Augmenting Smart Objects for Cultural Heritage: A Usability Experiment

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Abstract. In recent years the explosive growth of smartphones and the evolution of mobile communication networks have certainly revolutionized the way how people communicate and access information. This growing adoption of technology creates also some challenges. It is struggling to teach people who has had an increased exposure to technology. Cultural heritage organizations deal with this issue endlessly and look to the new technologies as an opportunity to transform and enhance the exhibition experience for matching the interest of the newest visitors. In this paper we focus on the augmented reality (AR) technologies and the role that they play to connect visitors to the modern exhibitions. Moreover, we define for the first time the concept of *Augmenting Smart Object* (ASO) that arises from the study of the state of the art of the AR systems applied to the cultural context and from our direct experience in a participatory design aimed at developing and evaluating an AR system for a museum exhibition.

Keywords: Augmented reality · Mobile devices · Participatory design · System usability

1 Introduction

Modern technologies are progressively becoming sewn into our daily lives. Small computational devices are integrated into common objects that people use to perform normal tasks or during leisure activities. This is more evident in *digital natives*, people born in the modern digital era who are used to touch and speak with their interactive devices to play, learn, and communicate or even to build their own smart and programmable toys with easy to use technologies like littleBits[1].

This growing adoption of technology creates also some challenges. As Prensky explains in [1], it is struggling to teach people who has had an increased exposure to technology. They not only will have developed an habit to use technology to look for information and to interact with others, but also they might have developed different

[1] http://littlebits.cc/.

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ways of learning [2] and in fact most of them are experiential learners [3], and with a capacity for multi-tasking.

In the domain of cultural heritage (CH so forth) there is a growing interest in making the cultural sites "enjoyable" to this new kind of users. As stated by Hein in [22] museums are perceiving themselves more as experience providers than as object exhibitors. In order to make such experiences more satisfying for visitors, exhibitions need to link the personal motives and values of visitors with the knowledge exhibited [4]. There are some examples of CH sites enhanced with digital technology, and particularly with augmented (AR) and virtual reality (VR) [5, 6]. For instance, the *Museo Archeologico Virtuale*[2] of the ancient city of Ercolano (Italia) does not exhibit real objects but allows visitors to interact with digital reproductions generated through holograms. In the nineteenth-century palace of *S. Teodoro*[3] in Naples, the curators enrich the visits using virtual and augmented reality to recall ancient events and settings. By means of the Augmented Reality, curators recreated rooms of the temple of *Hatshepsut* in Deir-el-Bahari, of the *Calatrava* castle and of other ancient buildings.

However, to pursue the original goal, improving the experience of visitors, integrating technology per se shouldn't be the main design driven force. As discussed in [7], technology should be conceived as a mediator to improve the visitor's experience not as a tool that diverts the attention from the cultural object or site to the technical device. The experience has to be attractive and enjoyable from the users' point of view but it also has to meet the educational goals underlying most cultural heritage sites. Csikszentmihalyi and Hermanson [26] identify two main factors that improve the visitor's engagement: *situational interest*, that happens when they are pushed to face challenging or intriguing situations; and *personal interest* that appears when the exhibition links with enduring visitor values and motives. The role that virtual and augmented reality technologies can play to promote situational interest is to deploy content and support an interaction that might generate stronger links with visitors. For example, authors of [25] explore the use of an augmented object to take profit from the social nature of people to improve the user experience.

In this context, we introduce the *Augmenting Smart Objects* (ASOs) concept as a way to support engaging experiences that combine both experiential and pedagogical value. An ASO is a nonintrusive and interactive device allowing users to access and interact with AR content in different CH contexts with a view to creating personal links between visitors and the exhibit. Following a participatory design approach, field research and interviews with experts were conducted to understand the features an ASO should exhibit. This knowledge informed the design of a prototype of ASO whose usability was evaluated with users who found the ASO as a way to experiment a more personal experience to interact with each object in the exhibit.

The rest of the paper is organized as follows: Sect. 2 presents the state of the art of the AR systems for CH sites. Section 3 describes the participatory process for designing an instance of the ASO and its usability evaluation. Section 4 formalizes the lessons learned during the whole design process. Finally, in Sect. 5 some conclusions are drawn.

[2] www.museomav.it.

[3] www.palazzosanteodoroexperience.com.

2 Related Work

The use of AR systems in CH sites are not a particularly recent practice. Back in 1999, Brogni et al. [15] discussed the growing interest and the technological limits of this kind of systems and tried to envision their future based on some kind of wearable or mobile devices. Nowadays, despite the expectations raised by devices supporting AR, such as large see-through screens or holograms, the most common solutions in CH sites are mobile devices, such as phones, tablets and AR glasses. These technologies are generally technically feasible and affordable, and, when the system is conveniently designed on the users' necessities, can offer a more personal and rewarding user experience.

