Learning about the Past through Situatedness, Embodied Exploration and Digital Augmentation of Cultural Heritage sites

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Highlights:

- Exploration and employment of a novel projective AR approach, namely the World-as-Support interaction paradigm, in the context of a cultural heritage site.
- Presentation of a design process of a virtual heritage experience for a bomb shelter built during the Spanish Civil War that includes different needs and viewpoints of primary students and adult experts.
- Evaluation of the potential and limitations the educational experience of a first prototype in situ.

Learning about the Past through Situatedness, Embodied Exploration and Digital Augmentation of Cultural Heritage sites

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Abstract:
The design of interactive experiences for archaeological sites entails the consideration of the particular characteristics and constraints of the exhibition space. Our aim is to address these challenges by exploring the potential of a recently emerging interaction paradigm called *World-as-Support*, which is based on projective Augmented Reality (AR). In this study, we present the design process of a virtual heritage experience for a bomb shelter built during the Spanish Civil War that currently belongs to the Barcelona History Museum. The goal of this study was twofold. First, we aimed to define the requirements for the design of a first prototype based on the World-as-Support interaction paradigm. Second, we carried out a study with a local school to evaluate the benefits of an educational experience based on this paradigm. Our results indicate benefits to complement the guided visit: (1) by using projective AR to explore different layers of the learning experience; and (2) by including collaborative activities based on embodied enactments to foster the understanding of historical contents that require emotional engagement and critical thinking.

Keywords: World-as-Support, Full-Body Interaction; Learning; Virtual Heritage; Augmented Reality; Children

1. Introduction

Digital technologies are transforming traditional learning experiences in museums. In history education, interactive media can provide meaningful and enriching supports for learners to experience exhibitions and Cultural Heritage (CH) sites. They often entail a meaning-making process that actively engages visitors in multiple acts of recollection, interpretation and communication (Giaccardi and Iversen, 2010). In this regard, they contribute to better understanding historical events, preserving cultural values inherited from the past, and making them available for today's generations.

The role of emerging technologies in the communication of these contents is increasingly at the forefront of the concerns of museums and other heritage custodians. Novel approaches tend to experiment with different augmented modes of visitor experience such as immersion, responsive environments and haptics (Flynn, 2013). In this landscape, learning experiences for spaces such as archaeological sites

have become an important field for the design of virtual cultural heritage (Ciolfi and McLoughlin, 2012). They physically differ from enclosed museum spaces in a number of ways. First, they allow visitors to approach the archaeological remains and artefacts. Furthermore, being situated in a specific space offers visitors a multisensory and immersive experience that cannot be provided by exhibitions in museum buildings that often display only representations or simulations of the cultural heritage site. The on site felt-experience entails, for instance, visual and auditory stimuli, sensations evoked by physical contact with the historical site, and so on.

Although these types of learning spaces allow visitors to become immersed in the site, the learning experiences provided often end up being little engaging. On the one hand, these sites are often empty of objects which are probably housed in museum buildings. Hence, they often display only the remains of architectural structures. Moreover, the weather can become an important barrier for having fixed information displays and even more so for audiovisual or interactive material. Finally, notwithstanding the weather, archaeological sites often have the disadvantage that they cannot be altered by the addition of physical objects or multimedia installations (Petrelli et al., 2013). Hence, many archaeological sites provide personal or audio-guides to direct visitors' attention towards aspects that are not necessarily obvious without further explanation. However, there are still aspects of historical contexts and people's practices in past cultures that are difficult for visitors to imagine (Ciolfi and McLoughlin, 2012). Therefore, there is a growing trend in the exploration of the benefits of ubiquitous advanced computing interfaces (Gena et al., 2016) and context-aware digital augmentation to provide additional information layers within the physical world (Price et al., 2015). In this context, relevant contributions can be found in Augmented Reality (AR) solutions. In particular, projective AR can help to overcome challenges at CH sites in relation to climatic conditions (e.g. humidity, rain or extreme heat) and heritage conservation policies (e.g. restrictions of modifications to the physical space) because they do not require the permanent installation of the hardware on site. Furthermore, they allow visitors to explore site-specific CH locations in meaningful ways and construct meaning around historical contexts. Building on these benefits, we are exploring the potential of a recently defined interaction paradigm named the World-as-Support (WaS) (Malinverni et al., 2017). This paradigm offers augmentation by projecting the digital content onto the physical world surrounding the user via a handheld device. The portable system, based on a hand-held device with computer vision capabilities and a pico-projector, potentially recognizes the surrounding physical world dynamically (i.e. topography, objects, users, gesture and motion) and projects the context-aware digital information directly onto it. In this paradigm, the world becomes not only a physical support for the projected content, but also, and most importantly, it is a support for meaning-making due to its intrinsic and situated value and meaning.

Nevertheless, the benefits of this new paradigm need to be carefully evaluated. Research in educational technologies has shown that the affordances of a specific medium can affect learning (Nathan and Robinson, 2001). Furthermore, when designing educational experiences for children, technological solutions and content must be aligned with the specific capabilities and interests of each target group. Therefore, the main purpose of this study is to design an educational experience based

on the WaS paradigm for primary school students in a CH context and to evaluate its benefits for in situ learning. We present the design process of a first prototype based on this paradigm in the context of a bomb shelter built by civilians during the Spanish Civil War. The cultural heritage site called *Refugi 307* is currently part of the Barcelona History Museum.

This paper is structured as follows. In Section 2, we provide an overview of the current tendencies for advanced interfaces for archaeological sites and children's educational experiences of heritage. Building on this background, we contextualize our technological approach and highlight the specific features of the WaS interaction paradigm. We also briefly introduce the limitations of designing educational experiences in this research field. In Section 3, we present a case study in which we first define the requirements for a digital heritage experience for the bomb shelter, and second employ and evaluate the educational experience of the WaS interaction paradigm in a first design iteration. In Section 4, we close by discussing how this paradigm can establish meaningful relationships between the learning experience and this particular type of CH site.

2. Related work

2.1 Advanced interfaces for cultural heritage

Despite the different content displayed, enclosed museum exhibitions often tend to follow general design principles (Hornecker et al., 2014) and thus allow a wide range of advanced interfaces and interaction techniques. Recent studies focus particularly on how visitors' learning experiences can be supported during a visit to a museum by interacting with large-scale environments (Flynn, 2013; Kenderdine et al., 2014; Kourakis et al., 2012; Pietroni and Adami, 2014; Price et al., 2015), mobile technologies such as tablets and smartphones (Lanir et al., 2016; Rennick-Egglestone et al., 2013), mobile eye tracking technologies (Mokatren et al., 2016), or smart tangible objects (Marshall et al., 2016). In contrast, in the context of designing for outdoor heritage sites, museum experts often have to consider very specific requirements and constraints (Hornecker et al., 2014), e.g. the specific spatial configurations of the heritage site, the effect of weather conditions on the use of certain technologies, heritage conservation policies, social-cultural aspects on site, and so on. These constraints shape the ways in which technology is designed for and utilized in these spaces.

These challenges have been addressed by exploring the potential of different types of digital augmentation and interaction techniques. Digital auditory, visual and haptic augmentations create distinct opportunities for layering the experience and displaying stimuli around the learner's physical surroundings. In this regard, recent studies have shown how advances in technological innovations of portable devices can provide the potential to change how learners engage with the physical environment (Hornecker et al., 2014; Sakr et al., 2016) and enhance the user's learning experience (Rennick-Egglestone et al., 2013). For instance, Hornecker et al. (2014) proposed using smart objects coupled with auditory, haptic and visual feedback to augment learning experiences on historical cemeteries. This approach engaged visitors through a multisensory experience and provided the possibility to integrate museum objects in guided tours of outdoor heritage sites. Other approaches suggest the implementation

of participative strategies guided through auditory augmentation. For instance, in the project *Reminisce*, Ciolfi and McLoughin (2012) proposed to overlay the visit in a "living museum" using digital auditory memories narrated by fictional characters that were associated with the site. A mobile application system allowed visitors to reproduce and collect these stories that were represented by QR-markers. Furthermore, visitors were encouraged to record their own reflections and to share them on a web platform that could be accessed online and in a specific building on site. These approaches present potential and meaningful ways to engage visitors with the learning contents. However, in historical contexts, visitors still need to imagine missing artefacts, people living during that period, or related events. If the visitors' experience and knowledge about the historical context are limited, it may be particularly difficult for them to imagine some of these contents and situations (Schaper et al., 2017).

