the experience for museum visitors from an interdisciplinary perspective. The study by Nigay et al. ([33]) focuses on the domain of archaeology to improve the work of archaeologists considering two fundamental aspects: field studies and SBD. The SBD is used to get a concrete view of the current and future activities of the users. In this work, scenarios have proved to be very useful in the design of augmented reality (AR) systems. In particular, they allow to visualize how AR devices would affect the way professional users perform their individual and collective activities. In the work of Nigay et al. ([33]) the method is organized into two steps: 1) design scenarios based on an analysis of the real task (explanation by the end-users of her/his relevant work phases, away from the work setting); 2) design scenarios based on an analysis of the activity (observation and video recording of the activity of the end-users on site).In this case, the SBD is a tool in the hand of designers to obtain a guide for the requirements of the AR solution in which the users are a fundamental part of scenario, but are not involved in an effective co-design process.

For the purpose of our research, the interesting issue is the identification of the functional advantages of scenarios in the design of interactive systems, including simplicity and accessibility for all actors involved in the design process; the possibility to share a common language in the

design process; the enhancement of including various needs and extending creativity; and the real opportunity to develop the design solution at all stages from brief to release.

In relation to the accessibility of cultural heritage and the application of UCD principles therein, SBD is an appropriate approach to gain an in-depth understanding of the interaction of users with different accessibility needs to improve accessibility by digital solutions. In the study by Partarakis et al. ([36]), the interaction of different users with digital solutions for exhibitions is represented through indicative scenarios. In this study, scenarios and personas are tools to better understand a typical situation where different skill levels are involved in the interaction with digital exhibits. The use of scenarios, in this case, is aimed to describe in a more practical way an ordinary situation at the museum in relation to different types of user needs. The purpose of the research is to focus on the elements that allow the visit to be enjoyable and satisfying. As in our case, with the premise that the provision of universally accessible multimodal solutions for cultural heritage is critical to providing equal access to cultural resources for all citizens including the elderly and people with disabilities, the authors highlighted with the help of designed scenarios the following Human-Computer Interaction (HCI) challenges to be addressed in order to achieve accessibility to cultural heritage:

- new paradigms of interaction;
- new forms of user interface adaptation;
- new interaction techniques for accessibility, designed for everyone;
- alternative means of displaying information;
- mechanisms for personalized retrieval;
- intelligent assistive solutions customized for all domains.

To address these requirements, they finally propose an architecture that integrates every component needed to solve the proposed issues.

Despite the fact that projects using SBD are on the rise, there is a lack of research focusing on the use of this approach to support the identification of the requirements for an effective interaction with a VR solution in the context of cultural heritage accessibility. Moreover, to the best of our knowledge, SBD has never been used as an actual co-design tool; most commonly, scenarios have been created for users' evaluation to improve the proposed solutions. In our project, SBD is used as a tool in the hands of the end users in a co-design process aimed to develop a digital solution from a *Design for All* perspective. For the purpose of this research, the proposal by Yanagida et al. ([46]), for a structured SBD method in HCI, focused on ubiquitous computing and represented in Figure 1, is adopted as a reference.

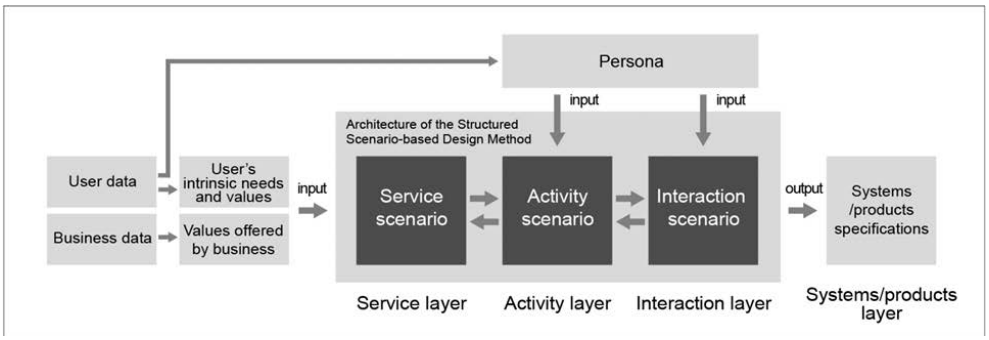


Figure 1: Basic model for the Structured Scenario-based Design Method. Source Yanagida et al (2009).

Following this method, a persona, reassuming needs, values, values offered by business, is used as input information. In this work, the information is useful to develop three different scenarios, service, activity, and interaction to obtain the systems/product specifications. The scope of the proposal by Yanagida et al. ([46]) is to provide a framework for the SBD allowing users' intrinsic needs and values to be considered throughout every stage of the systems/products development, through the specification stage. The input requirements are users' intrinsic needs and values and values offered by business identified by collecting user-related data such as questionnaires as a quantitative approach, or photo diaries, photo essays interviews, or observations as a qualitative approach. In order to develop a service scenario into an activity scenario and an interaction scenario, persona synthesized from data collected from users are used to help better articulate users' behaviors and emotions in scenarios. As described in the next section, this approach was adapted to the present research to include users with different accessibility needs in the design process of a compensatory VR solution to support a visit to a partially accessible archaeological site.