Some examples are given by Vanoni et al. [16] and from the Casa Batlló[4] (Spain). In the first case, a tablet allows visitors to select different layers of virtual content to add to the exhibited pictures of the *Salone dei Cinquecento* in Florence's *Palazzo Vecchio*. In the second case visitors looking through a smartphone and using earphones can experience a virtual and augmented visit of *Casa Batlló*. However, although mobile devices are easy to use, in [21] authors highlight that similar systems act as a distraction during the visit and the attention is transferred from the environment to the technology. Also for such reason AR designers are looking to other technologies such as AR or VR glasses.

An example is given by the "Dreams of Dalí"[5] project. The project is hosted in the museum, sited in St. Petersburg, in Florida. The VR glasses allow visitors to experience for a while the immersion in one of the a Dalí's masterpieces. The company Guidgo[6] in 2014 developed a AR guide for museums exploiting the Google Glass[7]. The device guides the visitors and add extra information to the exhibit. A significant experience about AR application is given by ARtSENSE [14]. It is a European project which aims to create mobile museum guides based on AR applications. The ARtSENSE interface is based on AR glasses and other wearable devices used to allow visitors to interact with virtual objects. Similar projects are ARCHEOGUIDE [13] and LifePlus, [12]. Differently by ARtSENSE, the AR glasses are used to augment archaeological sites. Also in this case visitors have to use other wearable devices to use the system. In [29], researchers present a system aimed at supporting tourists in the city of Naples during their cultural visits. The system is based on AR glasses, hand recognition and head movements detection. Differently by the previous projects, the users have to wear only the AR glasses integrating several needed components and carry a mini pc. However, preliminary results describe the interaction uncomfortable and difficult.

The designs of AR systems generally share some common characteristics and limitations. First of all, they try to be didactic and recreational offering multimedia content to support visitors in understanding the exhibit. Their aim is to be helpful by assisting users during the whole time spent at the site (i.e. suggesting itineraries). Moreover, they require a continuous attention and they lack an adequate study of the interaction. Indeed, in order to recognize the objects to augment, visitors often have to explore the CH site using the

[4] www.casabatllo.es/en/visit/videoguide.

[5] thedali.org/dreams-of-dali.

[6] www.guidigo.com/glass.

[7] www.google.com/glass/start.

provided device and have to stop and carefully stare at the exhibited items. In other cases, they are required to wear uncomfortable devices during the whole visit or in some concrete points and they may need some external helps to use them.

In [19], the authors notice that AR designers chiefly focus on visual augmentations and disregarding other visitors' necessities. Pedersen remarks in [18] that "*human users needed to be treated as centers, immersed in AR interfaces rather than as viewers, seeing interfaces or graphical overlays*". In [20], the authors present a list of AR system requirements for CH sites. In particular, they highlight the necessities to have a full interactive, recreational and didactic AR system. Moreover, the system must focus on aspects that help users relax during the visit in order to enjoy the CH experience.

Van der Vaart and Damala in [17] try to deal with these issues through the design of an AR loupe. Such device is a smart object, that is a common object integrating sensors to understand and react to the environment [28]. In this specific case, the loupe integrates an iPhone to exploit its screen and sensors. The goal is to provide a more appropriate device for a museum context, to exploit the loupe affordances and make the interaction more intuitive. The loupe is able to recognize the exhibited objects and to add any multimedia content. The visitors have to stare at the exhibited objects through the loupe to see the content. Different functionalities can be selected by moving, tilting or shaking the device. Even if the loupe tries to address some of the mentioned issues, after an experimental study, the researchers recognize that the task to look for an object to augment may easily distract visitors especially the youngest one. More in general, some testers declared to focus more on playing with the device rather than the same exhibit.

These researches highlight there is still a need to understand how to integrate useful, usable and enjoyable technology in the museum in a way that does not divert the attention to the technological devices [7] and makes it possible to provide a more satisfying experience. A participatory design approach like the one described in this paper could help to understand better how to design these technological interventions balancing the goals of the CH professionals with the traits, motivations, values, and expectations of current visitors.

