A Tour in the Archaeological Site of Choirokoitia Using Virtual Reality: A Learning Performance and Interest Generation Assessment

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Abstract. A Virtual Reality (VR) application of the archaeological site of Choirokoitia has been designed and developed. The virtual reconstruction of the site simulates its current structure and is based on real data acquisition. The VR application allows the participants to virtually navigate through the archaeological site and acquire historical information for various important points of it. This study assesses the learning performance of the application's users and their interest for the topic. Findings demonstrated a strong significant improvement in learning performance of the users with the change in their interest following a bell-shaped distribution. This indicates that the developed VR application can be used as a teaching tool for Cultural Heritage purposes.

Keywords: Virtual Reality · Cultural Heritage · Virtual worlds
Virtual heritage · Learning assessment

1 Introduction

Preservation and promotion of Cultural Heritage (CH) sites are nowadays achieved also with the support of modern technologies. Towards this end, digital media are used for the digital reconstruction of archaeological sites and monuments [4] and dedicated terms, such as that of virtual archeology [13] and virtual heritage [3], exist in literature demonstrating the wide interest of the community about these topics. ICT technologies, such 3D visualizations, multi-touch surfaces, interactive multimedia applications have been widely used in the last years with topics related to Cultural Heritage. The most advanced technologies and usually those with a high cost of production are hosted in the place of interest, such as for example within the museums, while applications affordable and accessible to every day users are mostly limited, at least up to now, to standalone desktop, mobile devices and online applications.

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In a comparative study of interactive systems in a museum by Michael et al. [12], the authors evaluated the experience of young users with six in total (traditional or technologically supported) exhibits; a traditional exhibit, that was a traditional printed map, and five interactive ICT systems; a virtual tour projection, a multi-touch table application and three different augmented reality applications. They quantified high-level interaction qualities such as enjoyment, satisfaction and desire to perform again. They concluded that the experience scores top marks for the interactive ICT systems.

Virtual Reality (VR) is also one of the advanced technologies used towards this end. VR is used to immerse the user into a computer-generated world often resembling the real world, where he can explore and manipulate interactively the 3D environment [10]. The use of VR for entertainment reasons [8] is probably the most well-known amongst the general public and even though the educational use of VR is often overshadowed, interesting applications and studies covering these topics have been already demonstrated. Virtual Reality Learning Environments (VRLEs) simulate the real world through the application of 3D models that initiates interaction, immersion and trigger the imagination of the learner [9].

According to Roussou [14], the key issue of VR in Cultural Heritage is not only to visually represent, in a photo-realistic manner, places, monuments or landscapes that do not exist, never existed, or may not be easily experienced, but to present these in a meaningful and engaging way, to add the extra touch that will render the representation an experience. The suitability of VR for learning about archeology and the past in CH settings was investigated in a study [16], and results confirmed that VR systems allow a different kind of learning but also questioned the common believe about their advantage for children in comparison with other interpretation methods.

Loizides et al. in their 2014 study [11] compared the visit in two virtual museums (an engraving museum and a virtual Byzantine icons museum). In both cases users had the opportunity to visit the museum using either a Head Mounted Display (HMD) or a stereoscopic Powerwall. Overall, both technologies were considered a positive way to present 3 cultural heritage to individuals and the virtual reality has easy portability for remote setups.

A study by Zaharias et al. in 2013 [17], investigated the user experience (UX) and learning effectiveness of the "Walls of Nicosia", a 3D multi-touch table. Two groups of students participated in this empirical study: (a) The traditional group where students took a guided tour throughout the museum and learned about the walls of Nicosia through printed maps exhibited at the museum and (b) the virtual group where students interacted with the multi-touch application. Results showed no statistically significant differences in the learning performance but the virtual group reported user experience at significantly higher levels.

A Greek Cultural Heritage institution, the Foundation of the Hellenic World, has offered a variety of educational VR exhibits in its Cultural Center [6] that are very popular amongst the visitors. In some of these exhibitions, the visitors can conduct virtual experiments, assist an ancient sculptor to create a statue of the god Zeus, and walk through the ancient city of Miletus. In 2009, the Center

unveiled "Tholos" [2], a 130-person VR theater [7] in which the first productions have featured interactive tours of ancient Athens' agora (market).