Addressing these needs, new approaches explore the potential of AR technologies that can provide concrete visual clues and representations of contents about past events to support visitors' imagination. Frequently, these approaches are based on the Window-on-the-World (WoW) interaction paradigm, a well-known ARMR (Augmented Reality Mixed Reality) approach that blends physical and virtual worlds in a single display. Technically, the WoW paradigm is based on using video displays to merge computer-generated images with the user's view of the physical environment (Milgram and Kishino, 1994). For mobile technologies, this paradigm can be achieved by overlaying the virtual world on top of a live video stream captured from the surrounding physical environment. This "see-through effect" allows users to view and interact with virtual objects in a similar way to physically interacting with real objects (Müller et al., 2016). In the context of cultural heritage sites, several scholars have taken advantage of the potential of this paradigm. For instance, Pacheco et al. (2015) proposed a location-based AR application for the Bergen-Belsen memorial site, which overlays virtual buildings on the views of the physical space where the now lost buildings were originally located in 1945. Nonetheless, recent studies have pointed towards the risk of these technologies drawing users' attention away from the physical space onto a framed window which tends to isolate and provide an individual experience (Betsworth et al., 2014). In this situation, WoW systems seem to miss the fact that the users are located in situ since they live the experience mainly through the screen of the smartphone or tablet device. Hence, the technology used can become a distraction or even the main focus of the visit, instead of the physical site. This has been formally observed by Müller et al. (2016) who analysed user behaviour in a collaborative task with a tablet-based AR application. They highlight that almost no participants paid attention to the physical environment during the experience.

To tackle these issues, during the last decade, scholars have made different attempts at using handheld devices to reveal content directly in the physical space of CH sites. For the visit of the Nottingham caves, Ghali et al. (2003) implemented an experience in which visitors used flashlights to explore the walls of the cave by triggering voices whenever the light crossed certain physical features. The same scholars also explored the potential of this tracking system to directly manipulate virtual objects via flashlights on visual interfaces (Green et al., 2002). However, this approach still implies a physical installation of the tracking system in the caves. As previously mentioned, this can be a crucial issue when designing for CH sites because often they cannot be altered and

permanently installed technology may not endure climatic conditions on site. To address this, Betsworth et al. (2014) presented a mobile prototype to research the benefits of performative, place-based projection. The system was based on detecting QR codes situated at key locations within the physical environment which then triggered place-based AR projections. The system was implemented for a guided tour in a botanical garden. The outcomes showed that the use of the system actively involved users in the experience and provided them with “an extra dimension” (Betsworth et al., 2014) of the learning content. Furthermore, apart from the QR codes as markers, the system did not require any additional alteration or technological installations on site.

Despite these first attempts in the research of human-computer interaction and CH, we argue that the learning potential of this approach has still not been fully researched. We have conducted preliminary studies applying the WaS interaction paradigm in an educational context (Malinverni et al., 2017). The results have shown that the paradigm has the potential to enhance students’ learning experience in multiple ways. The paradigm is based on projective AR; i.e. augmentation is achieved by projecting the digital content on the physical world surrounding the user via a handheld device. This portable system, based on a mobile device with computer vision capabilities and a pico-projector, dynamically recognizes the surrounding physical world (i.e. topography, objects, users, gesture and motion) and projects the context-aware digital information directly onto it. This allows interaction designers to take advantage of the benefits of Reality-Based Interaction, such as environment awareness and social awareness (Jacob et al., 2008). Moreover, as users act within the physical world to interact with digital content (Dourish, 2001) it affords the potential of bodily and tangible interaction such as tangible manipulation, spatial interaction, and embodied facilitation (Hornecker and Buur, 2006). In previous studies, we compared the affordances of the WaS and the WoW paradigms in the context of a storytelling application for primary school students. Our results provided strong evidence of the potential of the WaS paradigm to support environment awareness, context awareness and shape the social relationships between users (Malinverni et al., 2017).

In the context of interaction design for archaeological sites, we argue that using the WaS paradigm can provide the following potentials:

(1) It addresses the risks of students focusing only on the on-screen experience. Consequently, it provides a balanced addition of historical contents without disrupting the immersive experience of being on site.

(2) It provides opportunities for multi-user engagement and collaborative tasks that can help reveal new layers of the experience and promote different viewpoints of historical events. Thus, this shared action of meaning construction allows students to obtain a holistic understanding of the historical context.

(3) Furthermore, this paradigm allows students to interact with digital content directly on the physical world. This provides an interesting potential related to the user’s body and its relation with the world and objects, such as: spatial interaction, tangible interaction and embodied interaction. Thus, the embodiment of actions of people from

past civilizations offers students emotional anchors and strengthens their empathy.

However, the WaS paradigm is still unexplored in the field of learning experience for heritage education with school children. Its benefits and affordances for educational strategies at CH sites need to be examined carefully.

2.2 Designing educational heritage experiences for children

Digital technologies can provide relevant support for learners to engage with heritage contents. During this decade, several learning experiences have been developed for museums and CH sites addressing different aspects of learning such as fostering students' skills towards the understanding of past events (Sakr et al., 2016; Tarumi H.a Yamada, 2008), culture and identity (Smith et al., 2011), perspective-taking (Kourakis et al., 2012), critical thinking (Rowan et al., 2016), and collaboration (Carreras and Pares, 2006; Kynigos et al., 2010), among others. To achieve these educational goals, scholars have investigated the benefits of a wide range of interaction modalities with young visitors. For instance, Sakr et al. (2016) investigated how emotional engagement had an impact on children's learning experience about events related to World War II. Students were engaged with a set of location-based tasks while using a digital environment designed for the iPad. Stanton et al. (2003) researched the benefits of adult-child interaction to facilitate children's discovery, reasoning and reflection upon historical places and events. The virtual heritage experience *We Hunters* (Kourakis et al., 2012) invited children to experience and learn about hunting strategies which were illustrated in a cave painting by using Full-Body actions. This helped them to "embody" certain enactments of people from ancient cultures and to better contextualize underlying socio-cultural meanings in relation to the museum exhibition.

Despite the long-standing tradition of co-design practices (Muller and Druin, 2003), research in educational heritage experiences for children is often based on a Designer-Driven approach (Malinverni and Pares, 2014). As a consequence, recent studies claim that children, particularly, are often not attracted by museums' standard communication styles (Dindler et al., 2010). To address these shortcomings, current research increasingly involves stakeholders such as experts, teachers and children in the design process. For instance, the *Digital Natives* exhibition project (Smith et al., 2011) focused on contemporary heritage practices of young people. Thus, six teenagers were involved as co-creators and protagonists of an exhibition based on five interactive experiences. They allowed visitors to experience teenagers' everyday cultures, identities and communication practices in new ways and stimulated intergenerational dialogue about heritage content in the digital era.

We argue that there are still significant limitations in the involvement of children and the employment of adequate design methods in this research field. Thus, in this paper, we present a design process of an educational heritage experience aimed at exploring design strategies that allow researching the different needs and viewpoints of child and adult stakeholders.

3. The study: design of a virtual heritage experience for the Refugi 307 bomb shelter

Our study was carried out in the context of a cultural heritage location; namely *Refugi 307*. The site is one of the 1,402 bomb shelters that were built by civilians during the Spanish Civil War in Barcelona aimed at protecting the population. Today, the shelter is part of the Barcelona History Museum which provides guided visits through the site. The goal of the project was to explore new possibilities to complement the current guided visit with an educational virtual heritage experience.

