Did We Just Travel to the Past? Building and Evaluating With Cultural Presence Different Modes of VR-Mediated Experiences in Virtual Archaeology

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Over the past years, Virtual Archaeology has introduced more experiential elements in virtual reconstructions, therefore going beyond the traditional visualization of 3D architectural models. In the case of dissemination, these experiences equate to a trip in time, in which users witness what the past was like and learn about it. However, due to a lack of explicit theoretical frameworks and/or systematic evaluation focusing on such experiential elements, it is uncertain whether the intended goals are achieved and why. Based on a novel theoretical framework arising from the concept of Cultural Presence, this article will investigate if and how current virtual environments achieve the feeling of traveling to the past. To that end, six different virtual reconstructions of the Neolithic site of Çatalhöyük (Turkey) were built and evaluated in a between-subjects experiment. The results support the role of content meaningfulness, responsive characters, enhanced interaction, and multisensory realism in the achievement of successful Virtual Reality–mediated experiences.

CCS Concepts: • **Applied computing** → **Archaeology**;

Additional Key Words and Phrases: Virtual Archaeology, Cultural Presence, VR-mediated experiences, evaluation

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1 INTRODUCTION

Over the past years, Virtual Archaeology has introduced more experiential elements in virtual reconstructions for both research (e.g., Morgan 2009; Paliou and Knight 2013; Papadopoulos et al. 2015; Woolford and Dunn 2013) and dissemination (e.g., Andreoli et al. 2016; Bogdanovych et al. 2010; Champion 2015; Champion et al. 2012; Devine 2013, 2014; Ename 2015; Park et al. 2006; Pietroni et al. 2016a; Pietroni et al. 2016b; Reunanen et al. 2015; Virtual Multimodal Museum 2017). The use of multisensory stimuli, embodiment, storytelling, responsive characters, emotivity, or enhanced interaction has taken Virtual Reality (VR) applications in Archaeology beyond the traditional visualization of 3D architectural models. The current success of this approach can be ultimately

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traced to the recent evolution of contemporary western societies, in which the socioeconomic focus has shifted from providing services to providing experiences (Gentile et al. 2007; Pine and Gilmore 1999).

"Experience" is considered a complex phenomenon, involving perception, action, motivation, and cognition (Hassenzahl 2013). Consequently, it can be analysed from a psychological, organisational, and/or sociological perspective (Zatóri 2013). Although there is no formal definition for "experience" in the wider Digital Heritage field, in which Virtual Archaeology is included (López-Menchero 2013), current uses seem to oppose more holistic multisensory engagements to traditional purely intellectual and object-based visits. However, there have been previous relevant investigations in tangent fields, such as museums and visitor studies (e.g., Csikszentmihályi and Hermanson 1995; Dewey 1934; Falk and Dierking 2013; Kocsis et al. 2010; Macdonald 2007), tourism (e.g., Dicks 2004; Urry and Larsen 2011), and Human-Computer Interaction (e.g., Blythe et al. 2006; Forlizzi and Battarbee 2004; Hassenzahl 2013; Norman et al. 1995; Wright and McCarthy 2010). From these, it can be derived that Digital Heritage experiences involve memorable, meaningful, engaging, emotive, multisensory, and embodied predefined sets of events taking place at or in relation to (e.g., before/after/instead of visiting) a Cultural Heritage setting, which are mediated by digital technologies, and which encourage the active participation of and collaboration/sharing between visitors-users. In the case of Virtual Archaeology, these experiences are implicitly or explicitly equated to a trip in time, in which users witness what the past was like (Forte and Siliotti 1997; Gaitatzes et al. 2001; Kantner 2000; Park et al. 2006; Pietroni et al. 2016a; Pietroni et al. 2016b) and learn about it (Andreoli et al. 2016; Ibrahim et al. 2015; Koutsabasis 2017; Pujol and Champion 2012).

However, as other authors point out (Ibrahim et al. 2015; Koutsabasis 2017; Madsen and Madsen 2015), there is still a lack of systematic evaluation, based on explicit theoretical frameworks (e.g., Bonini 2008; Pujol and Champion 2012; Mikropoulos and Strouboulis 2004; Rahaman and Tan 2011; Winn 1993) in the Cultural Heritage field. As a result, it is uncertain whether the intended goals are achieved and why. Most current assessments focus on usability, user experience, or recall, but not on the experiential dimension of the application; consequently, it is not clear whether, for instance, learning is due to the experiencing of a trip in time. In our opinion, such disagreement between the goal and the evaluation of VR applications in Archaeology is due to an implicit assumption that visual realism, immersion, and navigation are sufficient to simulate the past, and constitute a universal didactic method. Unfortunately, several studies have evidenced that photorealism can sometimes be counterproductive to understanding (Alessi 1988; Gooch and Gooch 1999; Lee et al. 2005; Pujol 2011) or not engaging enough (Madsen and Madsen 2015), and that empty architectural 3D models generate only superficial knowledge about specific recognisable elements (Bonini 2008; Ibrahim et al. 2015; Ijaz et al. 2014; Pietroni et al. 2016a; Pietroni et al. 2016b; Pujol and Economou 2008; Rahaman and Tan 2011).

We argue that to create virtual environments (VEs) that are useful according to the goals of the field, Virtual Archaeology needs to focus on three fundamental issues: (1) building one or more theoretical frameworks for design and evaluation based on the idea of traveling to the past, (2) testing if and how this notion is achieved, and (3) evaluating if it enhances learning. Such were the goals of the LEarning of Archaeology through Presence (LEAP) project (FP7-PEOPLE-2013-IEF, no. 625537), a two-year Marie Sklodowska-Curie Action undertaken at Pompeu Fabra University of Barcelona. LEAP defined both theoretically and empirically (Pujol 2018) the concept of Cultural Presence and tested its suitability as a framework to build VR-mediated experiences for Cultural Heritage. To date, there have been a few projects that aimed to introduce and evaluate Cultural Presence in the Cultural Heritage field (Champion et al. 2012; Devine 2013, 2014; Jones 2005; Pujol and Champion 2012); yet, they remain limited in the deployment of the concept, and consequently in the scope and depth of the evaluation.

The present article will investigate if and how current virtual environments achieve the intended middle goal of feeling that one has travelled to the past. To that end, it will first review previous projects aimed at designing and evaluating "experiential" virtual environments for archaeological dissemination. Then it will define the relevant concept of Cultural Presence. The next sections will present the technical description, methodology, experimental procedure, and results of an empirical study based on the UNESCO World Heritage Neolithic Site of Çatalhöyük (ÇH) in Turkey (Figure 1). Finally, the discussion and conclusions will interpret the results of the study and outline future research opportunities.

Fig. 1. Building 49 at the Çatalhöyük north shelter (Turkey).