3 Participatory Design: Understanding the Requirements of Cultural Heritage Professionals

With a view to understand how to design experiences with the CH site, we adopted a participatory approach where stakeholders were involved in the elicitation and analysis of the requirements of potential technological devices. During this process, interviews and field work was conducted. In particular, we conducted three interviews: one with the director of the archaeological site of the Villa de Fuente Alamo in Cordoba (Spain); a second with an archaeological practitioner working as a guide at the ruins of ancient Stabia near Naples (Italy) and as a children archaeological teacher; and, a third interview with the technological manager of the S. Teodoro Palace in Naples (Italy). Moreover, we spent time in the sites where they work to observe activities and visitors. We discussed with our interviewees the kind of visitors they usually work with, the way they interact with them, and the main difficulties they can have when trying to

connect with them. Moreover, we also explore their confidence on the role of technology, and their willingness to use it in their work and in their daily life.

We obtained similar answers from the first two interviewees. The average age of "spontaneous" visitors is between 30–50 years and most visitors are women. Moreover, it is common to work with groups of school field trips. Spontaneous visitors generally show an initial interest for history and the ruins but after a certain time they get mentally tired. Pupils are more distracted and do not pay specific attention to the context. The guides try to deal with attention issues using some techniques based on a continuous interaction with visitors and trying to involve them in some recreational activities. Three examples used to get the attention of visitors through recreational activities include: (a) having actors playing the roles of the ancient dwellers of the city or recreating famous or mundane events; (b) proposing experiential activities such as having children excavating fake ruins to discover objects or (c) inviting visitors to touch and play with replicas of ancient objects found in the that archaeological site.

Apart from the attention issue, interviewers also highlighted another interesting point they have to deal with: the way to make visitors understand the different eras of the archaeological site. For instance, the director of Villa Fuente explained that some ancient ruins belong to Pre-Roman era, the thermal baths to the Roman, the Villa to a second Roman era while the cemetery was from the Arab period. The differences between periods that might seem obvious for experts are quite difficult to perceive by visitors but they make up an important fact to understand the site.

When asked about their confidence with modern technologies and their willingness to integrate them in their work they also provided similar answers. They use on daily basis devices for their personal life and to organize their work activities. For example, during the visits they use sometimes smartphones and tablets to write down notes, communicate with colleagues, take pictures and show pictures also to the same visitors. On the one hand, our interviewees do not consider themselves distrustful towards the introduction of some kinds of technological supports for their work, but on the other, they were afraid that the technology could be intrusive and could grab the attention of the visitors and divert it from the real goal: understand and appreciate the CH site. As one of the interviewers put it "*we are a small site in a non rich area, so we need people from the community liking and needing us. They have first to appreciate the value of this site and to perceive why we are valuable for the region*". When asked which kind of objects can be considered not intrusive, portable and respectful of the context small thinks like coins, lamps, pictures, shrines, or ancient bricks, were suggested.

The last interview gave us a different point of view. In the S. Teodoro Palace, visitors are led not by a human guide but by a digital guide speaking through some totems strategically located in the different rooms. The visit is enriched by the usage of VR helmets that allow to recreate ancient events and sets of the palace. The kind of visitors is really varied. It is common to have visitors of any age and any gender. Most of the visitors come fascinated by the idea of experimenting a new kind of visit. All the technologies are installed in strategic points and require the users' attention just there. This is to allow visitors to explore the rooms without to focus continuously to the technology. However, as the technical manager of *S.Teodoro* Palace confirms: "*If on the one hand there is a necessity to improve the visits using digital content, on the other, there is a real risk to completely draw the attention on it*".

3.1 Augmenting Smart Objects

We capitalized the knowledge gained from the fieldwork and interviews in the form of scenarios of working practices, from which we could start our brainstorming activities to envision ways to integrate technology in CH sites. Scenarios are a well known technique in design that we will use to illustrate alternative solutions [24]. In particular we introduce the concept of Augmenting Smart Object (ASOs henceforth), which are nonintrusive objects that can be naturally integrated in the physical context and that combine the ludic component with the didactic one. With that purpose an ASO is usually an existing physical object that is somehow related with the goal of the CH site. Moreover, the affordances of its physical shape [23] can be exploited to provide an easier and quicker interaction. The ASO is also a portable and interactive device aimed at providing users with AR to improve their visit without grabbing the spotlight: they can be used only in specific locations set by the administrator of the archaeological site. In the next paragraphs we describe two scenarios of use of ASOs.

Scenario 1 – Augmented Guided Visit. In this scenario the guide leads a group of visitors through the ruins of an ancient Greek-Roman colony. (S)he carries an ASO in form of a Roman lamp and uses it when (s)he wants to make people see the different eras of the site. Connecting the ASO to one of the totems distributed in the ancient city (see Fig. 1), an augmented reality system is started. A large see-through screen integrated into the totems superimposes on the reality some virtual objects recreating the ancient coast line. By changing the orientation of the ASO on the base, screen displays how the quarter looked like in the Roman era. In this case, the AR system is controlled by the expert guides, so the communication with the visitors is still managed by them.