Therefore, we first conducted a contextual inquiry (Wixon et al., 1990) and informant design study (Scaife and Rogers, 1999) with (10 to 12 year-old) students and teachers of a local primary school and a team of experts of the history museum. During the informant design approach, the researchers involved the stakeholders in stages for which they considered their input as appropriate and critical (Walsh et al., 2013). The aim was to analyse the requirements for the design of the educational experience based on the WaS interaction paradigm and include different needs and viewpoints of the stakeholders involved. Subsequently, we implemented a set of educational activities in a first prototype. We then evaluated students' educational experience of the prototype during a guided visit of the shelter. We will now outline the methodology applied in each design stage.

3.1 Gathering requirements for the project

3.1.1 Procedure

Consulting experts

To analyse the educational goals of the project, semi-structured interviews were conducted with four teachers and three guides at the facilities of the shelter after a visit (in addition, one teacher sent us her answers by e-mail). The questions focused on how they perceived children's reactions during the guided visit, which interests students had in the historical context of the Spanish Civil War, and how the visit could be improved. At the time of the study, the general visit with school classes was structured around a session of 90 minutes. The group was accompanied by the explanations of a guide who stimulated students' participation and reflections through questions about the historical context. At the end of the visit, a short video was projected in the shelter that showed general scenes of civilians in Barcelona during the Spanish Civil War.

Furthermore, before the study, three project meetings were carried out at the premises of the museum in which three researchers, a curator, a museum educator and a visit guide discussed topics concerning the goals of the study, the proposed technological approach and the procedure of the activities. The team from the museum was specialized in CH and educational museum activities. Our design team contributed with an interdisciplinary background in design and engineering.

Involving children

An important requirement for our project was to involve the viewpoints of all stakeholders. Specifically, we aimed to give students, the main users of the educational experience, a voice in the design process. Hence, we observed their behaviours in situ during the visit. Furthermore, to obtain additional information about

their understanding and interests, we explored different strategies of on site and classroom activities that could elicit contributions by the children.

Session 1

The first session lasted 120 minutes (a 90-minute guided visit to the shelter and 30 minutes of workshop activities). In total 40 children (girls = 18, boys = 22; mean age = 10.78 years) of two school classes participated in this design stage. We accompanied two guided visits of 20 students each. The students in each group were peers from the same school class. Both visits followed the same procedure. The children were first introduced to the historical context using posters placed at the entrance area, just outside the shelter. They depicted historical photographic material and written descriptions (figure 1, left). The content was then contextualized within the shelter. The guide drew the children's attention towards specific physical features and illustrated content through anecdotes and historical facts about the Spanish Civil War and contemporary events (figure 1, right). Two researchers accompanied each guided visit. The two sessions were video recorded. Furthermore, the researchers took notes about (1) students' interactions within the space (movements, gestures, body posture), (2) facial and verbal expressions, and (3) social interactions with each other, with teachers and with the guide at the different locations in the shelter.

Figure 1. The procedure of the guided visit was divided into two parts: (1) an introduction outside the shelter, (2) a visit inside the shelter to contextualize the learning contents.

After the visit to the shelter, we divided the children into groups of 3-4 members and instructed them in an activity based on the KidReporter technique (Bekker et al., 2003). Each group was asked to record a 2-minute video interview about the place in the shelter they found most interesting. To do so, we handed out a map of the shelter to each group and gave them 10 minutes to choose one place of interest and brainstorm how they would perform their recorded interview. The aim of this activity was to give the students an opportunity to revisit locations of their interest that they had previously seen during the guided visit. We assumed that being in situ would help them to better reflect upon the historical context and connect with civilians' feelings during the Spanish Civil War.

After this activity, we handed out a questionnaire to each child aimed at assessing their interests, their understanding of the site, and their preferences in accordance with the learning topic and the physical space. The questionnaires were based on open-ended questions that the children were asked to complete such as *"What I most dis/liked*

about the visit was … because…", "The place I found most interesting was … because…", "I was disappointed by…"

Session 2

The second session was held at school a few days later and lasted 180 minutes. The children were again divided into the same groups. Using the maps of the shelter, they were asked to indicate and explain the places that they remembered and that had most caught their attention (figure 2, left). The children wrote their comments on post-it notes and placed them on the map. We interviewed each group individually during the activity. The purpose of this activity was to provide the children with a link between the content of the visit and subsequent activities during the workshop session. We assumed that the activity would draw the children's attention particularly towards the physical features of the shelter and its relation to the historical context. This was important for the design of the educational experience based on WaS because one of its main features consisted of the possibility to interact with digital content onto the physical world.

Then, each child received a different storyboard template (figure 2, right) that was already filled out with a first scene. Each template depicted a different drawing made by children during the Spanish Civil War. They were encouraged to think of a narrative related to the drawing presented. The aim of this activity was to evaluate the children's interests and personal values in relation to the historical context, and how they contextualized it in their present time.

Figure 2. The children received a copy of a pre-defined map of the shelter and used post-it notes to indicate their interests. They then received a storyboard template and were invited to think of a narrative related to the drawing presented.

Subsequently, the children were instructed to re-design the guided visit according to their own interests and preferences. To introduce this activity we presented them, for the first time, with the concept of the WaS system based on a Philips PicoPix PPX3414 pico-projector. Subsequently, we asked the children to help us to redesign the educational experience of the guided visit to the shelter. The children were then asked to produce low-tech prototypes using "projection flashlights"; i.e. drawings on transparent plastic, placed at one end of a paper roll with a flashlight inside to simulate the projection capabilities of a handheld device based on a pico-projector (figure 3). During all workshop activities, we recorded short video interviews with each group while they were working on their proposals. Finally, each group gave a 5-minute presentation to explain and enact their ideas with the low-tech prototype.

Figure 3. The children presented their ideas for the improvements for the guided visit using a low-tech prototype.

3.1.2 Analysis of requirements

The aim of this design stage was to conduct an analysis of the current learning experience on site and to compare them with the educational goals defined by experts. This comparison allowed us to identify aspects of the existing guided visit that could be complemented using the WaS paradigm. To analyse the children's contributions, we applied a multimodal analysis approach (Kress, 2010; Malinverni et al., 2016; Sakr et al., 2016; Van Mechelen et al., 2016) to collect, analyse and interpret the multiple resources that the children employed during the activities (e.g. body postures, spatial interaction, facial expressions, gaze, verbal expressions, drawings, etc.). Multimodality is an interdisciplinary approach, derived from socio-semiotics, that aims to understand how people communicate and represent meaning in different forms (Price and Jewitt, 2013). In our study, the goal of the evaluation was to better understand stakeholders' meaning-making of the educational experience in the shelter by including their contributions from a perspective that went beyond the limits of verbal language. Particularly, when working with children the multimodal approach has been seen to effectively inform the design process (Malinverni et al., 2016; Van Mechelen et al., 2016). Due to children's limited language skills, it is often difficult for them to express their thoughts and explain their ideas adequately. By focusing the evaluation on different semiotic resources that are employed to construct meaning, we argue that this approach can provide us with insights into how children express their worldviews in relation to the educational context through their bodies and person-environment interaction. Hence, this approach could help us to understand how in situ learning during the guided visit influenced the children's meaning-making processes.

Therefore, the material from video and audio recordings, annotations and the children's contributions (drawings, post-it notes, storyboards, maps, etc.) was transcribed in a descriptive format and analysed using NVivo 11 software. We used a coding scheme derived from the five dimensions of experience in physical space proposed by Lentini and Decortis' (2010), namely *Geometrical and Geographical experience*, *Sensorial*

experience, *Cultural experience*, *Personal experience* and *Relational experience*. According to these authors, these analytic lenses combined aspects of both computing research and environmental psychology by considering the complexity of relationships between humans and the physical space. This framework is meant to inform the design of technologies that support meaningful interactions with and in the physical space. We decided to build our analysis on this coding scheme because it focuses on user situatedness. In our study, we claim that the WaS interaction paradigm unfolds its full potential when it is employed in site-specific contexts. Furthermore, we argue that the separation of the in situ learning experience into different layers could help us identify deficiencies in the current experience and specific requirements for our technology-enhanced learning approach. However, the original framework was not specifically aimed at analysing learning experiences. Thus, for our purpose, we extended and regrouped the original lenses (Table 1). Finally, we defined the following four-layer model for our analysis:

Physical Space Layer: Analysis of (1) the specific physical features of the shelter and (2) possible opportunities and restrictions for using technology on site.