A new era arrived this year for Virtual Reality; the first VR commercial headsets have launched for the public. VR is now accessible for everyone to use, not only for developers and researchers. This opens new doors for the Virtual Reality field, by giving the opportunity for everyone at his own space and pace to exploit the advances of Virtual Reality. Sites of interest that are not easily accessible by visitors, either due to distant location and mobility limitation or due to the structure of the site, are now virtually accessible by anyone who owns a low cost VR headset. Moreover, possible visitors located remotely, have the opportunity to experience the site virtually at first and travel to visit the site at place in case they assess due to their virtual experience that it is worth it.

The first aim of our study was the design and development of a Virtual Reality tour of Choirokoitia due to the fact that is one of the most important prehistoric sites in the eastern Mediterranean. Choirokoitia is a Neolithic settlement [1] located in the district of Larnaca, Cyprus. The excavated site of Choirokoitia is intact and includes all the attributes that express an outstanding universal value. Choirokoitia is included in World Heritage list of Unesco and was given enhanced protection status. It is a popular destination and there are organized school trips from all over Cyprus. The investigations of this study were two fold: (i) evaluate the user's learning performance and (ii) investigate whether their interest for the archaeological site increases due to the use of the VR application developed.

The following paper is organized in three sections: 'Materials and Methods' where adequate information is provided for the design of the study, 'Results' where findings of the data analysis are given and lastly a 'Discussion and Conclusions' section where the significance of the results are explored and ideas for future directions are described.

2 Materials and Methods

2.1 The VR Application of Choirokoitia

Excavations of Choirokoitia have shown that the settlement consisted of circular houses built from stone and mudbrick with flat roofs and that it was protected by successive walls. In order to reconstruct virtually the archaeological site as it stands in nowadays (Fig. 1), a visit to the actual site was made, and photos were taken from the site itself and the archaeological findings. The site has been digitally reconstructed, using 3D modeling, that was used within the interactive application. The user can navigate in the virtual Choirokoitia using a controller. He is allowed to virtually walk towards any direction (using the left joystick) and rotate the looking direction (using the right joystick) among the vertical axis. The developed application has been integrated with a VR Head Mounted Display (HMD) which allows the user to be immersed and observe the virtual site. With the support of HMD's tracking system the looking direction can be

Fig. 1. The archaeological site of Choirokoitia has been virtually reconstructed with accuracy on spatial locations of the houses (top) and with attention in structural details of the site (bottom).

also changed intuitively by the user, around any axis, by physically rotating his head.

In the virtual world there are six information points noted with an information blue sign (Fig. 2), in specific areas. When the user visits one of these points, a stereo audio recording is automatically played by the system. Each audio lasts about half a minute each and includes information about the specific area that is located. The information included in the audio recordings have been acquired by the information plates which exist at the real site.

2.2 Experimental Design

A within group experiment was conducted. Quantitative data were collected using two questionnaires. The first one was a pre-test questionnaire (PreQ) which contained three parts, one part for collecting demographic information (age, gender, education, computer use knowledge, previous VR experience), a second part for evaluating learning performance, which was a knowledge test (KT) regarding the archaeological site of Choirokoitia and a third part for assessing the participants' interest in visiting the real site and learn more about the CH of Cyprus.

The second was a post-test questionnaire (PostQ) containing three parts, one part evaluating learning performance once again, another part assessing the participants' sense of presence in the virtual world and lastly a part evaluating again the participants' interest.

Fig. 2. An information point, noted with the blue sign, near the entrance of the virtual archaeological site. (Color figure online)

The two parts of the test, testing the knowledge and the interest of the participants were identical in both, PreQ and PostQ. All the questions related to the interest and presence were measured with a 5-point Likert style questions. The knowledge test included 10 multiple choice questions with 4 choices each, related with the archaeological site of Choirokoitia. All the information for the correct answers is included in the audio clips played when the information points were visited. The presence questions that were used are based on the Slater-Usoh-Steed (SUS) presence questionnaire [15].

2.3 Materials

The VR system that was used for the experiment included the HMD Oculus Rift DK2 which was coupled with a positional tracker. The desktop computer used was equipped with an NVidia GeForce GTX 770 graphics card. A Speedlink Torid gamepad and stereo headphones were also used. The virtual site was created with the game engine Unity3D. The 3D models were created using the software Autodesk Maya and were textured using the pictures taken during the visit to the site. The audio clips played in the application were recorded and edited in Adobe Audition CS6.