2 RELATED WORK

The studies related to the design and evaluation of more experiential archaeological virtual environments for dissemination can be classified into three groups. The first one corresponds to projects that design more experiential virtual reconstructions but do not evaluate them. For instance, "Ullastret 3D" (Virtual Multimodal Museum 2017) uses a combination of automatic navigation, immersivity, high photorealism, and evocative storytelling to propose a journey to the Iberian site of Ullastret (Catalonia). Another example is "Ename 1290" (Ename 2015), which transforms a previous pioneering 3D model for visualisation (Callebaut 2002) into a game-based experience: gesture-based interaction allows users to explore Ename abbey and manipulate objects to unlock descriptions about them. Greeff and Lalioti (2001) went a bit beyond and adopted a role-playing approach. In their interactive story "Cato Manor Shebeen," users explored the township tavern as one of three different virtual identities. This implies different camera perspectives, abilities, and affordances for interaction, which should help in understanding this South African community from the inside. A final step in this direction is that of Okapi Island, a reconstruction in Second Life of the settlement and the archaeological campsite of Çatalhöyük in Turkey (Morgan 2009). At Okapi Island, users could interact between them and, more importantly, modify the environment to propose their own interpretations about the main archaeological finds.

The second group of studies corresponds to projects that design more experiential virtual reconstructions, but their evaluation does not focus on the experiential dimension. Publications come from both the Computer Science and the Cultural Heritage fields. Regarding the former, we have selected an early publication describing an Augmented Reality application for tourism in Cultural Heritage sites (Park et al. 2006). The evaluation focuses on rating basic aspects of the user experience (immersiveness, interest, understandability, intention of use) but does not analyse in depth their effect on the Cultural Heritage experience. Another project investigates the role of avatars to learn about past cultures (Ijaz et al. 2014). The researchers built a Second Life replica of the Mesopotamian city of Uruk in 3000 B.C. and populated it with virtual agents endowed with artificial intelligence. The evaluation evidenced the pedagogic and motivational advantages of the virtual approach in comparison with books and videos but did not confirm directly whether this was a result of social interaction. Finally, another technical work analyses the factors that contribute to learning in Web-based virtual reconstructions (Ibrahim et al. 2015). Although explicitly based on theoretical frameworks related to embodiment (Bonini 2008; Rahaman

and Tan 2011), the study analysed transmission of information rather than the experiential dimension of the reconstructions.

Projects originated in the Cultural Heritage field also stop at technical or communicational aspects. For example, applications developed within the V-Must Network of Excellence (Fanini and Pagano 2015; Pietroni et al. 2013, Pietroni et al. 2016a; Pietroni et al. 2016b) use a combination of gesture-based navigation, storytelling, human characters, and emotions to enhance the understanding of Roman archaeological sites. Yet, evaluations focus on usability, user experience, and recall, taking for granted the role of the aforementioned experiential elements in the final results. Seemingly, the reconstruction of the *Vrouw Maria* 18th-century shipwreck (Reunanen et al. 2015), another example of immersive, gesture-based application aimed at recreating the experience of visiting the underwater site, concentrates on interface performance, easiness of navigation, and retrieval of textual information. In conclusion, some potential for learning is confirmed by all of these studies, but we do not know exactly which features are responsible for it.

Within this second group, we would like to mention separately some projects that introduce the concept of Presence (see definition in Section 3) as a theoretical framework for virtual reconstructions. Andreoli et al. (2016) propose a game-based immersive experience to browse through the history if a historical building in Salerno. Devine (2013, 2014) proposes a journey through time to learn about the first European settlement in Sidney. In both cases, Presence serves as a theoretical framework; yet, the evaluation does not investigate its relationship with learning: the first study aims purely to assess learning effectiveness, whereas the second investigates aspects related to usability and user experience (effectiveness of communication, most liked features, preferred interactive modes for learning).

The third group of studies corresponds to projects that design and/or evaluate the experiential dimension of virtual reconstructions. Champion et al. (2012) examines the influence of different user roles on cultural understanding through a virtual reconstruction of the Mayan site of Palenque. The results indicated that game-based, inhabited, interactive worlds were considered less authentic, interesting, and suitable for cultural learning. It was argued that one reason might be the conservative perception that audiences and experts had of archaeological virtual environments back in 2006. In another study, Pujol and Economou (2008, 2009) focused on the immersive interactive systems of the Foundation of the Hellenic World in Athens, which aimed to enhance Cultural Heritage learning by means of a guided trip in time (Gaitatzes et al. 2001). The study compared the Dome VR theatre, the CAVE-like installation, and the exhibition to reveal the factors underlying visitors' feeling of experiencing the past. From more to less important, these appeared to be relevance and accessibility of content, immersivity, exploration, human presence, multisensory stimuli, and psychological predisposition. Another relevant conclusion was that despite its lower visual accuracy, the CAVE-like installation conveyed better than the Dome VR theatre an experience of the past. According to visitors, this was explained by the fact that it was stereoscopic, more immersive, populated, and allowed full-body, meaningful interaction with the guide, with other visitors, and with the virtual world.

In conclusion, as also emphasised by Koutsabasis (2017), most evaluations in Virtual Archaeology currently focus on assessing the communicational effectiveness of digital technologies, disregarding the reasons for successful user experience. Still, the previous studies provide indications about the potential components of VR-mediated experiences: storytelling, human presence, social exchange, free exploration and control, intuitive/meaningful interaction, immersivity, embodiment, multisensory realism, visual augmentation, content meaningfulness, content accuracy, representation of daily life, and sense of place.

3 THEORETICAL FRAMEWORK

The design and evaluation of more experiential approaches in Virtual Archaeology may be supported by a theoretical framework based on the concept of Cultural Presence. Presence is a highly interdisciplinary field of research at the confluence of Psychology, Computer Graphics, and Human-Computer Interaction. Initially

defined as the "feeling of being there" (Heeter 1992; Steuer 1992), during 20 years of theoretical and empirical development, new perspectives were included (e.g., Lombard and Ditton 1997; Slater and Wilbur 1997; Witmer and Singer 1998), and new terms were coined, such as *Co-Presence* (Schroeder 2002), *Social Presence* (Swinth and Blascovich 2002), and *Cultural Presence* (Riva et al. 2002; Spagnolli et al. 2003). The latest was defined as "the feeling of being and making sense there together" (Villani et al. 2012).

The concept of Cultural Presence was adapted to the Cultural Heritage field early on (Champion 2005, 2007, 2015; Pujol and Champion 2012), as the latter may benefit from its well-grounded theories of perception, interaction, learning, and psychology, as well of its diversity of well-tested methodologies for assessment. In the new domain, the concept was defined as "the feeling of being there and then together" (Champion 2007) and constituted a means to serve the different, evolving purposes of Cultural Heritage (e.g., understanding, awareness, conservation, identity). It was suggested that the feeling of Cultural Presence may be achieved through exploration, interpretation, and social exchange (Pujol and Champion 2012) within virtual environments endowed with "hermeneutic richness" (Champion 2015).