Materials and Methods

According to Carrol ([8]), SBD changes the object of design from an artifact or system in the world to a series of actions and experiences in human activity, and the previous review of literature showed how it is a helpful tool to better understand the real needs of a larger audience of visitors with different levels of accessibility needs in order to design for all. For this reason, this approach is used in this research to support the identification of the functional and experiential requirements of the digital solution from the users' point of view, according to the holistic perspective proposed by Hassenzhal ([22]) and in line with the requirements suggested by Bekele and Champion ([3]) in relation to immersive reality technologies and interaction methods for heritage experiences. To this end, this study engaged users, mainly with permanent mobility impairments, in all the stages of the design cycle through UCD, which is depicted in Figure 2. In line with the principles of Design for All, users have been involved in order to take into account every possible instance in relation to different accessibility needs.

The co-design process was carried out in collaboration with three associations of disabled people and accessible tourism. It is organized in four main phases:

1) Concept generation with users;

2) Personas design;

3) Preliminary scenarios design;

4) Prototype design with users and system development.

In the first phase, a multidisciplinary approach blending tourism experience design, HCI, accessibility of cultural heritage has been applied for the explorative research aimed at identifying the core elements of accessible heritage experience with VR and the target groups for developing personas through an online survey, a focus group and in-depth interviews ([28]). Then, personas have been developed on the profile features of the main target groups for the VR experience, in relation to three features: 1) accessibility needs ([39]), 2) engagement with cultural heritage, 3) attitude and use of technologies in tourism, including VR (the designed personas are reported in Figures 3-6). In the design of preliminary scenarios, the four personas represent the protagonists of four corresponding preliminary scenarios. Each scenario was matched with three elements, as detailed in Table 1: a) level of accessibility of the site; b) users' motivation for visiting the heritage site and c) expertise or attitude in use of technology. Table 1 described all the possible scenarios for a person with total or temporary impairments about to visit a cultural heritage site; they are presented in the form of "open ended" scenarios, so as to be completed directly by users and designers in the following co-design activity. As an example, in the first scenario Alfonso, a man with permanent mobility impairment, has to define the annual recreative program for his association, in which a cultural visit is planned: the scenario (Figures 8-13) describes the reactions and problems that can arise in this typical situation. In the last phase, the SBD co-design activity has been carried out: the design concept, the software simulation and the prototypes have been developed for the creation of the digital solution, which subsequently have been used in the final stages to design a last scenario with a low-fidelity prototype to be evaluated by the same users involved in the design cycle.

Tha co-design activity

The activity was structured in two sections: the first outlined objectives and methodology and included general reflections, the second focused on the co-creation of the scenarios with users to contextualize the elements relating to technology applications and provide design elements to be satisfactorily designed. The overarching aim of the activity was to obtain the guidelines for the development of the VR solution, for both the experiential and functional users' requirements.

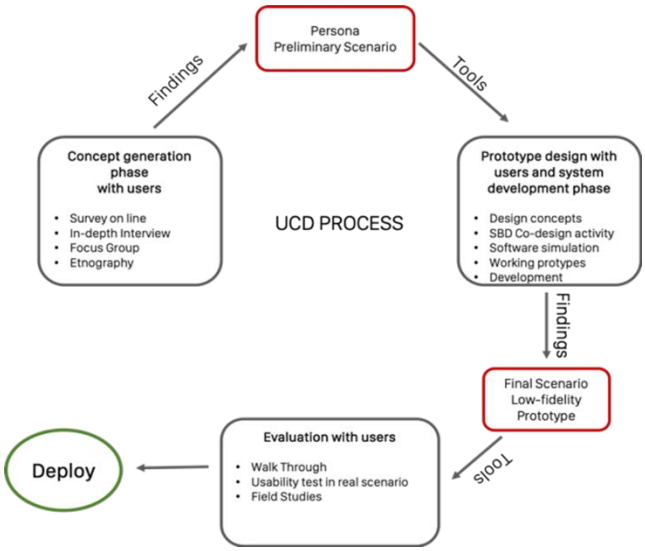


Figure 2: The UCD Cycle for the research project.

The core of the co-design activity was the identification of functional and experiential requirements useful for the implementation of the VR solution. The participation of users, stakeholders and designers provided points of view and information on the specific needs of users, with particular reference to those with mobility impairments, regarding some pragmatic elements and contextual indications useful for the sustainability of the application. The specific goal is the extrapolation of the design drivers for the release of mockups, i.e. prototypes that precede the development of the low-fi application.

The activity has been articulated in two sections aimed at:

- obtaining general background information on the cultural visit experience;
- understanding the users' needs more closely tied to the hedonic-experiential dimension;
- imagining the specific moments of the overall experience that the VR solution could support to improve accessibility;
- obtaining some specific elements on the usability and the user interface of the solution;
- obtaining drivers for the narrative modes of the virtual experience;
- understanding the needs to satisfy through envisioned solution.