Narrative Space Layer: Analysis of the content of the guided visit in relation to (1) the specific features of the physical space and (2) the learning goals of the educational experts.

Personal Space Layer: Analysis of the interest and in situ experience at an individual level that are promoted by (1) an understanding of the historical context, (2) emotional engagement, and (3) sensorial contact with the physical space.

Collective Space Layer: Analysis of (1) social interactions during the guided visit that offer opportunities for collective learning activities and (2) the understanding of socio-cultural values among children and experts.

Table 1: Overview of similarities and differences between Lentini and Decortis's and our approach of dimensions for experiences in physical space

Lentini and Decortis's Dimensions		***Our approach***	
Geometrical and Geographical experience	The apprehension of the spatial qualities of the environment, i.e. estimation of distance, structure, shape of the setting, and the spatial disposition of the different elements composing the setting.	*Physical Space*	The specific physical features of the shelter and possible opportunities and restrictions for using technology on site.
-	-	*Narrative Space*	The content of the guided visit in relation to the specific features of the physical space and the learning goals of the educational experts.

Personal experience	The meaningful experiences-in-place that are mainly experienced at an individual level. These are the opportunities that places offer for reflection, introspection, self-under-standing and personal growth.	*Personal experience*	The interest and in situ experience at an individual level that are promoted by the understanding of the historical context, emotional engagement and sensorial contact with the physical space.
Sensorial experience	The apprehension of the sensorial qualities of the environment: the colours, the smells, the material, and the textures.		
Cultural experience	The apprehension of the behavioural appropriateness, of the cultural expectations and understandings of behaviours, and corollary of the activities that are expected (and accepted) to occur in a particular setting.	*Collective Space*	Social interactions during the guided visit that offer opportunities for collective learning activities; the understanding of socio-cultural values among children and experts.
Relational experience	The opportunities for interpersonal relationships and interactions that take place in places, contributing to our development as individuals and as members of a community.		

The analysis was performed by two researchers. After a process of individual coding, a common agreement was reached through a number of meetings and discussions about the results.

3.1.3 Results

Physical Space Layer

The shelter consisted of a long twisting tunnel of approximately 200 metres in length, with a height of 2.10 metres and width of between 1.5 and 2 metres (figure 4, left). The narrow space limited visitors' movements. For instance, only one group of a maximum 20 children and four adults was allowed in the shelter at any time, and they were asked to walk in pairs due to the spatial constraints. Visitors can get an impression of the living conditions during the Spanish Civil War and some facilities inside such as bathrooms, benches, an infirmary, a children's room, a chimney built into the mountainside, etc. The general light conditions in the shelter were very poor.

Therefore, the guide illuminated certain spaces with a flashlight to direct the children's attentions towards specific physical features and traces of objects (e.g. the original lighting system, signs with instructions on behavioural rules, holes to fix stretchers to the wall, etc.) that were once installed inside. The high degree of humidity in the shelter prevented permanent multimedia systems from being installed. Safety policies for the shelter stipulated that visitors should always be accompanied by a member of the museum. Furthermore, direct physical contact with the walls or artefacts inside the shelter should be avoided to preserve the cultural heritage site.

Figure 4. A school class on the guided visit of the Refugi 307 cultural heritage site.

Due to these restrictions, we discussed the benefits and possible limitations of our technological approach with the museum experts. During the interviews, the museum experts expressed the need to maintain the sensation of "simplicity and sparseness" of the shelter. The aim was to illustrate its original "living" conditions in similar ways to how civilians may have experienced them during the war. One expert explained: *"We do not want to fill it with museography because it would lose the feeling of entering an empty place that (originally) did not provide anything".* They saw potentials in the pervasiveness of the WaS interaction paradigm and the possibility to selectively augment the physical space without altering it. *"These projections you describe, should allow projecting at one moment and then everything disappears and the walls remain as they were".* On the other hand, one guide pointed out the risk that using augmented content may not leave sufficient space for children's imagination and own reflections, particularly if too many interactive learning contents are presented during the visit.

Narrative Space Layer

The analysis of the visit showed that the museum had organized the contents inside the shelter in chronological order and in accordance with the spatial configuration (figure 4, right) of the cultural heritage site. The construction of the shelter was started from three different entrances at once which were meant to connect to each other. However, only the tunnel parts of the eastern and central entrances were finalized while the western entrance remained isolated. During the post-Civil War period, the western part of the shelter was extended and the entrance finally connected to the rest of the shelter. Due to the different building methods, we can easily recognize these two construction periods. Whereas the older parts had a solid construction based on brick walls and Roman arches, the newer part consisted only of simple excavations into the

mountain. The tour guides used these physical references to distinguish between historical contents during the Spanish Civil War and the time after (post-War period, contemporary topics, etc.). Therefore, the visit began at the eastern entrance and followed a linear narrative finishing at the western entrance. (The part of the tunnel that led to the third entrance was not accessible during the visit.) The guides explained historical events and anecdotes in the context of the Spanish Civil War from the year 1936 to the present time.

Personal Space Layer

The analysis of this layer involved two main aspects. On the one hand, we investigated the experts' educational goals related to the visit. On the other, we focused on how the students themselves understood the historical context during the visit, with which topics and locations engaged them emotionally, and which sensorial experiences triggered reflections and interpretations.

A) Experts' educational goals

The findings from the interviews with the educational experts from the museum and school determined that one of the main goals of the interactive experience should be to foster children's competence in understanding the relation between historical events of the Spanish Civil War and similar contemporary conflicts occurring today (e.g. the civil war in Syria). This aim involved strengthening feelings of solidarity and empathy with people who have suffered and/or are still suffering war. To offer children emotional anchors to the learning context, they recommend linking the content of the experience to situations children can relate to their own identity; e.g. family members from previous generations or children in war zones in other countries. Furthermore, the teachers proposed to use (1) audiovisual material such as testimonials, original documents, photos, (2) real objects (e.g. a pickaxe, stretchers, medical supplies, etc.), (3) actors performing specific situations, and (4) post-activities to contextualize the content explained during the visit and to support children's interpretations.

B) Students' understanding and interests

Our analysis of the children's behaviour during the guided visit and their contributions during the workshop sessions helped us to obtain an in-depth understanding of their understanding and interests towards the historical context and in situ experience. During the visit, the children showed surprise and astonishment when they were told anecdotes about civilians in the shelter which contrasted with their own "protected and comfortable" lives. For instance, the guide explained that some women put their children under the benches so that they could stretch out to sleep and were protected in case the ceiling collapsed. In response to this explanation, some children looked disbelieving under their bench and made comments about how uncomfortable that must have been. Another example is when they expressed disgust at the fact that people were forced to eat parts of food that people usually would throw away (e.g. soup made out of mashed fish bones). Several children pointed out that they would never eat something that they did not like.

We observed that several children tended to enact the explanations of the guide to have an embodied understanding of the described contents, e.g. one child slapped her hands on the legs when the guide talked about children sleeping on parents' laps.

Other children that were sitting on benches started shaking their bodies when the guide mentioned walls shaking from bomb explosions. With the physical space, the children interacted mostly with their eyes, searching for more details in relation to the explanations. In certain spaces the children looked for direct contact through touch, for instance in the “infirmary”, they knocked against the wall to explore the sound it made because of the hollow space inside. Another example is when the children touched the wall of the mountain while the guide was contrasting pickaxe marks made by children and adults. The darkness and humidity in the shelter had a particular impact on the children. They responded to the low temperatures by expressing uncomfortable feelings through behaviours such as moving from one foot to the other to keep themselves warm, tightly closing their jackets, blowing hot air into their sweater, and so on. Also during the workshop activities, they stated several times that it was very uncomfortable to stay inside for a long period of time and they were glad to be able to leave after the visit. We also observed moments when the children were distracted from the guided visit. Some children started playing with each other or pulled a face expressing boredom. This behaviour tended to occur in situations when they were asked to remain still, e.g. in the introduction outside the shelter and during the explanations while sitting on the benches.