The LEAP project expanded this initial definition into "the feeling of being there and then making sense together," which expressed explicitly the goals of Cultural Heritage, as well as the social and active approach needed to achieve them. Subsequently, if Cultural Presence was to serve as a theoretical foundation for evaluation, the empirical manifestations of this theoretical definition needed to be investigated. On the one hand, previous authors (Pujol and Champion 2012) had raised doubts about the universality of the notion and learning of culture, and advocated for the situatedness of its manifestation and interpretations. Therefore, we defined, through successive workshops with site specialists from the Çatalhöyük Research Project (Pujol 2017b), the essential elements of Çatalhöyük as a culture (Pujol 2017a) and how to depict them in a VR-mediated experience (Section 4.2). On the other hand, we developed the general concept of Cultural Presence into an operational definition (Pujol 2018), according to which Cultural Presence is a gestalt temporary condition than can be manifested both through automatic behavioural and physiological responses to sensory stimuli, as well as through subjective interpretation of cognitive operations involving the processing of external and internal input. These top-down reactions and conscious considerations are determined by three groups of causal factors:

1. *Technological*: Capacity of the system to adapt to our physical characteristics and simulate our perception and interpretation of the world and interaction with it
2. *Human*: Physical, cognitive, psychological, and cultural characteristics of users
3. *Communicational*: Purpose and context of use of the application.

With the help of previous literature about Presence measurement (e.g., Schubert et al. 2001), these factors were transformed into the 11 subscales of a novel Cultural Presence Questionnaire: General Presence, Perception, Self-perception, World's authenticity and behaviour, Interaction, Attention, Willingness to experience Presence, Suspension of disbelief, Emotions, Social Presence, and Culture. The questionnaire was pilot- and statistically tested, then used to evaluate the Çatalhöyük virtual environment with users. This allowed us to determine (by means of Exploratory Factor Analyses) which were the underlying factors of Cultural Presence: cultural representation and engagement, Social Presence, and communicational aspects of technology (Pujol 2018).

4 EMPIRICAL STUDY

4.1 Research Questions and Hypothesis

With regard to the experiential dimension of virtual environments, LEAP intended to solve the following research questions:

1. What are the design elements that constitute a VR-mediated experience?
2. What kind of current VR applications achieve a more experiential dimension?

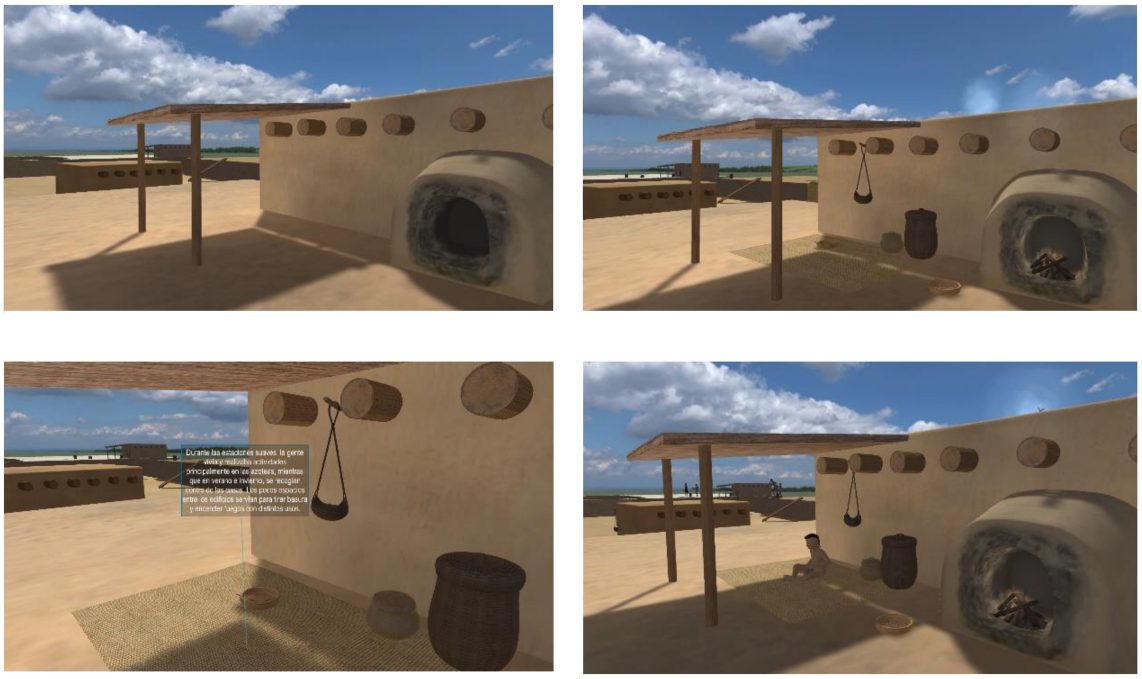

Fig. 2. From left to right and top to bottom, rooftop of building 49 at Çatalhöyük in conditions 1 (architecture only), 2 (objects), 3 (hotspots with text), and 4 (still characters). Conditions 5 (dynamic scenes) and 6 (storytelling) can be seen in a video at https://www.upf.edu/leap.

Our hypothesis was that the more simulational elements were added (e.g., objects, people, interaction, storytelling), the more complete the reconstruction of a society would be, and this would increase the feeling of Cultural Presence, regardless of visual realism.

4.2 The "ÇH3D" Experience

To define the content, a mixture of traditional and innovative methods was used. Firstly, we obtained the basic information about the site and the landscape from published monographs about the excavations (Hodder 2013). Secondly, we held an exploratory workshop with two visualisation and site specialists about the defining elements of Çatalhöyük as a culture and the general aim of archaeological virtual environments. Thirdly, we conducted an on-site workshop with several site specialists (Pujol 2017b provides a detailed description). During the workshop, they described life at Çatalhöyük 9000 years ago using different "media" (the site, a reconstructed house, and an illustration) and suggested the best way to depict it with VR.

To design the virtual environment, we built an interaction matrix (Table 1) that combined the results of the previous participatory design workshops, the theoretical stances of the project, and its experimental needs. The resulting "ÇH3D" experience consists of a one-day trip to Çatalhöyük 9000 years ago, during which the user visits five points of interest (POIs), corresponding to the five essential elements of Çatalhöyük as a culture. By pressing a gamepad button or performing specific navigation actions in the environment, each POI is loaded, and the camera lands on a specific location, from which the user can explore the surroundings (within certain invisible limits).