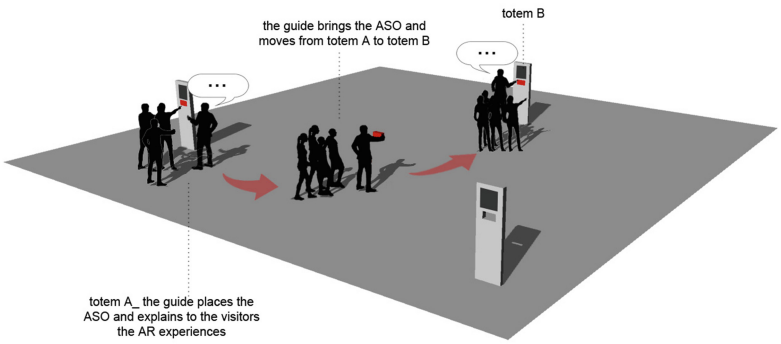

Fig. 1. A guide leads visitors through a CH site and uses an ASO to improve the explanations

Scenario 2 – Augmented Personal Visit. Visitors of the ruins of a Roman city enter the archaeological park and are provided at the entrance with an ASO in the form of an ancient Roman brick that has an integrated display. Visitors receive a brief explanation about how to use an ASO in the same way they do with a common audio guide. Then, they are encouraged to explore the site and pay attention to the bases allocated in strategic places. When a visitor puts the ASO on a base, the system recognizes the

position and the orientation view, the display gets alive and shows through augmented reality the recreation of a target building. Moreover, the visitor can rotate the object and put it again on the base. The scene changes and the screen will show the recreation of that building in a different historical era. Moreover, visitors can enter well-preserved rooms where they can admire remains of ancient mosaics (Fig. 2).

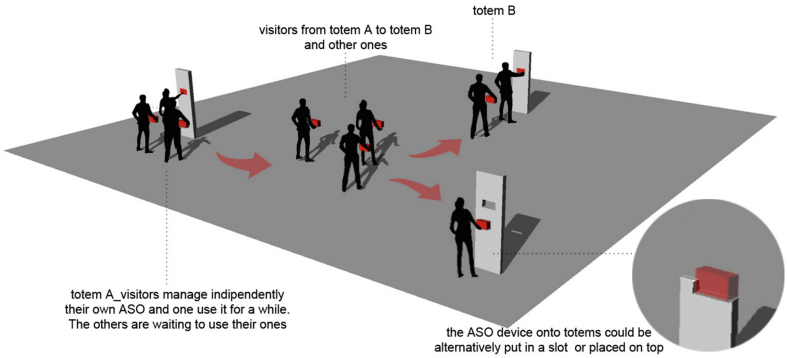

Fig. 2. Visitors exploring a CH site using an ASO

Besides an ASO's base there are coins' reproductions of different eras. After leaning the brick, they can pick a coin a put it in front of the ASO. It recognizes the exact coin and shows the reconstruction of the mosaic and the decoration of the corresponding era.

Starting from these scenarios we elicited an initial set of requirements divided into five categories according to the classification described by Preece et al. [10]. More relevant requirements are summarised in Table 1.

3.2 Prototype

In order to test the initial findings, a prototype of the ancient Roman brick presented in the second scenario. It was built since as suggested by Tom Chi in his inspiring talk "Rapid Prototyping at Google X"[8], it is always better to prototype an idea even with limited means and explore it than guessing how it will work. Also recreating the actual shape and physical properties of the ASO will help to understand better usability issues, following an experience prototyping approach [27]. Therefore, we built the brick in a fast and chip way using components that can be far from the final product but that can be combined quickly in order to have an immediate feedback.

To make the brick, we put together a Samsung Galaxy S3 running Android 4.2, an Arduino 1, a NFC reader, a tiny metal cable and a simple cardboard box. Some objects were put inside to make the brick heavy convincing.

[8] goo.gl/PXpLbF.