Participants

Participants were chosen from the individuals who represented the requirements derived from the preliminary analysis:

1. President of an association of people with disabilities, user with motor disability;

2. User with motor disability;

3. User with partial motor disability;

4. Stakeholder from tourism accessibility;

5. Hardware developer;

6. UI Designer;

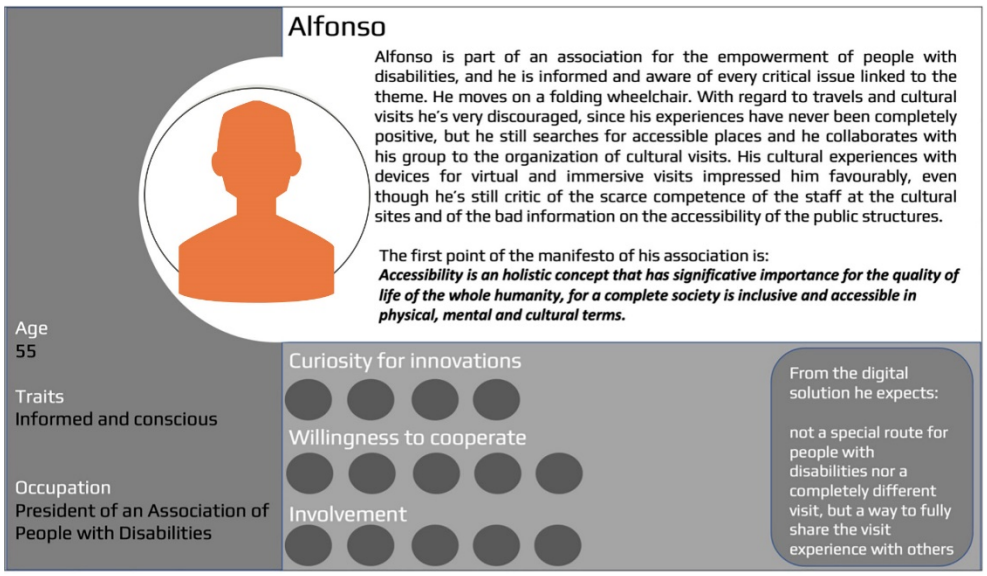
7. Experience Designer;

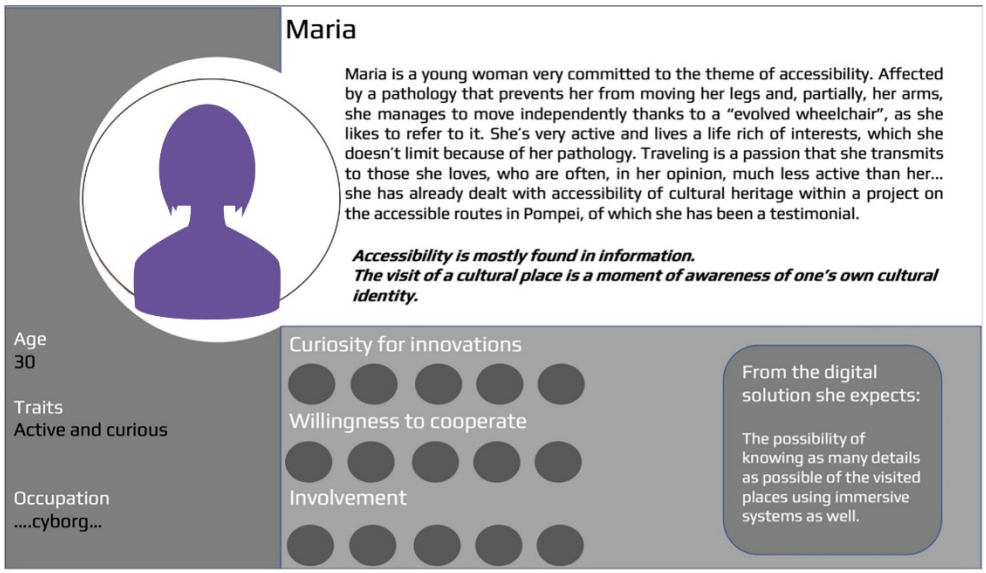
8. Experience Designer;

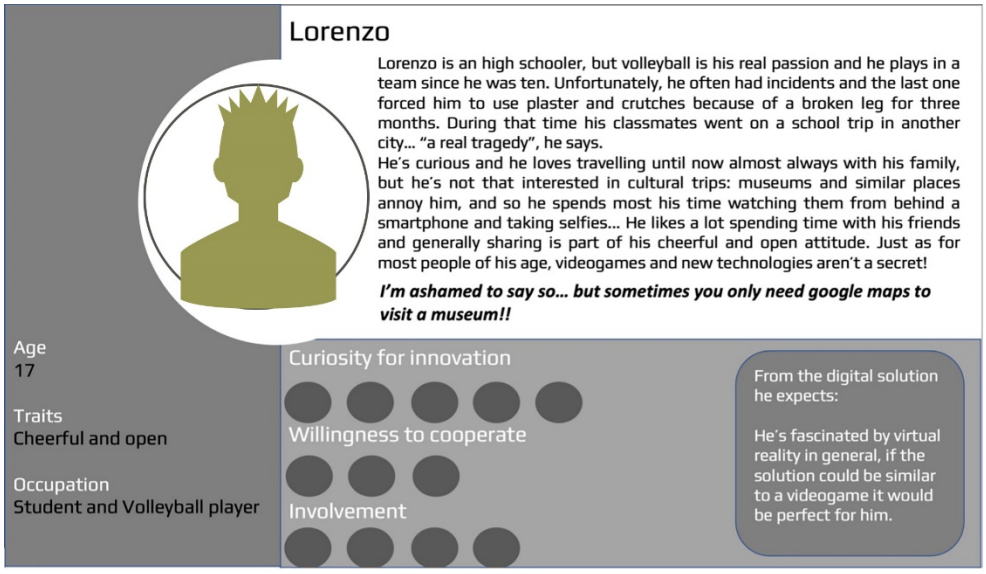
9. UX Designer;