However, to be able to test our hypothesis, we implemented six experimental conditions—that is, six "increasingly complete" versions of the same model (Figure 2 and Table 1), which aimed to reproduce and compare

Table 1. Interaction Matrix Used to Define the Information, Interaction, Landing Point, and Specific Features of Each Experimental Condition for ÇH3D

POI	Information	Place/Time	Interaction	Cond. 1	Cond. 2	Cond. 4	Cond. 5	Cond. 3/6
1	Different areas for different activities and people; death and life close	Inside B49. Space 100. Sunrise.	Look around, squat to enter side room	Only structures but feeling of clean/dirty spaces	Mats, baskets, wooden bowls, obsidian and bone tools, hanging bags, broom, clay balls	Sitting man knapping; squatting woman cooking at hearth; baby with elder man; kid polishing wall	The previous + sounds of baby crying, flint knapping, hearth cracking, elder humming	Text/Voice off talking (mouse)
2	Independent households of practical kin linked by social networks	Inside B49. Space 100. Morning.	Look around, squat to enter side room; exit using ladder	Burial 1492 empty	Burial 1492 with skeleton	Household + 2 visitors, ceremony of bone sharing	The previous + singing	Text/Voice off talking (spirit)
3	Mudbrick houses pressed up, use of rooftops and middens (crowded, busy place)	From rooftop of B52 close to Sp. 90 (garden), overview of the site and fields. Morning.	Look around and down to roofs and middens	Oven and roof over it	Mat, basket with bread	People in middens and on roofs doing different activities; child weaving baskets	The previous + sounds of activity, birds, wind	Text/Voice off talking (bird)
4	House cycles (renovation and tradition)	From midden (Sp. 60 to the right of B55). Afternoon.	Explore middens and ruined house	B55 in ruins, big pit	Timber posts laying on the ground, mudbricks in piles	People discussing house new cycle; woman and child making mudbricks	The previous + birds, distant voices, singing	Text/Voice off talking (house)
5	Domestication of plants and animals, still hunting and gathering (uncertainty, seasonal cycles)	At settlement outskirts. Sunset.	Explore midden and look over fields	South shelter and fields		People with herds and crops, young hunters at campfire	The previous + birds, distant voices, wind	Text/Voice off talking (dog)

the different kinds of virtual environments currently found in Virtual Archaeology: architecture only, objects, hotspots with written information, still characters; dynamic scenes with 3D sound, and narration. The six versions contain the same cultural information, have the same level of interaction (navigation), and equally combine different levels of visual realism and content accuracy.

ÇH3D was completed in 9 months by an interdisciplinary team composed of a professional 3D artist (environment and settlement); 3 training modellers/animators (objects and characters); two professional multimedia designers (soundscape); a professional sound engineer (sound mixing); 2 professors, 4 Ph.D. candidates in Human-Computer Interaction, and 5 students in audio-visual communication (voices and narration); and a professional VR programmer (3D sound, interaction, lighting, stereo visualisation, user interface). They used 3D Studio Max to build the environment and the scenes, Substance and Photoshop for the assets, and Unity Game Engine to run the environment.

The final experience is currently played on a Dell Alienware 17 Gaming laptop. It consists of a two-display mode. In VR mode, users wear a Razer OSVR HDK2 head-mounted display to obtain a fully pervasive, stereoscopic vision of the virtual environment. They also wear T'nB earphones for 3D sound output. Spatial navigation is achieved by means of a Logitech F710 wireless gamepad, which also triggers 3 of 5 POIs and allows entering and exiting the architectural structures in Conditions 1 and 2. In screen mode, 3D images are displayed on the laptop's screen. Interaction and navigation possibilities remain the same but are now performed by means of keyboard arrows and mouse buttons.

4.3 Methodology

To test our hypothesis, we designed a between-subjects experiment: participants would be divided into six homogeneous groups and experience one of the six experimental conditions. Data gathering relied on the following methods:

1. *Video-recording*: For triangulation with the information based on self-assessment
2. *Pre-experience questionnaire*: Contained 20 questions related to demographic variables, previous knowledge, interests, skills, and attitudes
3. *Post-experience questionnaire*: Consisted of the 98-item Cultural Presence Questionnaire (Section 3) composed of a 5-point Likert scale, multiple-choice, and open questions.

Information was stored in a database comprising 203 variables, which were analysed with IBM SPSS 19 and 24.

4.4 Participants

For our study, we recruited 84 participants (14 by condition). Although this sample was sufficient for the main purpose of the project, which was to investigate the factors underlying Cultural Presence (Pujol 2018), some precautions had to be taken in the case of inferential statistics (Section 5.2). Our participants were 47% male and 53% female, between 12 and 80 years of age (mean = 30–59 years old). Although the majority had no academic specialisation, those with higher studies had backgrounds in Computer Science, History/Archaeology, Law, Agriculture, Economics, or Education. They also had different levels of experience with and interest in technology, Cultural Heritage, Computer Games, and immersive VR. The average participant used computers daily but played games less than once a month. She had never experienced VR, had moderate interest in Archaeology, and average technological skills.

4.5 Procedure

Data gathering (Figure 3) lasted one month (July 2016) and was conducted either at the premises of Pompeu Fabra University in Barcelona or at the participant's location. Participants were evenly assigned (in terms of gender, age, expertise, and experience with VR and/or videogames) to one of the six versions of ÇH3D. After following the standard ethics protocol, each participant was shortly briefed about the project and the experimental procedure and filled in the pre-experience questionnaire. Then, instructions about the virtual environment were given, and the participant could explore ÇH3D at will, while being recorded. Participants were encouraged to think aloud and could ask for help if needed. Afterwards, they filled in the post-experience questionnaire. The average session lasted around 40 minutes.

5 RESULTS

To analyse the data, we used a combination of univariate descriptive and bivariate inferential analyses. Exploratory Factor Analysis was also possible, but such a global approach, already applied in Pujol (2018), extracts factors that are essentially inductive constructs (Schubert et al. 2001; Waller and Bachman 2006). For our

Fig. 3. Installation of the ÇH3D virtual environment for user testing.

purpose here, which was to investigate what kind of VR applications achieve an experiential dimension and what are the design elements that contribute to it, statistical techniques searching for significant differences (chi square, Kruskal-Wallis) and analysing the role of specific variables (means and counts) were considered more appropriate.

5.1 Univariate Descriptive Analyses

Univariate descriptive analyses were aimed at responding to Research Question 1.

Description of the experience. Answers were divided in three main groups: descriptions, opinions, and details. Regarding the former, 28.6% of participants emphasised the role technology; others described it as visiting a place (18.4%), a culture (12.2%), and another time or reality (24.4%); finally, a few users likened the experience to mass media (8,2%), to videogames (4.1%), and to 2D images (4.1%). Regarding opinions, participants mostly considered that the experience aroused interest and curiosity (31%) and that it was useful for learning (28.2%); others said it was fun (9.9%), innovative (8.5%), and even spectacular (7%). The overall judgment was positive: 64.8% of participants considered it was a satisfactory experience and/or would recommend it, whereas only 5.6% considered it was disappointing and/or not suitable for everybody. Regarding details, participants mainly gave reasons for their dissatisfaction: 27% mentioned VR sickness; 24.2% mentioned the lack of people (especially in Condition 1) and of dynamism (especially in Condition 4, where characters were static); 21.2% mentioned the lack of enhanced interaction (especially in Conditions 3, 5, and 6) to be able to interact with objects/people or to choose navigation speed; 15.2% mentioned the lack of visual realism (especially in Condition 3—hotspots); and finally, one person mentioned there was not enough information (in Condition 6).

Breaks in Presence. Switches from the virtual to the real world (Brogni et al. 2003) were mostly due (36.1%) to limitations (invisible colliders), lack of intuitiveness (clicking buttons), and lack of natural movements (match between headset and gamepad) during navigation. A second group of reasons were linked to the general experience (23.6%): when changing scenes, because of VR sickness or system malfunction, and because of the impossibility to suspend disbelief. Sensory realism (quality of textures, display, or modelling) also played a role in 13.9% of cases. Other participants were disturbed by noises in the external world or needing help from the researcher (6.9%), as well as by discomfort caused by the display (6.9%) or control (5.6%) devices. Finally, interaction (lack of interaction with objects and people) and content (not understanding the elements and/or scenes displayed) were mentioned respectively by 4.2% and 2.8% of participants.

