Extended Play at Faraday Museum

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ABSTRACT

Taking advantage of augmented reality technologies this paper proposes a solution to enhance human-machine interaction with museums. People are rarely able to manipulate objects in classical object-oriented exhibitions or when it is possible, they do it with constraints. Museums can use augmented reality technologies more often in a playful way to enhance interaction and deliver new content among their public. This project was created for Faraday Museum (FM) at Instituto Superior Técnico in Lisbon. In order to increase the amount of interaction inside and outside Faraday´s Museum exhibitions, we created and developed a gaming application that uses augmented reality technologies named *Extended Play at Faraday Museum*. Using this application, the user/player can learn content about real objects allowing her/him to interact with digital replicas of the original pieces. Our goal is to provide interactive experiences in Museums questioning the relationship between users/players and objects to understand if people connect more deeply with the available content and learn through the process of interacting with digital augmented content.

KEYWORDS

Augmented Reality;
Interaction Design;
Applied Gaming;
Player/User Experiences;
Museum Experiences.

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1. INTRODUCTION

Museums are eager to engage people in deeper ways in their exhibitions by using gaming technologies, virtual and augmented reality devices, robot guides, among other possibilities. The purpose of this paper is to present an experimental gaming experience named, *Extended Play at Faraday Museum*. This game takes advantage of augmented reality technologies in order to enhance the user/player experience of manipulating digital replicas of the original museum objects. The main goal of this research is to question if it is possible to cut or avoid some constraints in the relationship between visitors and museum artefacts with the usage of augmented reality devices. Making visitors feel like they are really engaging with the real objects presented at the museum, receiving knowledge about it in the process of playing the game, can help solving some interaction problems and enhance the overall player experience. Since the majority of time we are not allowed to touch museum artefacts due to their fragile structure or uniqueness this application aims to contribute to the field of gaming and interaction design applied to museums. We would also like to contribute to new forms of interactivity in museums. Peter Weibel once described the shift from the passive spectator to the active participant. According to this author,

> *"if there are any social aspects at all in modern art, then they must involve the spectator. We want to arouse the spectator's interest, to liberate him, to relax him. We want him to participate. We want him to seek interaction with other spectators. We want to develop together with him enhanced perception and action. A spectator who is aware of his power and tired of so many falsities and mystifications will be enabled to make his revolution in art and to follow these signs: act and cooperate."* (Weibel, 2007: 48)

2. BACKGROUND

According to ICOM (International Council of Museums),[1] "a museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment" (ICOM, online).

[1] http://archives.icom.museum/definition.html (accessed September 2018).

Chris Christou considers virtual reality as some type of a computer simulation where we find an environment to walk around objects and simulated people, commonly known as avatars (Christou 2010). Normally, this environment is a 3D replica of the real world, but we can also find imaginary spaces or building blocks games or sand boxes. One possible example of a 3D simulation of a real world was developed by Carvalho and Raposo in 2013. They developed a virtual reality replica with the purpose of simulating a museum cloister in Aveiro, Portugal.

Lanier (2017), founding father of a pioneer VR Company called VPL Research, considers, in his first VR definition, among many other dispersed in the book, *Dawn of the New Everything, A Journey Through Virtual Reality*, the field as "a twentieth-first-century art form that will weave together the three great twentieth-century arts: cinema, jazz, and programming." (Lanier 2017: 3) Virtual reality, as Lanier states in the above quoted book, is a powerful medium involving visceral sensations, haptic feedback and body perception and it contrasts with augmented and mixed reality. Following Lanier, we can consider that with virtual reality we can create new worlds and sensations to be explored in a first- or third-person perspective, this trend is common in gaming applications that take advantage of immersive strategies and technologies. In contrast, augmented reality is all about exploring and appreciating the real world in new ways. Pokémon Go[2] is a good example of merging the actual world with the digital one assembling, in a gaming space, real data with digital creatures.

Faraday Museum is already using some sort of Augmented reality. By using QR (quick response) codes they let the visitors learn more about objects that have those codes on them. However, the solution that will be presented is more than simple data acquired by pointing a Smart-phone to those codes. In the project *Extended Play at Faraday Museum* we will use augmented reality in the sense that our goal is not to merge immersive and hot virtual reality with headsets, gloves and other similar gadgets but more cold (McLuhan 2003 [1964]) and disembodied technologies like mobiles and tablets.

[2] https://pokemongolive.com/en/ (accessed September 2018).