2.4 Procedures

The participants were conducting the experiment one at a time. Upon arriving, participants were briefed about the study without providing any information that disclose its purpose. After that, they were asked to read and sign the consent form of the experiment. Then, they were asked to fill in the PreQ and were specifically instructed to answer all the questions carefully and to the best of their knowledge. After they completed the PreQ, they received written instructions about their task in the virtual place, the navigation controls, the information points and their available time. The Oculus Rift HMD and the headphones were fitted on each participant and the experimenter started the application. The exposure of the participant in the virtual environment lasted up to eight minutes. After the

completion of the eight minutes, the HMD and the headphones were taken out and the participant was asked to complete the PostQ.

2.5 Scenario

The participants were put in the VR application of Choirokoitia (Fig. 3). They were free to navigate anywhere they wished for up to eight minutes. They were instructed though that in the virtual world they would have to locate six information points, which were visually represented with blue information signs floating in specific areas of the archaeological site. When participants were close enough to one of these points, the corresponding recorded audio was played automatically and participants listened information about the specific area that they were looking at.

Fig. 3. A participant immersed in the virtual archaeological site of Choirokoitia. (Color figure online)

3 Results

In total 23 participants took part in the study from which 4 of them quited the experiment before its completion. Data collected from the remaining 19 participants were used for the analysis. The 4 participants who did not complete the experiment showed signs of motion sickness. This is an common issue of HMD technologies, which constitutes a subject of research [5]. The 19 participants aged from 18 to 46 years old with a median of 21. 11 of them were male and 9 female. The majority (15 out of 19) of participants were university students with all of the rest of them holding at least a higher education degree. A high percentage (84.2%) of the participants reported that they are using computers in a daily basis, but only 4 stated that they use Virtual Reality technologies one or more times a week. All of the participants apart from 2 had not previously visited the archaeological site of Choirokoitia. It was verified that the participants were hearing clearly the audio clips, with the information about the archaeological site, with a relevant question at the post-questionnaire with a mean 4.11, SD = .809 and a median 4.

3.1 Presence

Participants had a strong illusion of presence within the virtual site. This information was recorded at the PostQ by using four 5-point Likert style questions ($\alpha = .632$). The median for all participants used in the analysis, was 3.5 on a scale of 1 to 5, which indicates that the sense of presence was quite high.

3.2 Learning

The assessment of learning performance of the participants is based on the analysis of the knowledge test (KT). By having a look at the graph plotting PreQ and PostQ scores in KT (Fig. 4), it was obvious that the performance of most of the participants improved after their experience in the virtual world. 15 out of the 19 people who participated demonstrated an improvement in learning performance in the PostQ KT compared to the PreQ KT. The rest of the participants had the same score while no one had a reduced score. The mean score of the participants in the PreQ KT was 4.11 correct answers out of 10, whilst in PostQ KT increased to 6.84 correct answers.

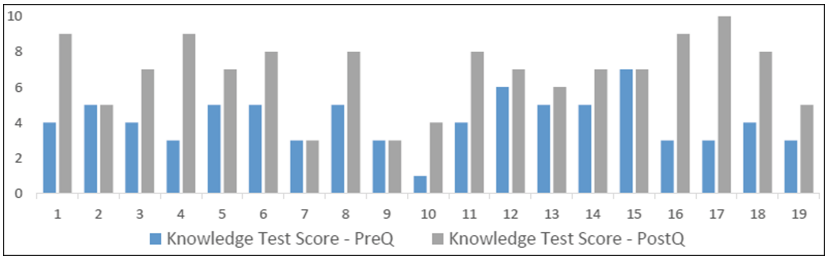

Fig. 4. Participant's scores in the pre- and post- knowledge test demonstrating an improvement in learning assessment.

A paired-samples t-test was conducted to compare the participants' score in pre-questionnaire and post-questionnaire knowledge test. There was a strong significant difference in the score in pre-questionnaire ($M = 4.11$, $SD = 1.370$) and post-questionnaire knowledge tests ($M = 6.84$, $SD = 2.035$); $t(18) = -5.468$, $p = .000$. This result suggests that the use of the VR application of Choirokoitia increased the knowledge of the participants about the archaeological site. However, the change in score of pre- and post- knowledge test has not been found correlated with the illusion of presence ($r = .014$, $n = 19$, $p = .953$).

3.3 Interest

Through the questionnaires we recorded the participants' interest in the Cultural Heritage before and after their virtual visit in Choirokoitia. The change in the

overall interest (post- minus pre- interest) of the participants are following a bell shaped distribution (Fig. 5). The interest of six participants was increased while five participants showed a decrease. For the remaining eight participants no change was occurred.