The analysis of the interviews during the KidReporter activity gave us specific insights into the children’s interests and understanding of the historical context. Six out of 10 groups chose to perform the interview in the “infirmary”. They focused on the fact that the place was located in the middle of the tunnel and thus the safest place in the shelter (which has an entrance door at either end). The children also expressed the importance of having a place where injured people could be treated and their respect for volunteer nurses who had only very limited medical resources available to help them. Three groups performed the interview about the “fireplace”. They expressed their admiration for the person who had built a chimney and ventilation system into the stone of a mountain. They recounted two anecdotes related to the place. First, despite the harsh conditions in the shelter, a family from southern Spain lived in it during the post-war period for ten years. Second, a man in the nineteen eighties used the shelter to illegally grow mushrooms on the walls as the main source of income for his family. Only one group performed the activity in the “children’s room” and expressed their sadness at an event in which the ceiling collapsed during a bomb attack and two children were injured.

The results extracted from the open-ended questionnaires revealed further interests of the children. Several children mentioned the physical characteristics of the shelter; e.g. the zig-zag shape of the entrance aimed at preventing shrapnel from bomb explosions from entering to the inner part of the shelter; the rounded finish of the walls around corners to facilitate the transport of injured people on stretchers, etc. Furthermore, other children reported their interest in aspects related to people; e.g. dead bodies, the blood of injured people, getting to know a Spanish Civil War survivor, etc.

During the subsequent map activity in class (figure 5), in addition to the previously presented places, all groups reported on at least one other location related to people’s basic needs: toilets (9 groups), a water fountain (8 groups), and a power generator for the lighting system (3 groups). In addition, they explicitly mentioned that they were

interested to see the original wall signs on behavioural rules (1 group), they asked to see images of bombs and shrapnel (1 group) and expressed their curiosity about tunnel segments that were not included in the guided visit (2 groups).

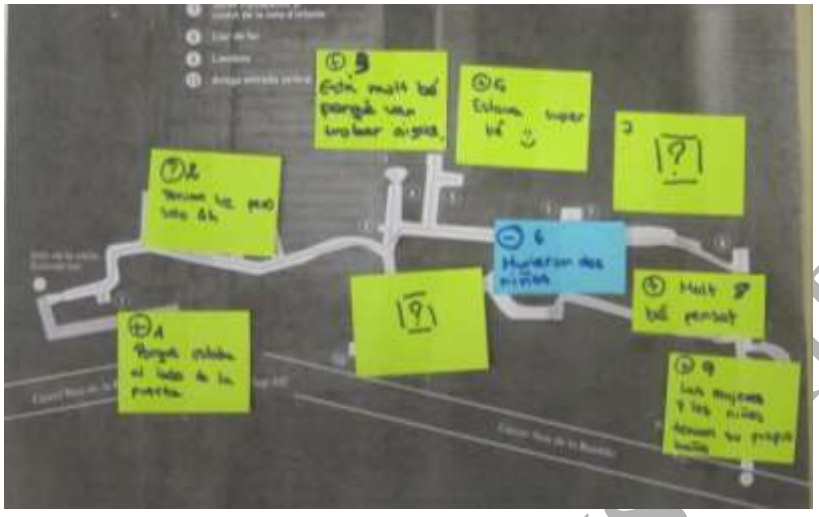

Figure 5. This group was particularly interested in the water fountain and the power generator. The children expressed their sadness at the accident in the children's room. They also expressed curiosity towards parts of the shelter that were not included in the guided visit.

In the redesign activity, the children mainly proposed changes related to making the experience more participative. They proposed several hands-on activities, e.g. (1) a treasure hunt activity with clues to provide a playful experience during the guided visit; (2) an activity where the children could dig up the destroyed children's room and discover what was hidden under the stones; (3) to perform a drill activity of the bomb alert and the experience of entering the shelter.

The children's main misconceptions concerning the different design activities were related to their expectations of finding weapons in the shelter of people who tried to protect their family against dictator Franco's army (6 out of 40 children). In other words, they did not understand that the shelter represented a "passive" form of defence, in contrast to "active" defence that involved using weapons. Further analysis showed that particularly boys (83% in total) tended to report a higher number of misconceptions than girls related to this topic. Moreover, two children expected to find a fully equipped kitchen in the shelter. Another child thought that the room in which children waited during the bombings was used as a playground. These findings indicate that these children had difficulties to imagine the living conditions in the shelter and how civilians had probably felt and behaved in it. Another child thought that men were not allowed to work on the construction of the shelter. The boy was not aware of the fact that during the Spanish Civil War men were forced to go to the frontlines.

To sum up, triangulating different semiotic resources (verbal explanations, body language, manual contributions such as drawings, etc.) that the children expressed during the activities helped us to obtain a holistic picture of their personal perspective of the historical context and in situ experience during the visit. Our results illustrated that, in general, the children showed much interest in the historical context and were very engaged in the explanations during the guided visit. Individual fate, civilians' living

conditions in the shelter and particularly anecdotes that involved children as protagonists caught their attention. Furthermore, the students were intrigued by the physical characteristics of the shelter and their functions. The children's felt-experience in the physical space, their enactment of explanations and sensorial contact triggered reflections and meaning-making of the historical context. Nevertheless, the students showed some misconceptions in relation to situations that were unfamiliar to them or involved abstract concepts (such as "passive defence"). Furthermore, they reported the need to visualize missing and hidden artefacts of the physical space. Finally, they proposed participative activities as improvements to the guided visit. Also during the visit, we observed that the children preferred to move around and explore the space than to sit still and listen to the guide.

Collective Space

The museum experts highlighted that one main purpose of the guided visit was to transmit to children the benefits of collaboration and the implications of being part of a community. On the one hand, the shelter itself was a symbol and reflection of social values because people of all ages contributed to its construction in order to protect themselves, their family and friends against bomb attacks. On the other hand, the museum experts emphasized the fact that the war had caused a collective trauma and influenced civilians' attitudes towards certain political and social movements in society. From a historical perspective, understanding these two aspects was important to prevent such past mistakes from repeating themselves.

The storyboard activity helped us to gain a deeper insight into children's socio-cultural values. The goal of this analysis was to identify differences in the understanding of the children's socio-cultural values and the educational goals defined by the experts. In almost all groups, the children tended to describe their stories from a third person perspective. Four children wrote their stories about the lack of food and how people had to find provisions to survive. One child wrote about men who went to the frontlines. Another child mentioned that people had lost their houses. Two children explained how people were forced to leave their country. However, many of these stories had a "happy ending", i.e. as soon as the war ended everything went back to "normal" (figure 6). This result can be interpreted in multiple ways. On the one hand, the results could be primed by common narrative structures of contemporary children's literature (e.g. fairy tales). On the other hand, these findings could point towards children's generally positive attitude to solving problems (Van Mechelen et al., 2016). Finally, these outcomes could indicate that the children were not conscious of the long-term effects of the war. Comparing these results with the educational goals defined by the expert indicated that the educational experience in the shelter could benefit from activities that promote reflection on social values and help children to understand the concept of "collective trauma", such as the need for collaboration and solidarity.