In this sense we consider that mix reality would be a hybrid technology between virtual and augmented reality, allowing the user/player to be immersed in digital information, with the possibility to interact directly with it, without losing focus of the real world. Some work done by Birchfield *et al.* (2008) shows that it is possible to interact with the virtual object by using two external controllers with the aspect of glowing balls. Other authors, like the above quoted Jaron Lanier, consider that these days mixed reality is equivalent to augmented reality technologies, but we decided to also take into consideration the classical Paul Milgram (1994)[3] definition of a "virtuality continuum" between digital and real data to open the discussion concerning mixed reality in a broader perspective. In *Extended Play at Faraday Museum* we will use augmented reality to enhance human-machine interaction to further develop user/player experiences.

We can consider the usage of other technologies to enhance human-machine interaction in museums such as the robot guides presented in the New York Times article, "Let a Robot be Your Museum Tour Guide". As Carvajal (2017)[4] states, the author of the above-mentioned text, "a robot walking in a museum gallery, becomes its own exhibition, inciting curiosity and people´s imagination" (Carvajal 2017: online). This robot is available at the Museum of the Great War in France and it shows a screen where people can see how it was the military life in the trenches of the World War I.

Since the solution that we propose will be a game with some learning purposes it can be included in the category of a serious game. A serious game is a game that has as its main purpose teaching something about a certain concept. According to Alexiou *et al.* (2012) "these software applications aspire to bring into the world of learning, those elements of digital games that stimulate, immerse and engage players" (Alexiou *et al.* 2012: 1243-47). An example of a serious game is *Treme-Treme*[5] (Barreto *et al.* 2014) a game that teaches children, from 7 to 9 years old, how to survive

[3] http://etclab.mie.utoronto.ca/people/paul_dir/IEICE94/ieice.html (accessed November 2018).

[4] https://www.nytimes.com/2017/03/14/arts/design/museums-experiment-with-robots-as-guides.html (accessed September 2018).

[5] http://www.treme-treme.pt/en/treme-treme-pt (accessed September 2018).

in an earthquake and its aftershocks.

Other games were analysed during the process of creating a game for Faraday Museum with the aim of enhancing users or players interaction experience. *Parthenon Frieze*[6] is an online game with mini-games with mechanics such as dragging, solving puzzles, detecting differences between images and so on. Smithsonian American Art Museum's *Meet me at Midnight*[7] is a game where the narrative guides the player through the experience, in order to learn about three objects from the museum. This game design approach is structured, which means that the player can only go to where the narrative allows. *Rugged Rovers*[8] is a game where the player constructs a rover, placing its wheels where she/he wants in order to check how long it takes to travel with that setup. The gaming application *Blockworks: Recreation of the great London fire of 1666* uses Minecraft "to build a detailed virtual model of the 17th century London – and then burn it down" (Blair 2016). In this game the player can walk in London in 1666[9] when the fire took place. *Minecraft Infinity Project*[10] is a game that uses cooperation in order to build popular pieces of art. Finally, *Labours of Hercules* (Antoniou 2015) is a game that teaches about the myth of Hercules in a playful way. Players learn about the myth while they are playing the game in a structured design in which the player can only go to where the narrative allows. This is a game design option that we will not use in our gaming application *Extended Play at Faraday Museum*. In our case we can select objects randomly freely without a pre-determined order.

In terms of augmented reality applications, we can quote as our main guides some medical surgery usage of robots with the help of augmented reality (Aparicio 2012) which overlaps digital content with the real world in order to precisely know where veins are. *ATTech* (Chantzi 2013) was used to learn about specific biology content

[6] http://www.parthenonfrieze.gr/play (accessed September 2018).

[7] htttp://2.americanart.si.edu/exhibitions/online (accessed September 2018).

[8] http://www.sciencemuseum.org.uk/games-and-apps (accessed September 2018).

[9] htttp://www.museumoflondon.org.uk/discover/great-fire-1666 (accessed September 2018).

[10] http://www.biennial.com/minecraft-infinity-project (accessed September 2018).

with the help of image marks that showed 3D models of an embryo. *Augment*[11] is an application where the user can upload its specific content in order to show it to clients or friends. *Reblink*[12] is an augmented reality experience where users or players view specific portrait art, making the inside of the portrait alive with augmented reality help.

Location-based augmented reality game demonstrated by (Rubino 2015) is a game where the player plays pieces of the play differently if she/he is located in different museum rooms. Finally, we can quote the example of an augmented reality game teaching about boats inside the naval museum of Ílhavo (Costa 2013). This game detects if the player is at a specific location when she/he points the smart phone's camera to the correct place in the museum in order to show info about boats.

Fig. 1
One of Faraday Museum's Rooms and Gower-Bell telephone.

3. GAME DESIGN, METHODOLOGY AND DEVELOPMENT

The created application, *Extended Play at Faraday Museum*, is an augmented reality game for a public with 12 years old and up with basic Portuguese and English knowledge and skills. The augmented reality game asks museum visitors to create an object-oriented collection as a way to engage them in the available museum content. The player will be able in the future to choose up to 9 specific objects from the museum but to do so he needs to be in the room where the objects are in order to detect them with a mobile phone.