Table 1. ASO requirements

Requirements	Rationale
Functional requirements	
The system provides visitors with AR functionalities based on image recognition and localization	Augmented reality allows visitors to access to digital content without loosing the reality. AR techniques should be implemented taking into account different settings (i.e. indoor, outdoor). In the scenarios the ASOs use outdoor a technique based on recognition and indoor an image recognition technique
Different ways to interact should be implemented based on the specific affordance of the ASO and its base	The used devices have specific shapes suggesting how to interact with them. For example, in the second scenario the ASO is in a form of a brick and its base entails the usage position and the view orientation. Moreover, visitors can explore different AR experiences by changing the vertical rotation of the brick
Environmental and contextual requirements	
In CH sites some explicit areas or spots will be signalled to make users aware that can use the ASO	The AR system does not require a continuous users' attention in order to allow visitors to focus mainly on the exhibit. In the scenarios specific bases are placed to allow them to exploit the AR just when it is really needed
The environment set can be crowed	Groups of people can be small as just two or large as 20. In the first scenario the visitors are a numerous group of people led by a touristic guide while in the second some visitors explore individually the site
The visit can be outdoor and/or indoor	An archaeological site as an exhibit can have both outdoor and indoor area. Our scenarios are set in an outdoor archaeological park but some indoor areas are present (i.e. rooms of a temple)
Users may receive training before using the ASO	Exactly as it happens with audio guide, in the second scenario operators briefly explain the way to use the ASO. This is particularly useful for people not familiar with the used technology
The technological devices can be integrated in portable and contextual objects	The interviewees stated that during a visit reproductions of small ancient objects are often present to stimulate the visitors interest. The ASOs can be integrated in objects related with the CH site. In the first scenario, a lamp used to activate the AR system is carried by the touristic guide. In the second, an ASO in form of roman brick is given to each visitor by a CH operator at the entrance

(*Continued*)

Table 1. (*Continued*)

Requirements	Rationale
Data requirements	
The system must be able to manage different media: image, video, holograms, audio, 3D models …	The digital content that can be superimposed to the reality is heterogeneous. As reported in the *related work* there are AR systems for CH sites providing users with a plethora of media: from simple text to full-immersion 3D experiences
Data must be accurate and updated frequently	As shown in the scenarios, an ASO can recreate digitally different eras of abuilding. To make such recreation realistic it is necessary to be accurate in positioning the virtual elements on the ruins and in giving the right dimensions
User profiles	
CH guides and curators are willing to use some technological devices as far as they are not invasive	All of these requirements come from the interviews conducted with experts and the filed study
Most of the users is familiar with smartphones. The grand part of the youngest users is familiar with AR and VR technologies	
The range of the instruction level varies between primary school to postgraduates	
Most of the current users are in the range of 30 to 50 and 10–16 years	
Most visitors are occasional users	
Usability requirements	
The user interface should be effective: it should provide a simple management of users mistakes	Visitors should focus only into the CH experience without caring about the technology. Therefore, it is paramount to reduce the number of possible unintentional user mistakes
The ASO should be easy to use and should require little training effort	As we learnt from the interviews, users do not visit the same CH site frequently and do not have the opportunity to learn a complex system. In the second scenario, CH operators give only a brief explanation of the ASO and let visitors to experiment it
The object must support mobility.	As described by the scenarios, the visitors walk to explore the site and interact with the ASO standing and moving from a base to another one. Therefore, mobility is an important component to consider in the interaction design

Fig. 3. The early prototype of an ASO

Then, we build a support base with another box and a NFC label. Figure 3 shows the final result.

The mobile phone results really useful because integrates several elements, such as camera, GPS, movement sensors, gyroscope, permanent internet connection all elements necessary to build the system.

The mobile phone is used to control the ASO and to realize the augmented reality. Arduino is programmed to link the NFC reader to the phone. Finally, the metal cable is simply an extension of the NFC antenna and allows to read an NFC label nearby its bobbin (Fig. 4).

From the software point of view, we developed a real versatile mobile application. It can manage different augmented reality techniques based on image recognition or positioning. It is based on the AR framework Wikitude[9] that allows to easily manage videos, images and sounds and Vuforia[10] combined with Unity[11] that better manages 3D objects and animations. In this way, we are ready to provide a plethora of AR experiences. The assembled box looks like a lifeless object but when it is placed on a NFC label, a trigged event activates the screen and the mobile application selects the AR experience associated to that label. In this way, it is possible to associate different AR techniques and behaviours to each NFC label.

Two interaction modality were implemented: (1) Rotation movements, (2) item recognition.

[9] www.wikitude.com.

[10] developer.vuforia.com.

[11] unity3d.com.

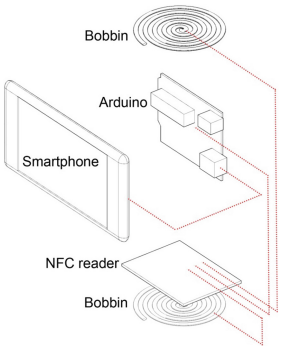

Fig. 4. The Roman brick hardware scheme

Rotation Movements. Users can select a different AR experience by rotating the box and placing it again on the base. For example, let's suppose we are in front of an ancient Greek-Roman temple. We place our box on the base and we see through the screen how the temple appears set in the Greek period. We roll the box rightward making the scene change to the Roman period. By rolling it again leftward we go back to the previous scene. Removing the box from the base for a couple of seconds will make it apparently lifeless again. Figure 5 shows how the cardboard box works.