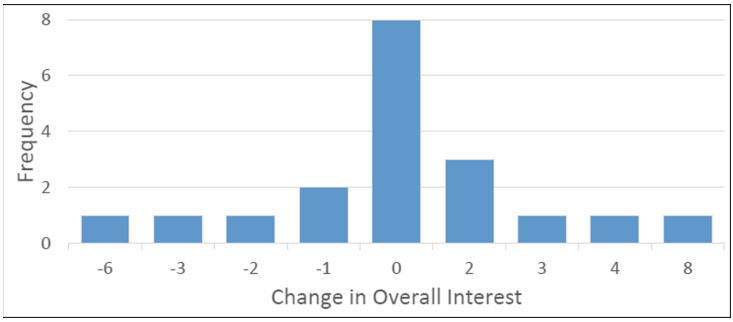

Fig. 5. Participants' change in interest after experiencing the virtual tour forms a bell shaped distribution.

To statistically compare the change in participants' overall interest in the CH of Cyprus, a paired-samples t-test was conducted. The overall interest for each participant was measured using the averages values from four questions; two regarding the interest in visiting and two the interest in learning about the archaeological site. There wasn't a significant difference in the interest assessed in the PreQ ($\alpha = .918$, $M = 3.6184$, $SD = 1.06839$) and the PostQ ($\alpha = .936$, $M = 3.7237$, $SD = 1.14229$); $t(18) = -.639$, $p = .531$. This result suggests that the virtual visit did not affect the participants' overall interest in CH.

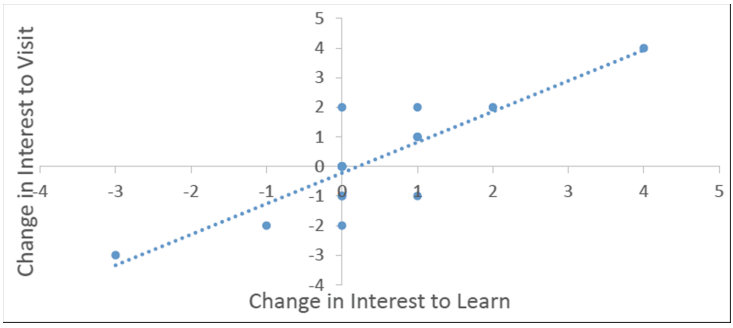

Fig. 6. Participants' change of interest in visiting and change of interest in learning about archaeological sites are linearly correlated.

We further investigated separately the change in interest in visiting archaeological sites and the change in interest in learning more about the CH by grouping

the two related questions for each analysis and by conducting paired-samples t-tests. None of these analysis demonstrated significant results. Neither the change of the overall interest has been found significantly correlated with the presence ($r = .342$, $n = 19$, $p = 152$). However the change of interest in learning and the change of interest in visiting archaeological sites have been found strongly correlated ($r = .835$, $n = 19$, $p = .000$) (Fig. 6).

4 Discussion and Conclusions

The aim of the study was to create a Virtual Reality application allowing a virtual tour of Choirokoitia and evaluating its contribution to learning performance of the participants and its impact on generating interest for the topic. The use of the Virtual Reality application of the archaeological site, demonstrated an improvement in learning performance of the users. The results show a high percentage of assimilation of the information by the participants, leading to the conclusion that it can be used as an alternative to traditional teaching method for CH. This can be exploited by educators, to convey information about remote sites to students, for places that are not accessible easily or are located in an isolate place. Moreover the VR application can be used for self education by the participants. However, safer conclusions about the learning performance will result from comparative assessments with traditional teaching methods and with other technologically supported ways of information presentation.

Ways of exploiting VR applications for the promotion of CH sites should be explored. Towards this direction, an aim is to achieve an increase in the interest of the participants in learning and visiting physically the archaeological site. This was not demonstrated through the results of the current study. A possible explanation for this is that all the information about Choirokoitia for which the participants assessed, was provided to the user through the audio clips played when visited an information point. Moreover, more knowledge was also gained through the observation of the visual representation of the site. We speculate that these led the participants to believe that all the knowledge that could be gained through a physical visit to the site, has been gained by their virtual visit, but this is not true. Ways that provide to the participants the feeling that more information could be explored should be further investigated.

In future studies, it will be also interesting to assess the user experience, the enjoyment and desire to use again the VR application. Serious games design principles could be incorporated in the development of the virtual tour contributing in satisfaction of use by the participant.

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