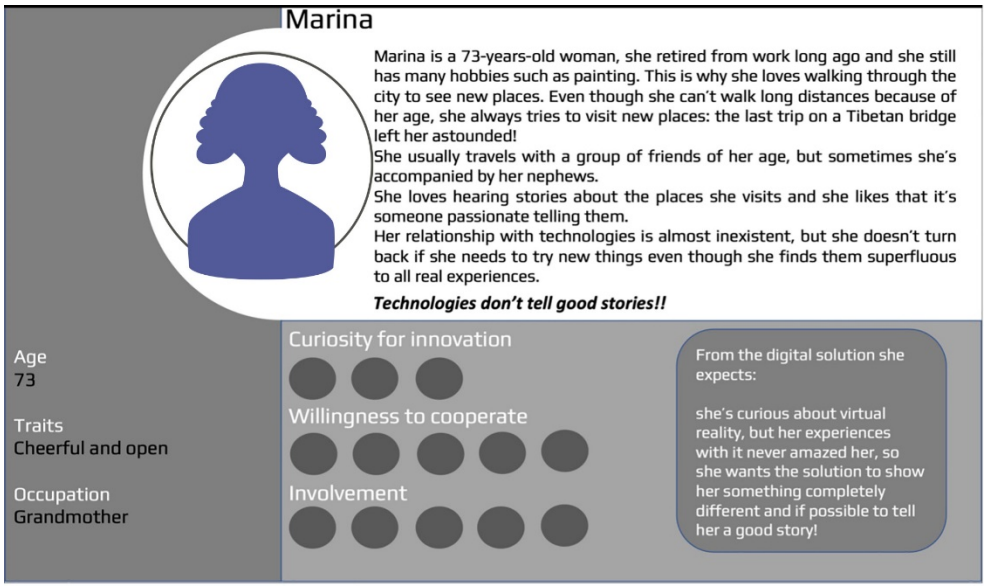
10. Accessible tourism expert.

The group included also one auditor, notably a manager from the IT company developing VR solutions for Cultural Heritage. In the co-design session, the number of participants was even as the activity was conducted in pairs alternating between moments of group reflection and design.




Maria
Maria is a young woman very committed to the theme of accessibility. Affected by a pathology that prevents her from moving her legs and, partially, her arms, she manages to move independently thanks to a "evolved wheelchair", as she likes to refer to it. She's very active and lives a life rich of interests, which she doesn't limit because of her pathology. Traveling is a passion that she transmits to those she loves, who are often, in her opinion, much less active than her... she has already dealt with accessibility of cultural heritage within a project on the accessible routes in Pompei, of which she has been a testimonial.
Accessibility is mostly found in information.
The visit of a cultural place is a moment of awareness of one's own cultural identity.
Age
30
Traits
Active and curious
Occupation
....cyborg...
Curiosity for innovations
Willingness to cooperate
Involvement
From the digital solution she expects:
The possibility of knowing as many details as possible of the visited places using immersive systems as well.


Lorenzo
Lorenzo is an high schooler, but volleyball is his real passion and he plays in a team since he was ten. Unfortunately, he often had incidents and the last one forced him to use plaster and crutches because of a broken leg for three months. During that time his classmates went on a school trip in another city... "a real tragedy", he says.
He's curious and he loves travelling until now almost always with his family, but he's not that interested in cultural trips: museums and similar places annoy him, and so he spends most his time watching them from behind a smartphone and taking selfies... He likes a lot spending time with his friends and generally sharing is part of his cheerful and open attitude. Just as for most people of his age, videogames and new technologies aren't a secret!
I'm ashamed to say so... but sometimes you only need google maps to visit a museum!!
Age
17
Traits
Cheerful and open
Occupation
Student and Volleyball player
Curiosity for innovation
Willingness to cooperate
Involvement
From the digital solution he expects:
He's fascinated by virtual reality in general, if the solution could be similar to a videogame it would be perfect for him.



Figures 3-6: Description of the personas.

Preliminary scenarios (P.S.)	Accessibility of the site	Personas' motivation and attitude towards technology	Scenarios' Storyboard
P.S. 1	Partially accessible	Persona 1: Medium motivation, medium attitude to use technology, low experience with VR.	Persona 1 is a man, Alfonso, with a permanent mobility impairment, a member of an association for people with disabilities, and he is looking for a cultural site for the annual recreation program. The scenario describes a typical situation in which he must find an agreement among members by proposing a site to visit. He eventually finds an interesting, but partially accessible site.
P.S. 2	Totally inaccessible	Persona 2: High motivation to visit heritage, high attitude to use technology (included VR)	Persona 2 is a young woman, Maria, with a permanent motor disability who would like to go on a cultural tour and a friend suggests her to visit an extraordinary church that unfortunately is totally inaccessible. The scenario shows Maria's need to escape her comfortable but boring situation and consistently with her character, her desire to visit and learn about cultural heritage that is often inaccessible.