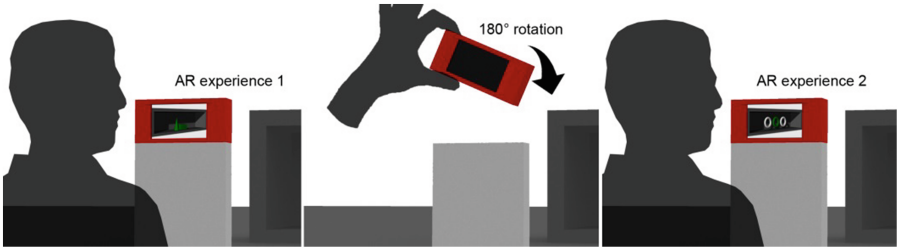

Fig. 5. Interaction based on rotation movements

Item Recognition. Users locate the ASO on the base, then, in order to select the experience, they put in front of the camera a coin to be recognized. To each coin a different AR experience is connected. Figure 6 shows a user experimenting this kind of interaction.

In the next section we report a usability evaluation and user experience linked to the usage of the prototype.

3.3 Evaluation

A usability pilot study was carried out to understand the potential of the ASO prototype. The goal of the study was to evaluate the quality of the interaction in terms of ease to use and user satisfaction. Ten users were asked to use and evaluate the brick. The group is formed by IT students and researchers, all of them have at least an idea of

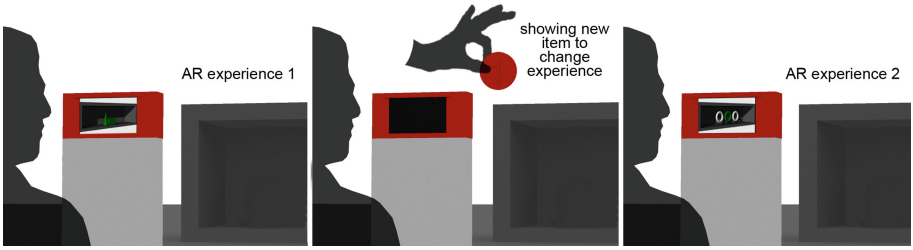

Fig. 6. Interaction based on item recognition

what an AR system is. This kind of background is typical for *digital native* users and moreover we want the testers focus on the whole experience rather than the technological newness. To evaluate the potential effectiveness and usefulness of the application, a "think-aloud" technique [8] was used. The "think-aloud" technique allows the observer to explore possible usability problems and to detect them in the precise moment they arise. Moreover, users were photographed and recorded by a video camera to allow the research team to review the experiment.

We asked the users to perform a specific task with the current prototype and discuss any possible suggestion to improve it. We focused on two aspects of the interface:

1. The usability: we checked whether the layout is effective to guide users in accomplishing their tasks. The interface must not confuse users or make them feel awkward.
2. The capability to navigate the different AR experiences: we needed to determine the best way to structure the navigation in order to avoid users getting lost during the interaction.

3.3.1 Participants Profile

The users were asked to fill out a questionnaire about their profile and their experience with CH sites. They had to answer and give a motivation to questions like how many times they go to a CH site in a year; if they were satisfied about the experience they are provided; what they need to improve their visit experience. Table 2 reports some of the answers to the questionnaire.

Mainly the users age is between 25–35 and just three can be consider expert of AR. Based on the questionnaire answers we score with 3 an expert user, with 2 an advanced user, with 1 a user with basic knowledge, and 0 those without any knowledge about such technology. The majority of our users (6) visit a museum or an archaeological place just one time a year. They do not feel attracted to visit CH sites of their own city but usually visit when travelling. Anyway all the testers, even those who visit frequently a museum, are never full satisfied of their visit. The main reasons they exposed were:

(1) Users feel the necessity to access to more information in order to understand art works or ancient and far places. They feel their background is usually not enough to have a rewarding experience with the exhibition. They also consider that the

Table 2. User profile questionnaire

ID	Age	Expert (min 0–max 3)	Visit frequency	Satisfied with current experiences (min 0–max 3)
1	25–35	2	Monthly	1
2	18–25	1	Annually	2
3	36–50	1	Annually	1
4	25–35	1	Annually	2
5	25–35	1	Monthly	1
6	25–35	3	Annually	1
7	25–35	3	Annually	2
8	25–35	1	Annually	2
9	25–35	1	Weekly	2
10	36–50	3	Monthly	1

information provided to them should be personalized on the basis of their own characteristics (i.e. language, cultural background, interests)

(2) Often the visit consists only in looking the exhibition and they would prefer to touch objects and have a more interactive experience.