Visual immersion and realism. In general, participants felt quite immersed in the experience (mean = 3.06 ± 0.923) and saw it as a positive contribution to the feeling of Presence. Visual realism, which had been

manipulated on purpose for experimental reasons, was both a positive and negative factor. Elements with a positive contribution corresponded, by order of importance, to the environment (sky, landscape, lighting conditions and dynamism of river, fires, birds, etc.—40.5%), the technology (immersion, embodied exploration, and depth—25.2%), the material culture (pottery, baskets, fireplaces, and many other objects showing a specific way of life—20.7%), the architecture (houses and building materials—9%), and the characters (presence of people making it a lively place—4.5%). Elements with a negative contribution corresponded, by order of importance, to technology (poor quality of textures—16.7%), characters (poor modelling—2.4%), the material culture (scarcity of objects—1.2%), and the environment (lack of/fake dynamism in clouds, sun, river, etc.—1,2%). These percentages need to be taken with precaution, as not all experimental conditions had objects and characters, whereas the environment, the architecture, and technology were present in all of them.

Auditory immersion and realism. Considering that only Conditions 5 and 6 had soundscape, 42% of participants did not feel surrounded by auditory aspects, and 10% considered the question did not apply. The lack of sound disrupted the participants' experience in 38.3% of cases. However, this negative influence was only mentioned if asked purposefully. This is coherent with the fact that some participants (8.6%) said they did not miss the sound, considered it was secondary, or even did not remember if there was sound. Yet, 4.9% of participants mentioned that sound would definitely improve the experience. One person also suggested adding user sounds, such as footsteps or wood noises when climbing up the ladder. In Conditions 5 and 6, the main elements contributing to realism were the sounds from animals (sheep, birds, and dogs—16%), human noises (conversations, chants, baby cooing—13.6%), noises resulting from tasks (4.9%), and environmental sounds (wind, fire—8.6%). A couple of people wondered about the language they were speaking (it was invented), and one person mentioned the directionality of sound as a positive aspect.

Input and output devices. Participants had some trouble with the gamepad during navigation (mean = 2.61 ± 1.213) but did not report explicitly on the reasons. However, we can extrapolate them from the relevant answers to breaks in Presence: lack of intuitiveness (clicking buttons) and natural movements (mismatch with headset) during navigation. Regarding the head-mounted display, participants provided mixed reports (mean = 2.39 ± 1.280). Visual realism, immersion, and real-time rendering were praised by some participants (13.8%) and criticised by others (20%). Other major problems were VR sickness (18.5%) and discomfort (12.3%). However, some participants (3.1%) said that eventually they became used to the head-mounted display.

Orientation. A total of 69% of participants reported feeling slightly or not at all disoriented within the virtual world. When users "got lost," it was due, by order of importance, to imposed, nonintuitive, or limited movements during navigation (44.7%); the complex configuration of the environment (31.6%); VR sickness (7.9%); the difficulty to make sense of content (7.9%); and the navigational mismatch between the head-mounted display and gamepad (7.9%).

Interaction. Interaction was restricted to navigation because this is the main modality currently found in most archaeological virtual reconstructions. Users felt they were very much in control considering that they could decide where to go, but they also felt very passive (Figure 4). Opinions about the naturalness and scope of navigation received neutral ratings (Figure 4), independently of the experimental condition. Yet, when asked what they would like to do, things changed completely: 26.5% of participants wanted total freedom of exploration, 25.6% wanted to be able to manipulate objects, and 19.7% wanted to interact with people. Other suggestions had to do with full-body or more natural interactions (7.7%); involving more senses (3.4%); and allowing activities closer to computer games (3.6%), such as performing daily tasks and role-playing. However, some people who experienced Conditions 1 through 4 took the chance here to express their dissatisfaction: 6.8% wanted to see people and daily life, 4.3% wanted to hear sounds, and 3.4% wanted to see material culture.

Human characters. Despite arousing interest, human characters affected users' behaviour only slightly (mean = 1.96 ± 1.476). The observations showed, and participants declared, that most of them approached to see the characters up close (40%) and some attempted interaction (20%), but very few felt connected to (12%) or avoided

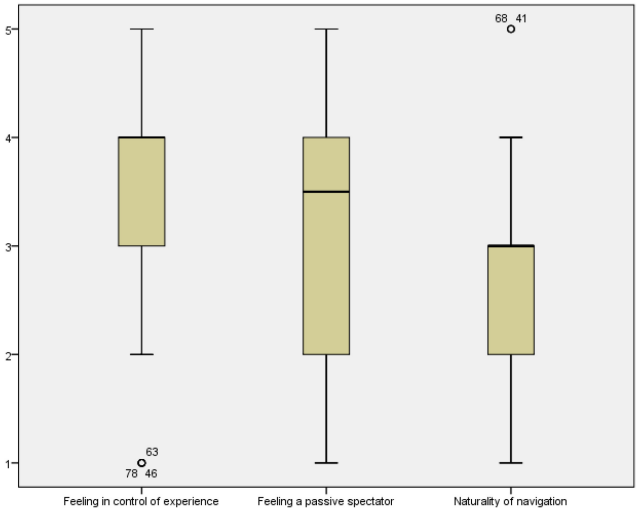

Fig. 4. Boxplots summarising users' self-reporting for different aspects of interaction. The Y axis corresponds to the Likert scale.

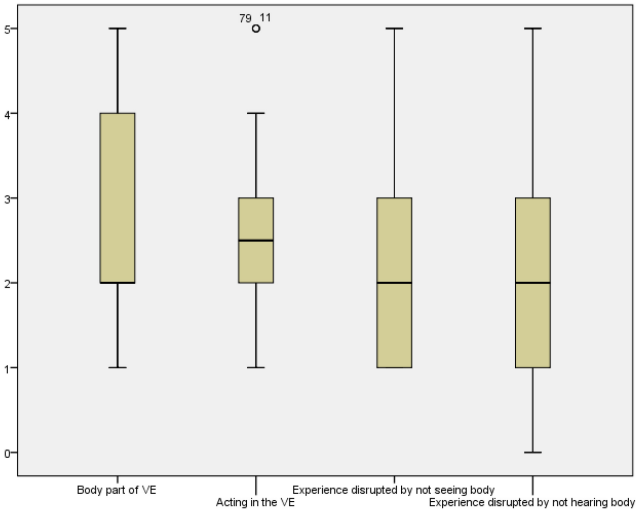

Fig. 5. Boxplots summarising users' self-reporting for different aspects of self-perception. The *Y* axis corresponds to the Likert scale.

running on them (8%). In 20% of cases, the virtual characters even hindered the experience because they were considered not realistic enough, either in terms of appearance or behaviour.