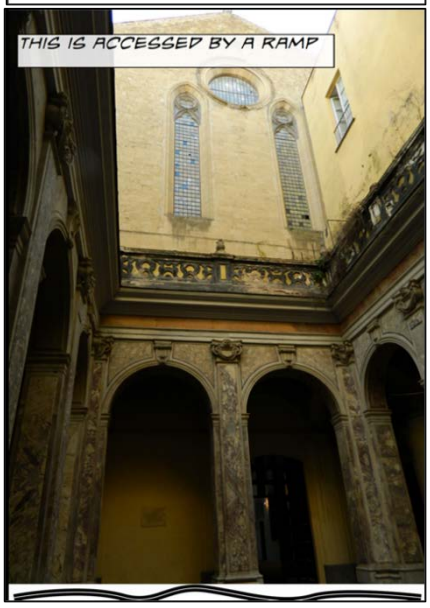
P.S.3	Partially accessible	Persona 3: Low motivation, high attitude in use of technology, included VR.	Persona 3 is a young boy with a broken leg, Lorenzo, who is visiting a site with his classroom, but he is very bored and the partial accessibility of the site is a barrier for him. It is not rare for teenagers to find cultural visits uninteresting, although this problem is not generally linked to momentary impairments.
P.S.4	Totally or partially inaccessible	Persona 4: Medium motivation, low attitude in use of technologies, no VR experience.	Persona 4 is Marina, an elderly woman with a great desire to visit a cultural site with her granddaughter, but her mobility is limited, and the site is not fully accessible. The proposed scenarios is devoted to the difficulties of older age groups in sharing cultural visits with younger relatives or friends, thus addressing the need of truly cross-cultural designs.

Table 1: The design features for preliminary scenarios.


HENCE...
ACCESSIBLE CULTURAL SITES...
...MMMM... WHEN YOU GO... THEY AREN'T!
AND WE ARE 15!!
HERE IT IS!


LISTEN UP, PEOPLE.
CHAP CHAP CHAP
THIS IS 95% ACCESSIBLE ... IS DOWNTOWN AND IF I UNDERSTAND CORRECTLY IS NOT COMPLICATED THE JOURNEY. TOMORROW I FOCUS MORE THAN NOW THAT I'M FED UP AND YOU SHOULD THANK ME BECAUSE I ONLY CARE ... A GOOD PIZZA NEARBY!!!!!


LATER...
GO... HOW TO GET THERE...
IT SEEMS... THAT YOU CAN... THEN....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Figures 7-13: Preliminary Scenario 1. Foto IlSistemone, CC BY-SA 4.0

The two sections of the activity were as follows: the first outlined objectives and methodology and included general reflections, while the latter focused on the co-creation of the scenarios. The presented preparatory tools have been used in the participatory design activities. The methods encompassed, as illustrated in Table 2, both traditional methods (brainstorming) and creative scenario design activities that facilitated subsequent readiness to provide insights into the storytelling modality for the VR solution.

Goals	Activities	Methods
Empathy	Know each other	Introduction to the research project Self-presentation of the participants
Specific skills on key issues.	Gathering information on the level of involvement and expertise on the proposed topics from users' and stakeholders' perspective: Accessibility Cultural Heritage Use of technologies	Presentation of the accessibility issues by means of videos, examples, etc. Brainstorming on the proposed topics. Using different VR solutions, by Oculus, Cardboard, Web.

Presentation of Co-Design Activity, Scenario Development	Sharing of design tools; Scenario presentation	Video sharing and description of the scenarios.
Co-Design activity, scenario development VR Experience Design	Co-design for the implementation of scenarios aimed at envisioning the experience with the VR solution and co-design of some of the pragmatic requirements of the VR solution.	Storytelling development activities in pairs, using the collage technique. Designers and users were provided with the frameworks of the chosen scenarios and images with pre-structured vignettes to continue the stories.

Table 2: Synthesis of co-design activity methods.

The activity was conducted during a Focus Group organized in a single day at the headquarters of an association of people with disabilities. It was divided into three moments:

1) the empathize phase: participants' self-presenting and get to know each other;

2) evaluation of different digital solutions for the cultural visit: in order to provide everyone with the necessary tools to carry out the activity feeling at ease, some preliminary moments of presentation of the contents and of the participants were carried out. An initial phase of brainstorming on the accessibility of cultural heritage and the actual technologies preceded a phase of direct experience of different VR solutions for cultural heritage visits designed for different devices:

a) web-based: a 3D model desktop base visit of an ancient cathedral;

b) for Oculus visor: a test of Oculus RIFT device with a VR cinematic experience of cultural site;

c) for smartphone+cardboard: an app for the virtual guided tour of a museum with smartphone and cardboard.

The examples served not only the purpose of imagining more accurately the solution that the project wanted to develop, but also of entrusting the meaning of functional requirements to concrete examples, so that users were comfortable in the subsequent activity.

3) co-design of scenarios (combination of pairs users/designers, introduction of preliminary scenarios structured as storyboards, co-design). The pairs worked together imagining the role of VR as a trigger and compensative solution to visit the inaccessible cultural site, using the preliminary scenarios as tools to implement and visualize a personalized story. The sharing of all the preliminary scenarios has happened through video, after which the relating materials have been supplied to the pairs consisting in sheets, images, balloon, and all would have facilitated the process of imagining the continuation of the chosen scenario. This choice was adopted in order to allow the designers to deeply understand the users' desiderata, letting them imagine exactly a situation in which they had repeatedly found themselves and in which the VR solution could be an advantage if designed according to the preferred requirements. Each pair chose one of the

preliminary scenarios and with the collage technique designed the sequel of the story visualizing the VR experience in relation to both experiential and functional requirements. An example of a scenario designed by the user with the designer during the activity is provided in Figure 14: the experiential requirements are underlined with a red line ("the Oculus must allow me to see what is on the upper floor") and the functional requirements with a yellow line ("I may need some of these commands").

Figure 14: An excerpt of a scenario co-created by user during the co-design activity.