(3) They cultural aspects are important for them but they will not spend some hours of their free time just to learn. They would like more fun activities to make the visit more enjoyable.

3.3.2 The Tasks

During the first part of the study, users received a short presentation about the prototype and were introduced to a scenario: a visit to an exhibition of ancient objects. Then they were left free to touch and get used to the prototype. This part lasted around 10 min.

After that, participants were left free to explore the exhibition and to use the ASO. During the visit they were asked to "think aloud". At the end of the activity they were asked to fill out a SUS questionnaire [9]. The SUS questionnaire is a reliable, low-cost usability scale suitable for an initial assessment of a system. Introduced in 1986, it is still broadly used in early usability experiments like the one reported in this paper. Indeed, the SUS questionnaire is considered reliable with large samples of users and also with very small ones [11].

In addition to the questionnaire, the observer interviewed them on some aspects he noticed during the visit. This part of the session took around 10–15 min.

3.3.3 The Exhibition

We simulated an archaeological exhibition with replicas of ancient objects set in a big room prepared for the experiment. Each object represents a different culture connected to the Spanish history including a small bronze board showing a high-relief of Minerva, roman coins, a pre-Columbian rainstick from Peru, a military hat of the 1900s and a completely virtual 3D sculpture representing a stone lion. Figure 7 shows participants interacting with the objects of the exhibition through the ASO.

(a) (b)

Fig. 7. Users interacting with an ASO during the simulated exhibition

Each object has one or more AR experiences associated to it. To access to each experience, participants had to interact with the ASO. In some cases, they had to rotate the ASO as shown in Fig. 5. For example, the rainstick has three experiences; the first experience is the reproduction of its sound; by rotating the ASO shows some evocative images of musicians in traditional costumes; by rotating again a short video shows the discovery location. In an other case, the users have to put a coin in front of the camera in order to select the experience. Figure 7(a) shows a tester using the coins. Anyway, anytime the ASO is positioned on a base, it gives hints on the kind of interaction in form of a splash screen, as shown in Fig. 7(b), and icons placed on the display borders.

3.3.4 Results

According to the SUS data, participants were satisfied with the experience (see Table 3) The score system in the SUS survey ranges from 0 to 100 points. There are 10 question items, SUS scales all values from 0 to 4. Odd-numbered items are scored by subtracting one from the user response. For example, if a user scores an item with five, the SUS score will be 4. Even-numbered items are calculated by subtracting the user response from 5. For example, if the user scores an item with 1, the SUS score will be 4. The final score of the SUS system ranges between 0 and 100. Therefore, it is necessary to multiply the average of the users' scores by 2.5. For example, an average score of 40 multiplied by 2.5 gives 100.

In [11] a threshold of 69 is considered valid to demonstrate the usability of a system. In our case the average score given by the users is 83.5 which is above the threshold so the ASO could be considered usable. Moreover, items 4 and 10 provide some insights also about the learnability dimension. The testers assigned to item 4 an average score of 3.2 on 4 and to item 10 a 3.3 on 4. Also in this case the learnability perception is pretty high. It is worth to remember that participants were introduced to the ASO by a researcher in the same way a museum operator would introduce an audio guide device to the visitors.

Since the SUS system is not diagnostic and can just measure the usability perception, we observed users during the experiment and, after they filled the questionnaire, we

asked them for more specific information. Most of them expressed they valued the experience for a variety of reasons. For example, one of them compared the ASO to the classic museum audio guide: "*I like to visit museums and often I do not have the right background to understand a kind of art or a specific historic object. For such reason I always use an audio guide when it is available. I see that using a AR system I can have a better experience than an audio guide because I can access to a quicker and easier information*". Most of them liked the idea of watching video animations with the real object as background, since as one of the participants said "*This is really evocative*". A user watching a video showing a stream captured by a camera in the ruins of Machu-Picchu (where the rainstick was supposed to be found) thought that the camera was truly alive: "*It's like having an open window to the external world, I feel linked to that place through this object*". Since all the participants were interested in watching the video of the discovery place, one of them was asked if he would have the same reaction with a normal screen in a museum. He answered: "*I do not think so, I really like the idea to hold this object and see through it, I feel it as something more personal*".

All the users stated that they might be encouraged to go to more exhibitions if they could experiment an AR system. "*I go to a museum or to an archeological site just when I travel. I would go to visit the museums of my city if they would give me something new like this*". Other users suggested that the content of the ASO could be updated with a certain frequency. This would encourage them to go back to the exhibit to explore new things.