We also investigated several human factors. The first was *self-perception* (Figure 5). Participants reported feeling only slightly that their body was part of the virtual environment and that they were acting in it (instead of operating from the outside). The extent to which this disrupted the experience was very diverse, but in general users did not seem to have problems with not seeing or hearing their body in the virtual world.

The second human factor was *attention*. Users declared feeling quite absorbed by the VR-mediated experience and only sometimes distracted by the real world, the display device, or the control device (Figure 6). The

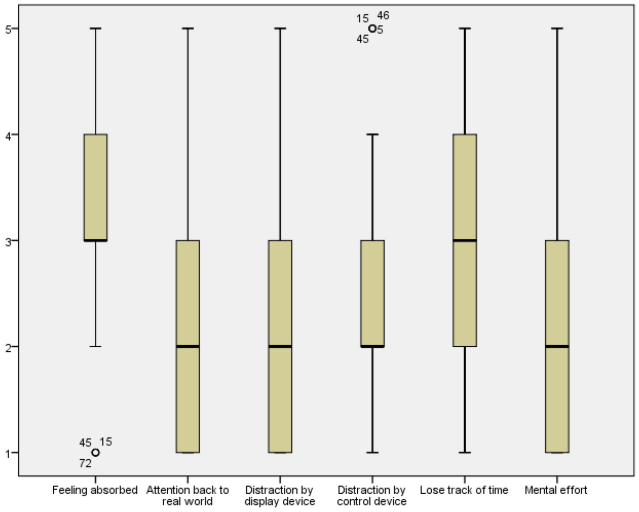

Fig. 6. Boxplots summarising users' self-reporting for different aspects of attention. The *Y* axis corresponds to the Likert scale.

main reasons for disruption were the following: need for external assistance for navigation or understanding of contents (19.1%), change of scene (19.1%), external noises (17.0%), nontransparency of mediation (14.9%), and VR sickness (10.6%). These results are consistent with previous results related to problems with hardware or breaks in Presence. Other human factors related to Presence are engagement and cognitive overload. In terms of *engagement*, participants declared a tendency to lose track of time (Figure 6). However, the environment did not require any significant *mental effort* from users (Figure 6).

Finally, we investigated the *emotions* awakened by the experience. On the positive side were interested (mean = 3.94 ± 0.868), having fun (mean = 3.80 ± 1.084), and excited (mean = 3.69 ± 0.974). We asked participants if there were other feelings they would like to report. Users mentioned expectation/intrigue (7.7%); understanding, meaningfulness, learning (5.1%); Cultural Presence (5.1%); and thrill (5.1%). On the negative side were dissatisfied (mean = 2.05 ± 1.498), disappointed (mean = 2.04 ± 1.046), and anxious (mean = 1.92 ± 1.1118). The first two came from the experience not fulfilling their expectations; the third was due to VR sickness. Other feelings mentioned freely by participants were VR sickness (23.1%), wanting more information (20.5%), frustration (15.4%), and "loneliness" (10.3%).

5.2 Bivariate Inferential Analyses

Bivariate inferential analyses aimed to respond to Research Question 2. Our goal was to look for significant differences in variables related to "experience" depending on the experimental condition. Given the nature of our sample (14 cases per condition) and variables (non-normal), we performed a series of tests, which included (1) Kruskal-Wallis (the nonparametric version of Analysis of Variance); (2) chi square test of independence with Monte Carlo permutation at 10,000 samples; and (3) visual inspection of mean graphs.

Kruskal-Wallis indicated (Table 2) that there were significant differences in means for auditory aspects and Conditions 5 and 6, and for variables related to human characters and Conditions 4 through 6. This is to be expected because these were the conditions endowed with soundscape and human presence. Three emotions had also significant differences in mean scores: feeling connected to characters in Conditions 4 through 6 (populated), feeling connected to events in Conditions 2 (objects) and 4 (still characters), and feeling self-satisfied in Condition 3 (interactive hotspots with text). It is important to note that in all three cases, the poorest scores always

Table 2. Significant Nonparametric Mean Tests (Kruskal-Wallis) for Variables Contributing to Cultural Presence by Experimental Condition

Variable	**df**	**Statistic**	**Sig.** (95%)
Auditory realism	5	39.397	0.000
Surrounded by auditory aspects	5	46.437	0.000
Control device interferes with navigation	5	13.048	0.023
Mental effort	5	11.895	0.036
Presence of people	5	26.017	0.000
Autonomous characters	5	18.279	0.003
Characters looked realistic	5	17.894	0.030
Characters behaved in a realistic way	5	19.209	0.020
Characters' presence affected behaviour?	5	20.370	0.010
Feeling connected to characters	5	13.793	0.017
Feeling connected to events	5	16.434	0.006
Feeling self-satisfied	5	10.293	0.067

Table 3. Significant Chi Square Tests for Variables Contributing to Cultural Presence by Experimental Condition

Variables	**df**	**Statistic**	**Sig.** (95%)
Auditory realism	25	57.855	0.000
Surrounded by auditory aspects	25	73.731	0.000
Control device interferes with navigation	20	29.977	0.065
Presence of people	25	64.180	0.000
Autonomous characters	25	44.840	0.006
Characters looked realistic	25	39.504	0.028
Characters behaved in a realistic way	25	37.167	0.048
Characters' presence affected behaviour?	25	39.737	0.025
Feeling connected to characters	25	36.278	0.058
Feeling connected to events	25	59.315	0.000
Feeling in control of the experience	20	37.169	0.010
Feeling passive	20	33.132	0.029

appeared in Condition 1 (architecture only). Finally, there were also significant differences for mental effort and for the control device interferes with navigation in Condition 5 (complex scenes of daily life plus navigation).

Chi square tests provided nearly or totally significant results for the same variables as the previous test (except feeling self-satisfied) and for two new variables related to interaction (feeling in control of the experience and feeling passive). Expectedly, auditory realism and immersion were linked to Conditions 5 (scenes) and 6 (narration), which were those with sound. Seemingly, all questions related to human characters scored higher in Conditions 4 through 6 (populated). In the case of emotions, there were two different situations: for feeling connected to characters, there was a clear opposition between Conditions 1 through 3 (empty) and 4 through 6 (populated); for feeling connected to events, participants declared a total lack of connection in Condition 1 (architecture only), a slight connection in Condition 3 (interaction with hotspots), and quite a strong connection in Condition 5 (daily life scenes). Participants also reported spontaneously on their emotions: frustration