Findings

The findings of the co-design activity provided the requirements and their translation in practical terms to inform the design of the VR experience. In particular, the findings include users' requirements from both an experiential and technological perspective of the use of immersive reality for cultural heritage, in line with Hassenzahl ([22]) and Bekele and Champion ([3]).

The experiential (ER) and functional (FR) requirements are described as follows (the quotations reported in relation to the requirements are gathered from the comments of the participants during the co-design activity).

Experiential requirements

ER1. Universal Solution - The VR solution is expected to be implemented as a single experience for all the potential visitors onsite rather than as a separated experience dedicated to users with mobility impairments. Dedicated solutions for visitors with disabilities are negatively perceived as marginalizing experiences.

ER2. Cultural engagement - Curiosity for the cultural experience is the driving force of every imagined scenario, independently from the level of cultural motivation. This also implies the importance of promoting offsite the possibility of an enhanced experience through VR in the pre-visit stage as a trigger to live an innovative heritage experience and engage potential visitors. For example, in relation to the P.S. 4 the participants have added a pre-visit narrative, in which Persona 4 wants to visit again a museum that she remembers not being fully accessible at the time of her last visit; she wonders if at the present time the site has been made accessible and after a search on the web, she finds out that a novel Oculus solution is available at the site.

ER3. Connectedness - The possibility to share the experience with other visitors emerges a fundamental experiential element in line with tom Dieck et al. ([42]). This is imagined by users also as the possibility to share the experience with others offsite ("Being able to share what I'm seeing with others- at the site or not*")* and it is further indicated in relation to the possibility to share related contents (e.g., pictures).

ER4. Intellectual stimulation - The virtual experience is a trigger to arouse the interest and motivation of users to acquire knowledge about the site, in line with a broad meaning of accessibility, including perceptual and cultural dimensions beyond physical accessibility ([37];[15]), as mentioned by a participant "true accessibility is in the information". In this regard, it also aligns with the role of VR to enable the understanding of cultural value of the heritage experience as outlined by Arenghi and Agostiano ([2]) and Paladini et al. ([35]).

ER5. Storytelling– The narrative modality emerges as an important element; the involvement through an engaging storytelling is requested by users, as previously found by tom Dieck et al. ([42]), especially in the initial moments of the on-site visit. As one participant noted, "what leads me to visit a place is its story and beauty rather than what I can explore".

ER6. Autonomy – this requirement emerged in relation to users' possibility of choosing an autonomous virtual exploration of the site next to a guided tour. The VR is expected to enable users to "deepen the aspects that most interest" of the heritage site. Further, it relates to the preference for personal smartphone over head-mounted displays in relation to the possibility to use the device more autonomously. For VR devices human assistance is requested by users ("the operator will assist me"). If the navigation has an immersive modality, it must include at least an interactive independent part through smartphone or a screen display ("The app system comes to you through your smartphone*").*

Functional requirements

FR1. Multimodal interaction - Narrative modalities of contents are strictly linked with the devices' functional requirements: for a more immersive visit with the possibility to explore many

details, multimodal interaction and the use of different device is preferred; in the designed scenarios participants imagined immersive systems through oculus but also smartphones.

FR2. Minimal action/Minimalist design - The immersive modality is requested in the first moment of the visit, but aim to autonomous use, the users need an interface menu useful to navigate in all directions and zoom on details of site through basic controls.

FR3. Capacity of immersion/Use of diegetic and extradiegetic sound - In relation to the point of view, generally it is described as very close to artifacts, even "from the inside", e.g., the visitor wants to be immersed into the scenes of a painting. In addition, sharing the point of view of those who are not in the same part of the site via streaming. During the co-design activity, users provided indications for a storytelling performed by an 'expert' character not necessarily being visible to visitors (e.g., voice over).

FR4. Capacity of immersion/user participation – For improved accessibility, the functional requirement should provide for details of the site, such as the presence of inaccessible areas as well as details regarding impediments and difficulties (floors, ceilings) in the areas that the user can visit; during the co-design activity the point of view is described as being very close to the works of art and this is also related to the ER6.

FR5. Application Access - No profiling is preferred, but just automatic link when the visitor is onsite through personal devices. This functional requirement is closely related to the experiential one concerning autonomy in the experience (ER6). "The app system comes to you through your smartphone", which implies the automatic activation of the content without the need for profiling, for an increased autonomy in the interaction with the solution.

FR6. Ease of use - Headsets/headphones are not preferred as they could not be handled independently.

FR7. Co-located collaboration/ Remote collaboration - The designed scenario includes the sharing of the experience through various modalities: posting photographs after the visit through the application, during the visit via chat (i.e. in the form of call out), through a form of interaction like multiplayer, in line with the ER3.

The requirements obtained with SBD method have been integrated into a design model that establishes a correspondence between experiential and functional requirements (Figure 15).

The model links the experiential requirements corresponding to the users' needs (on the left) obtained during the explorative research phase ([28]) to the functional requirements of the VR (on the right), which were designed by users and designers during the co-design activity, through the core drivers of the accessible heritage experience enabled by VR that were gathered from literature and confirmed through the first stage of the research. It thus establishes a correspondence between experiential and functional requirements obtained during the co-design activity to ensure that the solution meets the core experiential drivers, notably feeling part of a cultural community, living a social fulfilling experience, being intellectually stimulated and empowered to live an autonomous experience.