Five users considered the ASO bases as a limitation since they would use the ASO while walking whenever they want. However, this is exactly what the CH curators want to avoid: *the risk of technology grabbing the spotlight.*

Finally, participants were invited to provide suggestions. Three basic issues were raised:

(1) A more accurate choice of the interface icons. The icons are used to suggest to the users the way to use the ASO and the number of experiences they can access. Such icons made confused some users for a while. Moreover, the testers would appreciate to have some hints directly placed on the top of the ASO's base.
(2) The ASO should include an on-demand tutorial to make visitors feel more confident at the beginning of the visit even without a first explanation.
(3) Participants would like to interact with some of the virtual objects.

4 Lessons Learnt

In this section we give some considerations about designing of an ASO based on the state of the art of AR for CH sites, our cooperation with different CH practitioners and the experience gained during the design of the discussed artifact.

First of all, an ASO should be designed to be nonintrusive and to blend into the context. This is because an ASO is an external tool that can move the visitors' focus on itself. For such reason the designers should consider technologies that can be easily camouflaged into the context. Also specific areas should be strategically predisposed to use such technologies. In this way, the ASOs require the users' attention just there.

Table 3. SUS average score

SUS item	Average score
1. I think that I would like to use this system frequently	3.3
2. I found the system unnecessarily complex	3.5
3. I thought the system was easy to use	3.3
4. I think that I would need the support of a technical person to be able to use this system	3.2
5. I found the various functions in this system were well integrated	3.1
6. I thought there was too much inconsistency in this system	3.3
7. I would imagine that most people would learn to use this system very quickly	3.7
8. I found the system very cumbersome to use	3.5
9. I felt very confident using the system	3.2
10. I needed to learn a lot of things before I could get going with this system	3.3
Total score = 33,4	
SUS Score = 2,5 *33.4 = 83.5	

Moreover, the device should be selected to be comfortable. Wearable technologies should be avoided when bulky and heavy. Another factor to take in mind is that people usually visit a CH site as a group and interact with each other. For such reason, the selected technology should not be a barrier between visitors. Exploiting intensely headphones or requiring users to continuously look through a screen can completely alienate them.

Furthermore, the ASO is aimed at creating personal links between visitors and the exhibit. This experience is possible by exploiting individual devices that can be independently used without any external helps. From a practical point of view, the devices should be affordable for all kinds of CH organizations. Small CH organizations often cannot afford expensive technologies. A good choice is to exploit common smartphones.

To design the visit experience, we have to take in consideration some characteristics. The AR system has to be attractive and enjoyable to foment people to visit a CH site and to give more interest to the exhibit content. Indeed, the new CH visitors are in habit to access to information in new technological ways and it is important to match their inclination. Another aspect to carefully consider is that that the ASO is a didactic device. Visitors should not confuse it with a game. On the other side, we learnt that the system must provide for some recreational activities. Indeed, during long visits, people can lose interest and attention. Recreational activities can be helpful to avoid attention decreases.

Finally, particularly attention must be given to the interaction design of the ASO. Visitors are not just passive users who visualize overlapped images. They must be considered as the centre of the AR system and they can fully interact with it. Moreover, the interaction should be intuitive for each kind of users. The visitors, indeed, are likely *casual users* and should be able to use the device without a long learning process. This can be possible also exploiting the affordance of the ASO's size and shape. The ASO

behaviour should be context adaptable, providing different modalities of interactions as well as different kinds of media to match users' needs of the moment. For example, there are situations in which time visitors need to be supported in imagining a reconstruction through a digital reproduction, a specific era through an animation or a far land through sounds, colours or streaming videos. For such reason the kind of media must be selected painstakingly in collaboration with specific experts to achieve the desired goal.

5 Conclusions

In this paper we introduced the definition of ASO as a physical object designed to provide augmented reality experiences to the visitors of cultural heritage sites. The goal of an ASO is to enhance the visitors experience and generate more interest towards CH sites without moving the user focus on the technological device. As part of the study we have developed an instance of the ASO in form of an ancient brick. We followed a participatory design approach to develop an early prototype involving real CH practitioners. Then, we carried out a usability study with potential stakeholders to find potential issues and get first users opinions. On the basis of these evaluation and the experience gained along the entire research process, we have pointed out some findings that we discussed in forms of *lessons learnt*. The lessons can be exploited by AR designers to develop their own instance of an ASO.

In the next future, we plan to effectively integrate an ASO within a real archeological site. In this way, we aim at reaching a wider users base and extracting more quantitative and qualitative data to confirm the preliminary findings and understanding the real feasibility of the application of an ASO in CH site.

Finally, we want to improve the ASO prototype working in very close contact with CH practitioners to prepare more useful content and to develop new functionalities.

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