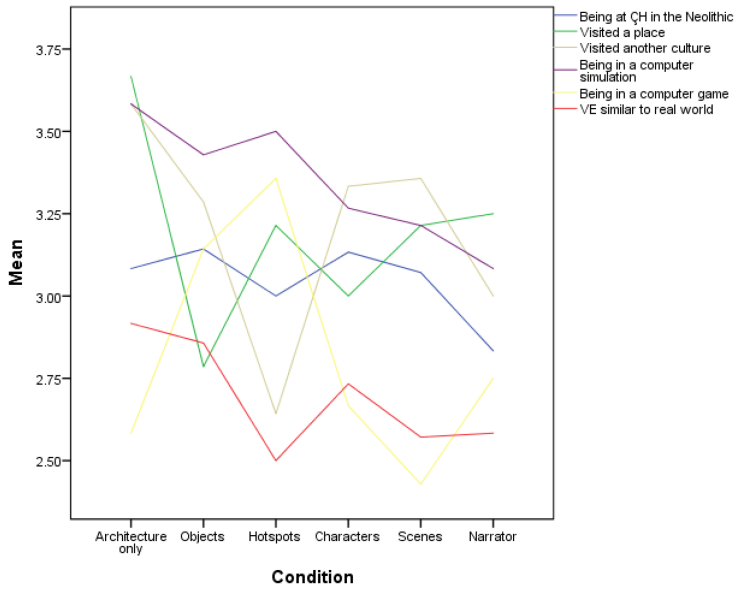

Fig. 7. Representation of mean values for variables defining the feeling of Cultural Presence in different experimental conditions.

and loneliness appeared mostly in Condition 1 (architecture only), understanding or learning appeared mostly in Condition 2 (objects), wanting more info appeared mostly in Conditions 4 and 6, sickness was the main aspect reported in Condition 3 (hotspots with text), and rejection towards the experience appeared in Condition 5 (dynamic scenes).

Continuing with the results of chi square tests, two variables were related to interaction. In the case of feeling in control of the experience, the clearest opposition was between Condition 3 (active search and activation of hotspots) and Condition 2 (navigation only). In the case of user activity, participants felt again more active in Condition 3 (interactive hotspots), neutral in Condition 2 (objects), and more passive in Conditions 4 through 6 (potential affordances for social and material interaction). Seemingly, the control device was perceived to interfere in Conditions 5 and 6 (complex scenes plus narration), whereas there was no problem in Conditions 2 and 3 (simple navigation and interaction).

The last type of bivariate analyses was based on the visual inspection of mean graphs. Even if there is no statistical significance, mean graphs always reveal interesting patterns.

We started with the main variables related with the feeling of Cultural Presence (Figure 7). Participants had a similar feeling of being at Neolithic Çatalhöyük in Conditions 1 (architecture), 2 (objects), 4 (characters), and 5 (scenes). Conditions 3 (hotspots) and 6 (narrator) scored low here, as well as in visiting another culture. The feeling of visiting a place was closely associated with Condition 1 (architecture). Condition 3 (hotspots) did well in the questions about ÇH3D as a computer simulation or as a game, indicating that participants spontaneously associated interaction with these kinds of virtual environments. Condition 1 (architecture) and Condition 2 (objects) were considered the closest to the real world, whereas Condition 3 (augmentation) scored the lowest. The opinions about Conditions 4 through 6 (populated) seem to be divided but clearly associated with visiting another culture.

Given the importance of the virtual environment, we also investigated the perception users had of it. The graph (Figure 8) shows that Condition 5 (populated, dynamic) was the most successful at generating the feeling of an independent, autonomous environment. However, augmentation (Conditions 3 and 6) disrupted the feeling

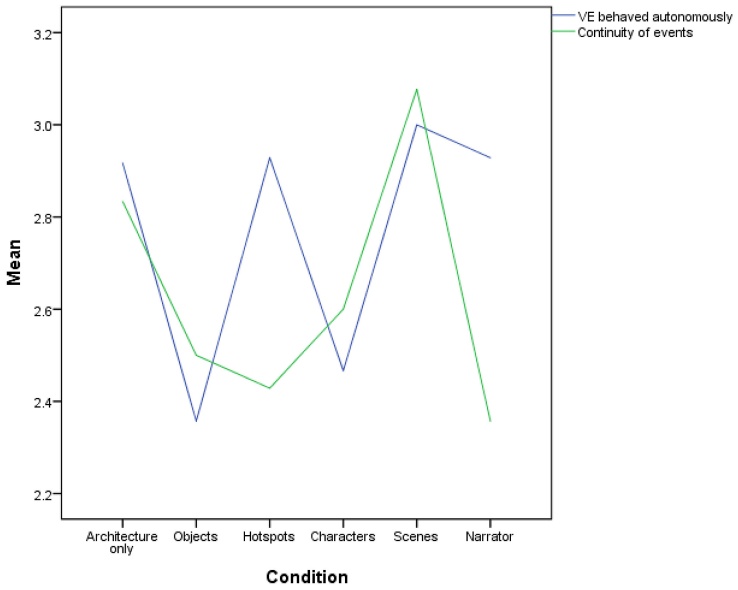

Fig. 8. Representation of mean values for variables linked to the realism of the environment.

of continuity. Condition 1 (architecture only) scored quite well in both autonomy and continuity, whereas the introduction of evidence of human activity (Condition 2) completely disrupted the feeling.

6 DISCUSSION

The statistical analyses, triangulated with observations, provided enough results to solve the research questions and verify the hypothesis.

Research Question 1: What are the design elements that constitute a VR-mediated experience? The overall impression about ÇH3D was almost equally divided between its experiential character (55%) and its communicational dimension (45%). Participants emphasised its educational potential but also manifested wonder. This was regardless of expertise, age, background, or type of virtual environment. Such results ratify many previous evaluations and surveys, which leads us to the conclusion that audiences' perception ("wow effect") and expectations (learning goal) about digital technologies/experiences in Cultural Heritage remain the same despite years of development.

The most important elements conferring an experiential dimension to the virtual reconstruction were the following:

1. Free, intuitive exploration of the environment and interaction with objects
2. Population by autonomous, responsive, realistic characters (both in terms of appearance and behaviour)
3. Previous knowledge and meaningfulness of content
4. Multisensory immersion and realism.

Research Question 2: What kind of current VR applications achieve a more experiential dimension? Architecture (Condition 1) was considered suitable to provide a sense of place but obtained the poorest scores in terms of engagement, emotions, understanding, and interest, indicating that purely architectural reconstructions do not connect with people. This would seem to conflict with participants emphasising the value of Condition 1 in terms of scientific validity. Seemingly, the introduction of objects (Condition 2) was considered sufficient for learning. This, in turn, seemed to contradict the participants' request of more explanations and declared lack

of understanding in populated versions (Conditions 4–6). Notwithstanding arising issues about transparency (Bentkowska-Kafel et al. 2012), this reflects, in our opinion, a dichotomic situation. On the one hand, there is what audiences accept, take for granted, or are used to because of cultural and contextual reasons: the association between photorealism and objectivity, as well as the superficiality of visual learning, which lie at the basis of most virtual reconstructions available to them. On the other hand, there is what audiences would like ideally and they express when the affordances are visible to them: unlimited spatial, social, and material interaction to achieve meaningful Cultural Heritage experiences.