The requirements informed the design of a final scenario, depicted in Figures 16-27, which supports the development of the low-fi prototype of the VR solution. In this final scenario, the

whole visitor journey is considered from the pre-visit stage to illustrate the case of use of the VR solution for providing enhanced accessibility to the archeological site chosen for the project. In relation to the onsite stage, it depicts the different requirements for the VR-enabled heritage experience, including the choice between autonomous and guided tour.

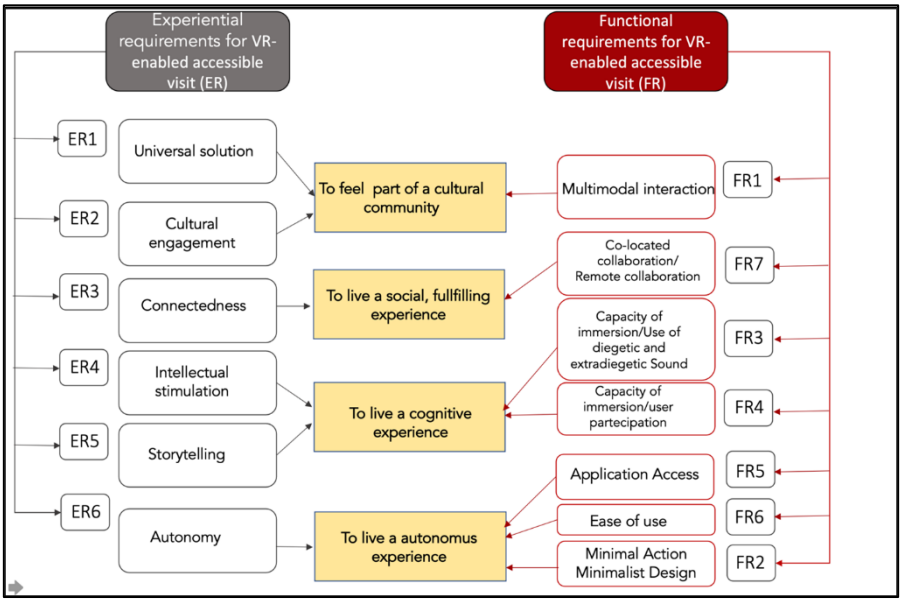
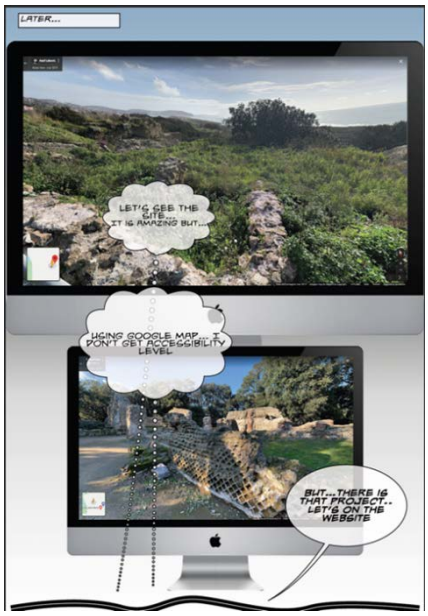


Figure 15: A framework of correspondence between functional and experiential elements of VR -enabled accessible visit.

Conclusions

This study provides insights into the process, tools and outcomes of a user experience design based on SBD illustrating how this method can be deployed to support the development of a digital solution as compensatory tool for cultural heritage accessibility through the identification of the requirements of users with disabilities, with specific regard to mobility impairments. For the possibility it offers to visualize the context and the visitor interaction therein, this method enables potential users to actively co-create the VR solution in relation to their expected experience along their visitor journey. Based on SBD, the research allowed to identify the experiential and functional requirements of the VR solution in relation to three different cultural heritage sites characterized by different level of accessibility. These findings were useful for VR designers to imagine a specific user to design for. In particular, the contribution of the co-design activity has been integrated in the development of the solution by proposing multimodal access to all the contents using personal devices and in all the stages of the experience taking into account the different needs for accessibility. This method is useful also in relation to the difficulties stressed by literature of evaluating the applications during the all iterative UCD cycle before a prototype is evaluated. In this sense, the SBD approach is useful for a continuous refinement of the interfaces that then will be evaluated imagining their use in specific contexts.

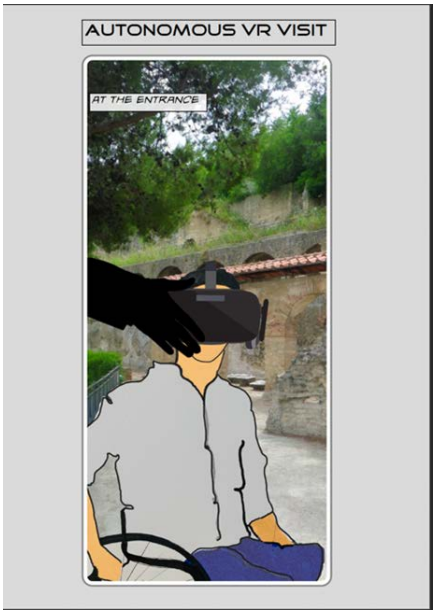
The study illustrates how SBD can be usefully applied for effectively involving users with accessibility needs in the whole UCD process, and not just only in the final stages of testing of the solutions. In this way, it provides a methodological contribution to address relevant design challenges in the specific context under investigation, in line with design for empowerment ([26];[27]). Notwithstanding the increased emphasis on user engagement to address the challenge of accessibility from a design for all perspective, research on the tools and methods for the co-creation and co-design of digital solutions for user empowerment is still in its infancy. The contribution also corroborates the usefulness of this method for tourism experience design ([43];[29]), by taking into account users' perspectives as humans (and not just consumers) within a holistic experience along the visitor journey. It finally supported its relevant role in facilitating interdisciplinary collaboration ([11]) in a context where collaborative interdisciplinary work is key to address the design challenge for accessibility ([27]).