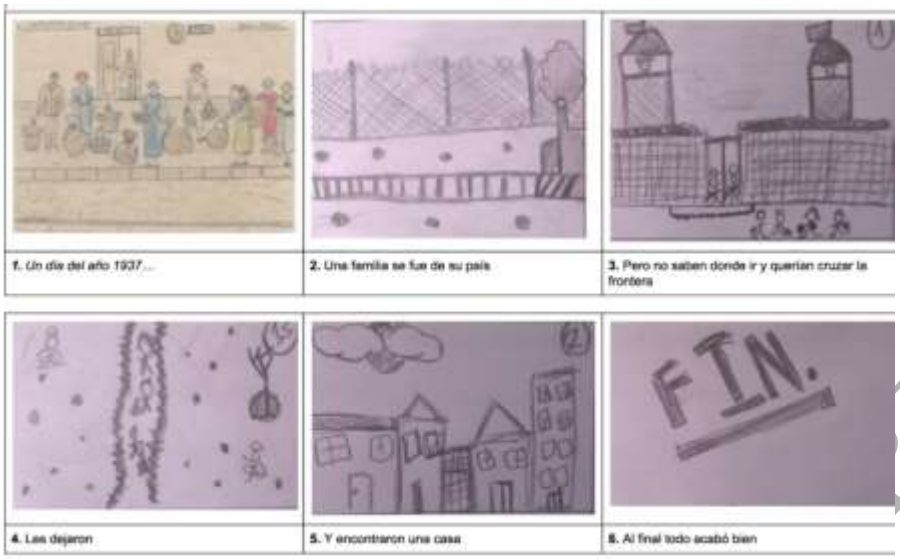

Figure 6: A girl explained in her storyboard how a family had to leave their home and found a "happy" life in another country.

Due to the educational goals defined by the experts, we focused our analysis on the children's social interactions and interpretations evoked by the guided visit and aimed to foster the aforementioned concepts and underlying values. Our results depicted that the enactment of content that was explained during the guided visit not only took place on an individual level but also involved interactions among different children at the same time. For instance, in the "infirmary" two girls re-enacted pulling up an injured person from the ground. Furthermore, the children interacted with each other by pointing at certain things in the shelter while the rest of the class followed with their gaze. In other situations, they answered their questions among themselves and discussed aspects of the guided visit that caught their attention. By analysing the children's proposals for redesigning the guided visit we looked for opportunities for interpersonal relationships and interactions that could take place within the space using the WaS paradigm. Interestingly, almost all of the children's proposals for redesigning the guided visit were group activities. They proposed specific participative and hands-on activities, such as performing a treasure hunt game, digging up the collapsed part of the children's room together, etc.

3.1.4 Definition of requirements for a first prototype

Our approach helped us to define key requirements for the design of a learning experience for this cultural heritage site. Our observations confirmed that the guided visit already had a high educational potential to introduce the historical context and some underlying values to the children. However, we saw several opportunities to complement it by using a virtual heritage experience based on the WaS paradigm (Table 2).

Table 2: Overview of requirements for the design of a first iteration

Layer	**Affordances of current learning experience and limitations**	**Opportunities for WaS**

Physical Space	(1) Spatial constraints restrict movement; (2) Poor lighting conditions; (3) Climatic conditions do not allow permanently installing multimedia systems; (4) Visitors must always be accompanied by a guide; (5) Direct contact with the physical space should be avoided; (6) Maintenance of the sensation of "simplicity and sparseness"	(1) Pervasiveness and selective use; (2) Projective Augmented Reality content does not alter the space and prevents direct contact with it; (3) Allows highlighting and completing traces of missing objects; (4) Allows balanced use of augmented content and verbal explanations to leave room for children's imagination
Narrative Space	(1) Guided visit is organized in chronological order and makes reference to the building process of the shelter and physical differences in its features	(1) Recognition and exploration of specific surfaces in the shelter to contextualize historical events and anecdotes
Personal Space	(1) Aim to strengthen feelings related to empathy and solidarity; (2) High impact of felt-experience in the shelter; (3) Guided visit triggers enactments and reflections on the harsh living conditions in the shelter; (4) Children are bored in situations when they just listen and keep still; (5) Guided visit fails to transmit the difference between active and passive defence; (6) Children had problems to understand difference in cultural values during the Spanish Civil War and today (e.g. the role of women and men in society)	(1) Participative and hands-on activities that involve the visualization of rule signs and bomb impacts; (2) Fostering children's interest in people and contrasting changes in cultural values by using testimonials and material showing civilians during the war; (3) Activities based on embodiment of actions from people in the past
Collective Space	(1) Aim to transmit benefits of community values was well understood by the children; (2) Children showed problems to relate to the significance of collective trauma (stories had a happy ending)	(1) Participative activities that foster social interaction and mutual reflection; (2) Connecting with contemporary contents such the problematic of refugees from Syria

Our findings showed that due to the spatial constraints of the shelter that the guided visit could benefit from the WaS paradigm as follows. Projective AR content allows drawing children's awareness to specific features in the environment and to augment objects missing from their original locations (e.g. the signs of behavioural rules can be projected onto the empty holes on the walls) without altering the physical space. These projections, based on surface and object recognition, may contextualize contents and help children to imagine objects they have never been in contact with. Furthermore, the WaS allows flexible utilization and can therefore be used selectively to complement the guided visit, i.e. only at moments when the guide considers that additional information is required to foster certain understandings and reflections on the learning topic.

We propose providing opportunities for children during the guided visit to explore and engage with the physical environment in different ways. For instance, participative activities could allow them to contextualize the physical aspects of the shelter with

certain learning contents. In this regard, our results showed that children were able to grasp social values related to empathy, respect, safety and a sense of cooperative work. However, the guided visit failed to transmit underlying values and interpretations that could help the students to understand abstract topics such as changes in society (the social role of women during the war and today), different standpoints on historical events (passive vs. active defence), and long-term effects of the civil war (e.g. collective trauma). The visualization of multiple location-based events allows presenting content from different perspectives and comparing them, e.g. observing civilians from different parts of the city during a bomb alert; linking the Spanish Civil War to contemporary topics such as the problem of refugees from Syria, etc. These activities could help children to understand the aforementioned concepts that are currently not fostered through the guided visit alone.

Conceptual changes of children's understanding in relation to these topics could also be achieved through social-aware AR activities. Participative activities based on social interaction have been seen to promote mutual reflections among users (Roberts et al., 2014). Thus, we envisioned implementing activities based on using projections of multiple content fragments and a common task (e.g. two children project one piece each of a larger image that together represent a stretcher. They have to move their images in synchronized fashion to take an injured person safely to the infirmary). We argue that by performing and embodying similar actions (Antle et al., 2013; Flynn, 2013; Lyons et al., 2012) to those performed by civilians during the war that these activities could help children better understand feelings of solidarity and empathy with people in these situations.

3.2 Exploration of a first prototype based on the WaS paradigm

Building on the results, we defined seven activities based on the use of two Philips PicoPix PPX3414 pico-projectors (figure 7). The system allowed the children to carry the device around and project audiovisual contents directly onto the physical environment. In this study, we focused on exploring how projective AR and participative activities that promote social interaction could enhance the educational experience. The surface recognition system and specific user interaction were still not implemented in this design iteration. Therefore, by pressing a button, the children could switch between and display different audiovisual contents that were uploaded onto the projector's digital library. The content was organized in chronological order and the guide indicated when it should be projected.

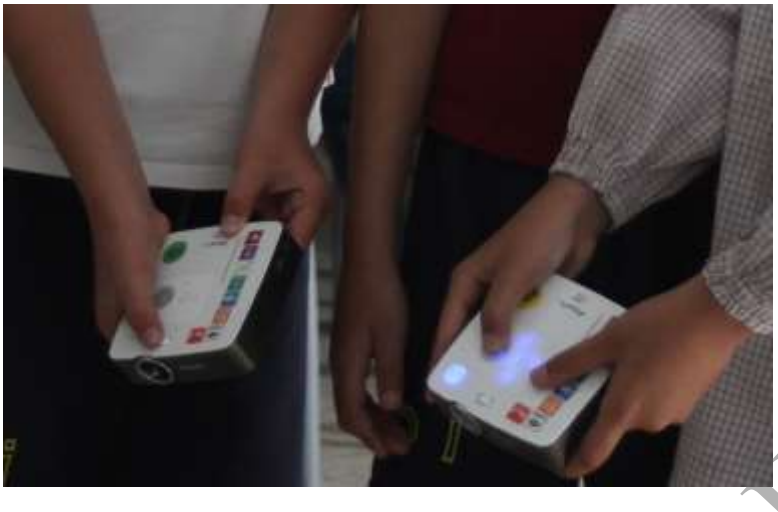

Figure 7: The children holding two Philips PicoPix PPX3414 pico-projectors. The system allowed them to ubiquitously (2) augment the physical space with digital content and (2) perform collaborative activities.