Hotspots with text (Condition 3) were considered the most interactive, and looking for them to obtain information generated a feeling of self-satisfaction. Curiously enough, they were associated both with videogames and with simulations, which may be due to our participants' variable experience with digital technologies. But most importantly, textual augmentation reduced the feeling of Cultural Presence and was not perceived as enhancing learning. Populated virtual environments (Conditions 4–6), especially those displaying scenes of daily life (Condition 5), were considered autonomous, culturally representative, and helped establish strong emotional connections to events and people. However, static scenes (Condition 4), common in current virtual environments, were not enough to generate understanding. Dynamic representations of the culture (Condition 5) required mental effort (to make sense of the scenes) and generated a sense of passivity because affordances for social and material interaction were visible but not available. Finally, contrary to what we expected, storytelling (Condition 6) contributed to enhance curiosity but reduced the feeling of Cultural Presence, generated cognitive overload, and was considered to induce passivity in users.

Hypothesis: The more complete the reconstruction, the higher the feeling of Cultural Presence, regardless of visual realism. The results did not allow confirming the hypothesis of the study. If indeed there was a correspondence between the number of elements and the level of experience, we should have seen a progressive increase in the feeling of Cultural Presence from Condition 1 to Condition 6. Instead, we saw that different elements contributed differently to the overall experience. Architecture was sufficient to generate a sense of place and scientific authenticity, objects alone seemed to foster learning (based only on the participants' opinion), sensory realism was only a positive reinforcement, and human characters generated an overall feeling of verisimilitude but hindered social believability. The most important result concerned Conditions 3 and 6: hotspots with textual information reduced the feeling of Cultural Presence and were associated with videogames; narration reduced the feeling of Cultural Presence and augmented cognitive overload.

All of these elements were investigated by the publications presented in Section 2, and our study confirmed their positive role in the case of content meaningfulness, responsive characters, enhanced interaction, and multisensory realism. The sense of place was also confirmed, provided mostly by the architecture but also by the presence of human beings. In this sense, the virtual inhabitants of Çatalhöyük may not be convincing enough from the purely social perspective, but they contributed to enhancing the feeling of a dynamic, autonomous cultural environment. It was a matter of general verisimilitude rather than of strict simulational accuracy. However, our study refuted the results of previous investigations regarding the positive contribution of visual augmentation (Condition 3) and storytelling (Condition 6). Unfortunately, the role of social interaction and embodiment (or meaningful interaction) could not be empirically demonstrated (ÇH3D did not contain these possibilities), but participants expressed a clear desire to see them implemented in VR-mediated experiences.

The study also nuanced previous results about graphic realism, interaction, and content accessibility. Graphic realism was important, but more as a positive reinforcement than as a fundamental perceptual or learning aspect. In the case of dynamic scenes, users' reactions during exploration, as well as their comments in questionnaires, evidence that realistic depiction is not enough to understand other cultures, and some kind of explanation, is needed. In the case of perception, users seemed to accept the rules of technological mediation: they were able to overlook graphic photorealism, as long as it was not too obvious (e.g., poor textures). This is probably also the reason they did not miss sound or elements of self-perception too much but considered them a positive reinforcement. A similar situation happened with interaction. In this case, we found that the key was not the

invisibility of the medium (users accepted the rules of mediation) but rather intuitiveness/consistency of use (in our case, integration of the head-mounted display and gamepad), and above all, feeling of control. As for content accessibility, the questionnaires and observations brought evidence that understanding does not equate with interface usability, and that meaningfulness is equally (if not more) important.

7 CONCLUSIONS AND FUTURE WORK

Over the past years, Virtual Archaeology has introduced more experiential elements in virtual reconstructions as a means to enhance learning about the past. However, due to a lack of explicit theoretical frameworks and/or systematic evaluation focusing on such experiential elements, it is uncertain whether the intended goals are achieved and why. The LEAP project proposed a novel theoretical framework arising from the concept of Cultural Presence and used it to investigate this middle goal—that is, if and how current virtual environments achieve the feeling of travelling to the past. To that end, six different virtual reconstructions of the Neolithic site of Çatalhöyük (Turkey) were built and evaluated in a between-subjects experiment.

The main conclusion of this study is that users understand archaeological virtual reconstructions as a mediated experience and therefore do not expect absolute photorealism or transparent interaction. It is possible that in the case of general audiences, a "wow effect" (which is not found in experts and gamers) contributes to this leniency. Users also implicitly accept the association among architecture, photorealism, and objectivity. Yet, they definitely prefer meaningful social and material encounters with past cultures (not buildings). Therefore, VR-mediated experiences need to allow full material and social interaction within a dynamic, autonomous, populated environment; be fully pervasive (visual and auditory immersion); use comfortable and intuitive input and output devices; and provide clear, integrated instructions, affordances, and explanations to enhance exploration and understanding.

The contradiction between what users currently accept and what they would prefer should encourage the widening of goals and concepts in Cultural Heritage to include "new" elements such as embodiment (Schaper et al. 2018), Generic Learning Outcomes (Hooper-Greenhill et al. 2003), audience interpretation (Schofield 2014), identity, or awareness. Until now, most Computer Science and Cultural Heritage professionals have understood virtual environments as a purely communicational or instructional element. As a result, gesture-based interaction has used the user body as a cursor instead of allowing an embodied approach to the past. Seemingly, storytelling, game-based strategies, or exploration are aimed at retrieving information, not at simulating past cultures. In our opinion, the problem is not that it is still early in the adoption of technologies in Digital Heritage, but that they have reinforced a previous positivist concept of Archaeology and an informational goal of Cultural Heritage. As suggested by Hamilakis (2013) for Archaeology, only when we approach the past with our body and not with our eyes we will achieve meaningful (VR-mediated) experiences.

Our results indicate virtual environments aimed at the dissemination of the past should contain many audio-visual details that provide a general feeling of verisimilitude. In addition, they should be continuous in space and time, and offer intuitive and unlimited exploration with objects and characters. It is better to invest in interaction than in photorealism. If this is not possible, it is still more convenient to put efforts into displaying a wide range of material culture, dynamic characters, and the associated soundscape. All of these elements positively reinforce interest and motivation, which are ingredients of learning. However, goals, affordances for interaction, and navigation should be evident and intuitive so that the virtual reconstruction is self-contained. This does not advocate for pure simulation, because even in the real world, some sort of guidance is needed to facilitate exploration and understanding of a foreign culture. In this case, instructions and explanations should be an integral part of the virtual world/culture. Furthermore, teams need to design for meaningfulness (not only accessibility) and therefore find ways to establish links with the users' previous knowledge and interests.

The results presented in this article open the way for three future lines of investigation. Firstly, two versions were missing in the experimental conditions: full interaction with objects and characters, and role playing. These

were not included in this investigation because the goal was to understand the experiential character achieved by current archaeological virtual environments. But the validity of our findings regarding the variables that influence Cultural Presence should be tested in the future with these new conditions. To that end, an HTC Vive version of ÇH3D is under construction. Secondly, having verified the elements that contribute to VR-mediated experiences, we should test their effectiveness for learning. The apparent "tension" between augmentation and simulation will be further investigated and published in a forthcoming article devoted to the learning outcomes of each experimental condition. Finally, the complex perceptions that users had of the different experimental conditions (shown in the visual inspection of mean graphics) seemed to indicate that demographic variables may also play a role in the perception of virtual environments and in the feeling of Cultural Presence. This will also be extensively reported in a forthcoming publication.

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