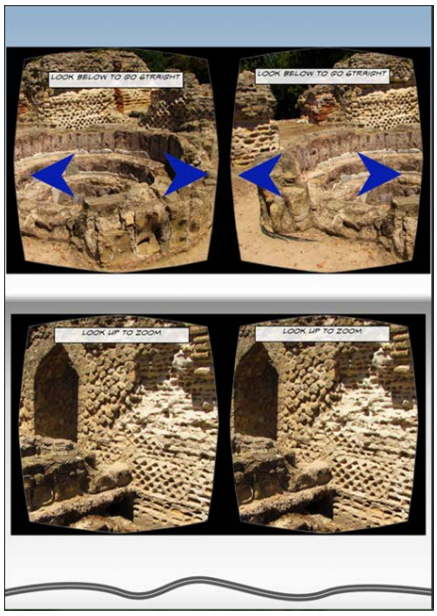

THE VIGIT DAY...ON-SITE!
THE ENTRANCE...
parco archeologico campi flegrei
#INHERITAGE
NEAR
Cinematic Virtual Reality
Visite guidate a 360°
Android App
Apple App

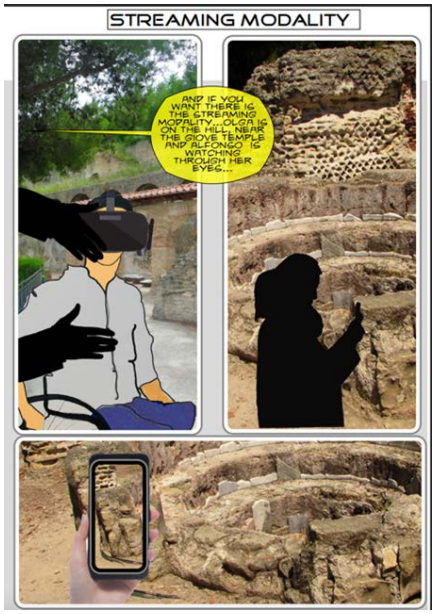

ON SITE.
WOW!!
OHHH... AMAZING!
YES! IT IS, BUT... THE VIGIT COULD CONTINUE IN EVEN MORE INCREDIBLE PLACES..., BUT THE WAY IS UPHILL...


...BUT MAYBE YOU HAVE VIGITED OUR WEBSITE AND ALREADY KNOW THAT IT IS ACCESSIBLE ALSO WITH A VR EXPERIENCE..
YOU CAN PUT ON AN HEAD MOUNTED DISPLAY, HELPED BY US, BACK AT THE ENTRANCE!
OR... YOU CAN USE YOUR SMARTPHONE FOCUSING THE IMAGE IN THE PANEL BEHIND YOU FOR VR EXPERIENCE.
IN THE SAME WAY, YOU CAN USE YOUR SMARTPHONE FOR AUGMENTED REALITY...IF YOU ARE CURIOUS!
360°
Cinematic Virtual Reality
Visite guidate a 360°
NEAR
tecnologia avanzata
per la realtà aumentata

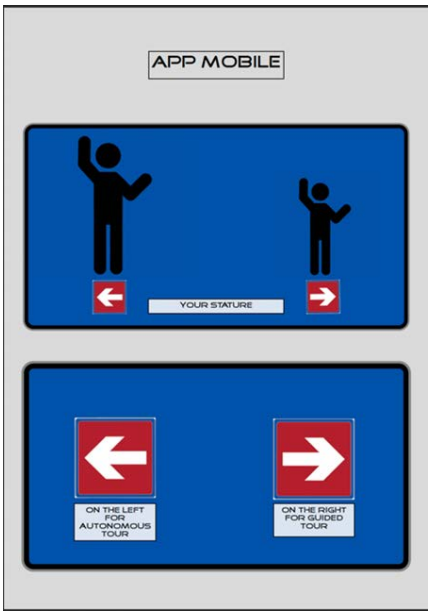

AUTONOMOUS VR VISIT
AT THE ENTRANCE


ON THE LEFT FOR AUTONOMOUS TOUR
ON THE RIGHT FOR GUIDED TOUR
ON THE LEFT FOR AUTONOMOUS TOUR
ON THE RIGHT FOR GUIDED TOUR
HI!
HI!
YOUR STATURE
YOUR STATURE


LOOK BELOW TO GO STRAIGHT
LOOK BELOW TO GO STRAIGHT
LOOK UP TO ZOOM
LOOK UP TO ZOOM


STREAMING MODALITY
AND IF YOU WANT THERE IS THE STREAMING MODALITY... OLGA IS ON THE HILL NEAR THE GROVE TEMPLE AND ALFONSO IS WATCHING THROUGH HER EYES...


AS SAID BEFORE YOU CAN VISIT THE TEMPLE USING THE APP.
FOCUS ON THIS IMAGE AND ENJOY YOUR VISIT!
NEAR
NEAR
tecnologia avanzata
per la realtà aumentata



Figures 16-27: An excerpt of final scenario.

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