3.2.1 Procedure

Six months after the design workshops, a user study was carried out with a preliminary prototype. A few days before the study, we met the guide in the shelter to test the WaS system one last time and discussed the procedure of the visit using the prototype. The guide selected the locations in which the digital content would be displayed during the visit. Due to time restrictions, she decided to reduce the original content of the visit and focus on the locations in which we would use the WaS prototype. A total of 20 children (girls = 11; boys = 9; mean age = 9.95 years) participated in the study. The guided visit lasted 90 minutes. We carried out seven activities based on the WaS system (Table 3) to complement the educational experience. Two researchers present during the visit video recorded and took notes about the children's behaviour and interactions with the prototype. We interviewed the guide about her impressions and reflections upon the activities with the mid-fidelity prototype after the visit. A few days later, we conducted a workshop session in school that lasted 30 minutes to evaluate the children's retrospective experience with the prototype. Two researchers facilitated the activities and the session was video recorded.

Table 3: Overview of the seven activities using the prototype during the guided visit

Activity 1: Entrance	The guide pointed at the floor with the projector and an animation of an air raid on the city of Barcelona was reproduced.
Activity 2: Benches	One child pointed towards the wall. A video was reproduced where the group could see people waiting inside a metro station and hear the sound of bombs exploding in the background.
Activity 3: Behavioural rule signs	One child pointed at a stain on the wall and a picture of an old sign containing the rules of the shelter was displayed. The guide asked the children to read out aloud the content of the sign.
Activity 4: Power generator	Two children projected onto two different parts of the original location of the generator: (1) a switch on the wall, and (2) the power source on the ground.
Activity 5: Infirmary	Each of two children projected a part of an image representing a stretcher. They were asked to synchronize their movements and to take a virtual person on the projected stretcher safely into the infirmary.

Activity 6: Construction of shelter	One child projected an image of a group of children helping with the construction of the shelter.
Activity 7: Comparing children's drawings about war	Two children compared two different images. One child pointed at the wall with the projector and a child's drawing from the late 1930s was displayed. Another child projected a child's drawing from Syria next to the first one.

Retrospective evaluation of the experience

We started the workshop with a drawing activity. Thus, the children were asked to draw themselves in the shelter using the projector (performer role) or, if they did not use it, in the role of the "observer" of the interactive experience. After that, the researchers went around with cameras and recorded a short interview with each child. The children explained briefly what they had drawn and why they had chosen that particular representation of themselves and the situation. The aim of the activity was to elicit the children's feedback on the educational experience and on using the prototype (Nicol and Hornecker, 2012). The drawings also facilitated prompting group discussions about the user experience. Therefore, we divided the children into groups of 3-4 members. They were asked to collaboratively reflect upon the educational experience and use of the prototype based on the drawing they had produced. The children wrote their reflections down on post-it notes. The researchers again went around with cameras and recorded a short interview with each group. The aim of the activity was to understand the children's perceptions of the user experience. At the same time, the procedure allowed the children to compare their attitudes and interpretations with those of other peers and to extend their own reflections.

3.2.2 Analysis

In this part of the study, the analysis focused on researching the *personal space* and the *collective space* of the experience. For this analysis, we summarized our findings in subcategories, namely (1) educational experience, (2) user experience, and (3) interaction with the prototype. The *physical space* and *narrative space layers* were not relevant for this design stage because they represented requirements of the guided visit which we did not aim to influence. Our main goal was only to complement the existing educational experience by not altering the physical space and predefined learning contents.

3.2.3 Results

Educational experience

Using digital augmentations in the shelter proved to enhance the children's understanding of the historical context in several aspects. In general, the children stated that the projected pictures helped them to imagine certain artefacts and situations in the past. One child said "It was like travelling in time". Another child particularly appreciated that content was displayed in its original locations, for instance the rule signs or the power generator. Two children explained how the activity about the children's drawings had particularly impacted them (figure 8). One boy said: "It is not normal for a six-year-old child to draw something like that". Another child explained: "I drew this because it made me sad that a child drew something like that and had to go through this in his country. The child was from Syria".

Other interpretations were evoked by the children's physical presence (situatedness) in the shelter. During the guided visit, the children expressed fear when the light was turned off. Several children complained about the cold. They also mentioned that they were afraid of getting lost in the tunnel and they doubted that they would find the exit.

Furthermore, the results indicated that activities based on embodied exploration triggered the children's reflections on underlying values in relation to the historical context. For instance, with regard to the activity in the infirmary, one child in the observer role stated "you needed two carriers for each injured person. If they had to do this for each one who needed help, it was impossible". This finding suggests that observing the enactment of actions by people during the war, helped the child to empathize with the severity of such situations.

Figure 8: The guide explained the drawing by a child from the war in Syria.

User experience

Analysing the children's drawings and interviews revealed relevant differences between the user experience of (a) the children who held and interacted with the device (performer role: 10 children) and (b) those who observed and interacted with the projection of the prototype (observer role: 10 children). Six children in the *observer role* represented themselves in a larger group (figure 9, left) during the activity in the "infirmary", "rule signs" and "construction of the shelter". One of these children drew himself facing the opposite direction and looking at the children's room. The child also explained during the interview how much he was impacted by this space because it was destroyed during a bomb attack. Three children drew about their experience with a video that showed civilians using a metro station as a shelter. Interestingly, they represented themselves sitting on a bench and another person projecting. One of these children added details to her drawings to depict that the shelter was built into a mountain (figure 9, right). One child represented himself alone.

Figure 9: The children in the observer role represented themselves in a group (left) and as passive spectators (right)

In contrast, only one girl in the *performer role* represented herself in a group. Eight children represented themselves alone and often in the centre of the picture (figure 10). One girl reported during the interview that she was particularly proud to be chosen to use the projector. One boy mentioned that he liked the activity but he could not remember what it was about. Despite having used the projector in a different space, one child in her drawing focused only on the children's room and did not depict any other child. Interestingly, after the visit the guide mentioned that she had perceived that using the projector gives the children a task with a high degree of responsibility. The reason for this perception was probably that they must make sure that the content was well displayed for a certain amount of time. This interpretation was in alignment with the values related to "being a community" that the museum aimed to provide during the visit.

Figure 10: The children in the performer role represented themselves alone and in the centre of the picture.

These findings (figure 11) indicate that activities where the children were forced to remain still and only watch the augmented content were perceived as a passive and less interesting experience. As a consequence, during these activities the children tended to focus less on the augmented content and instead explored the physical features of the shelter with their gaze. Furthermore, we observed a relevant difference between children using the WaS system and those who observed their peers interacting with it. Whereas the children in the observer role mainly lived the activities as a group experience, those who performed the activities using the WaS system were immersed in their task and concentrated on their individual experience. However, the current features of the mid-fidelity prototype did not allow them to feel part of the collective experience during the activities.

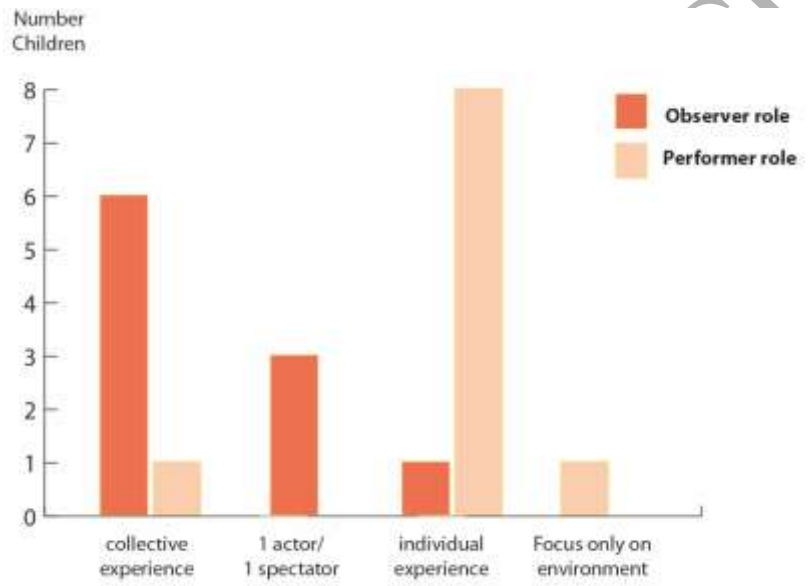

Figure 11: Overview of the children's perception of the experience in observer and performer roles.

Interaction with the prototype

Using the prototype in the shelter during the guided visit allowed us to analyse how the children were intuitively interacting with it. We observed several direct interactions with the augmented content. For instance, during the activity at the entrance when a bomb raid was projected, one child cringed when the virtual bomb exploded. Furthermore, one child projected a random image on the head of his peer who started to interact with it. On the other hand, the children tended to point at details in the projection directly with their hands (figure 12, left) or indirectly with their own shadows (figure 12, middle). One child tried to interact with the displayed content by enacting that he would turn off the switch of a power generator (figure 12, right). During the activity in the infirmary, two children immediately understood that the two image parts belonged together. They said "It's like a puzzle". Furthermore, they easily managed to perform the pre-defined enactment of synchronously moving the stretcher to one part of the space.

Figure 12: One child interacted directly with the displayed picture (left); one child interacted through his shadow with the displayed picture (middle); one child enacted switching off a power generator (right)

We observed that the use of videos vs. still pictures triggered different interaction behaviours. Whereas video tended to produce a "cinema effect", i.e. the children watched the displayed content attentively, still pictures left room for the interactions previously described. In general, the children enjoyed activities that required the active participation of the entire group. For instance, during one activity, they collectively participated in reading the rule signs out loud. In this regard, one child mentioned that he liked the fact that he could actively take part in the guided visit instead of only listening to the guide's explanations. At the same time, they liked to investigate and discover different sources, e.g. during the power generator activity.

A general summary of the results is presented in Table 4.

Table 4: Overview of outcomes of the first design iteration

Understanding content	• The displayed content supports children's imagination • Enactments of people's actions from the past help to empathize with war-related situations • Comparative tasks stimulate reflection-in action about past events and contemporary topics • Situatedness triggers different emotions and helps to foster certain aspects of the learning content
User Experience	• Most activities are perceived by the children in the observer role as a collective experience • Projections that do not promote specific activities cause a "cinema effect" and are perceived as a passive experience • Children using the projector perceive themselves as protagonists but its use prevents active involvement and being part of the collective experience
Interaction with Prototype	• Children perform enactments in relation to displayed content • Children point directly with hands and indirectly through shadows on the projected content • Using two image parts triggers the association with a puzzle • Children pretend that the displayed images would be interactive and trigger behaviour changes by certain interactions • Participative activities stimulate reflection and dialogue

4. DISCUSSION

We have presented the evaluation of a first design iteration of a virtual heritage experience for an archaeological site to explore the potential of an educational experience based on the WaS interaction paradigm for primary school students. Our results indicate benefits to complement the learning experience during the guided visit by (1) supporting activities that involve the digital augmentation of the physical space and (2) by encouraging embodied explorations such as spatial interaction, tangible manipulation and the performance of collaborative tasks. We will now discuss these aspects in more detail and outline opportunities for improvements of the prototype.

Digital augmentation

Employing the WaS system in the shelter allowed the children to visualize missing objects in the physical space and contextualize the guided visit at specific locations through audiovisual material that illustrated certain aspects of historical events. These projections helped the children to better understand the learning contents that were difficult to imagine. Furthermore, this feature allowed the students to compare different contents at the same time and some preliminary results pointed towards the potential of supporting children's capacity for perspective-taking (Ackermann, 1996). However, the museum experts warned of the risk that too frequent a use of the system could limit the children's imagination and their own reflections (see section 3.1.3, physical space layer). Consequently, the use of projective AR needs to be carefully balanced with other activities aimed at encouraging the interpretative construction of meaning.

Embodied exploration

In this design iteration, we found evidence that activities involving embodied exploration can enhance children's understanding of topics requiring emotional engagement (Sakr et al., 2016), critical thinking (Rowan et al., 2016) and the notion of collaboration (Stanton et al., 2001). However, we argue that due to the limited functionality of the current version of the prototype, this feature is still not fully explored. Previous studies (Malinverni and Pares, 2014) have demonstrated that embodied interaction (Dourish, 2001) can support the learning of abstract concepts. We envision, through the improved functionality of the prototype, fostering the students' understanding in underlying socio-cultural meanings such as the notion of identity (Smith et al., 2011) and solidarity. We believe that particularly activities building on collaborative learning (Doise et al., 1975; Malinverni and Pares, 2015; Nelson, 1994) and a shared construction of meaning (Ackermann, 2004) can promote a better understanding of these concepts. Therefore, we aim to design a system that dynamically recognizes the physical world (i.e. geometry, surfaces, objects and movements) and then projects context-aware digital information directly onto it. This will allow us to take advantage of the benefits of Reality-Based Interaction. These advances will improve the naturalness of the interaction and, consequently, the quality of the user experience which influences the educational experience.

Perception of agency

Moreover, we assume that the limitations of the prototype also caused the children who used the WaS system to experience some activities on an individual level or even

passively. Further research is needed to analyse if this shortcoming was caused by the design of certain activities or by the user experience that evoked the features of the system. In this context, it is also important to evaluate how the agency between the different users should be distributed. For instance, for some activities, it may be more appropriate for the guide to use the device. Conversely, other activities could be guided by children holding the device or, in different contexts, by the group physically interacting with the projected contents.

4.1 Limitations and future work

Due to the small sample size of the evaluation study, we argue that the results provide only a snapshot of the ways in which children can benefit from an educational experience based on the WaS interaction paradigm. Further research is needed to confirm our observations and explore the full potential of the WaS system with a more advanced prototype. We are currently developing a second design iteration which is based on a marker-recognition system (Betsworth et al., 2014; Willis et al., 2013). We claim that this approach will allow students to dynamically explore the physical space and increase their contextual awareness between certain physical aspects and the historical context.

Future work should also explore different formats of the guided visit in combination with the virtual experience. For instance, one variation could be to carry out the guided visit first and then allow children to revisit the shelter using the WaS. This procedure could permit them to explore aspects of the experience motivated by their own interests and leave them more time for discovering new aspects of the learning content at their own pace. However, this has implications on the duration of the visit, safety issues and potential liabilities.

Subsequent studies should also broaden the evaluation approach of the educational experience and incorporate assessment tools that allow researchers to elicit students' comprehensions and reflections on abstract concepts such as empathy, identity and solidarity. We also plan to conduct additional project meetings with the experts, to incorporate their viewpoints more strongly in the evaluation.

From a broader perspective, we see potential to employ the WaS system for general visitors in other areas of application such as guided tours at indoor and outdoor events, artistic interventions in urban spaces, etc. However, design and assessment tools for these site-specific experiences cannot be generalized and need to be carefully selected for each context.

5. Conclusions

Overall, this paper contributes to the body of advanced interfaces in cultural heritage by presenting and evaluating an educational experience based on the WaS interaction paradigm for primary school children in the context of CH. Our study indicates a first set of benefits of using digital augmentations and participative activities based on embodied exploration. On the one hand, it allowed children to explore the physical environment in meaningful ways and to construct meaning by discovering new layers of the educational experience. On the other hand, the enactment of specific situations allowed the students to more directly experience historical content during the visit that

required emotional engagement, critical thinking and collaborative learning. In future studies, we will explore further potentials of this approach with an advanced prototype based on a marker-recognition system.

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