[11] https://www.augment.com/ (accessed September 2018).

[12] https://ago.ca/exhibitions/reblink (accessed September 2018).

However, now, in our stage of research it is only possible to select one object, which is the Gower-Bell telephone (fig. 1). If the visitor selects it the application will show information about the telephone and the possibility to play a mini game where she/he has to do mandatory things to earn stickers to her/his book collection of objects. Afterwards players can show it to their family and friends.

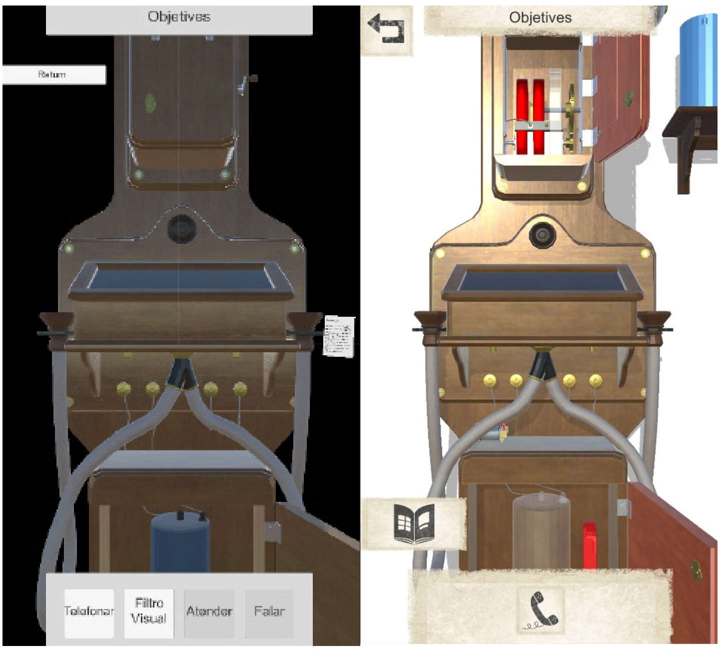

Fig. 2
Different stages of the game graphical interface.

In this first mini game, players should finish some missions about the Gower-Bell telephone. The first one is discovering why the object is not working properly. By using actions such as, grabbing, dragging, touching, zooming, listening and rotating they should find a missing object and introduce it into one of the telephone compartments (cf. fig. 2). This compartment has 3 magnets that produce electric energy if a lever is rotated and the player should put the third one in the correct place. Like that players will learn that in the past this was necessary in order to send an electric pulse to a telephone central for the operator to know that the person who rotated that lever wanted to dial again. After doing this challenge the player can try to call the digital phone but it still sends smoke from other places. Players need to find a microphone box and, finally, after exploring the Gower-Bell telephone doors and features players need to recharge a battery and "dial a number", in this case to click a button. To charge the battery players need to touch it five times but they finally solved the problem and can make a call with success and, if she/he does pick the earphones, a specific sound is played. With this mission accomplished the player can return to the book where she/he earned a special sticker connected to the Gower-Bell telephone (figs. 3 and 4).

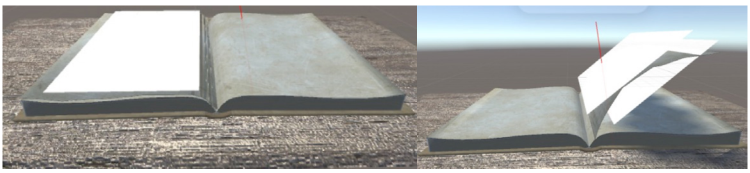

Fig. 3
Collectors book page animation

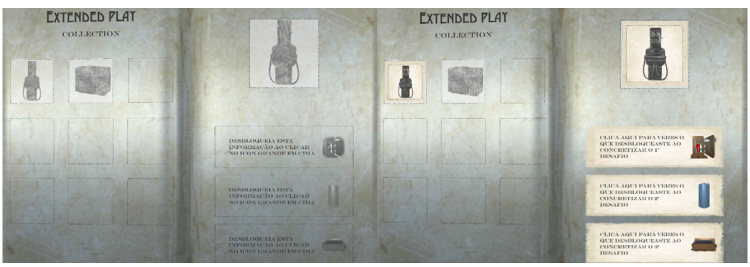

Fig. 4
Collection book - earned sticker in golden texture

The creation and development of the game application *Extended Play at Faraday Museum* had several implementation steps. The first one was to find the team of engineers and artists involved in the game creation. Two groups of people, from two different faculties, Instituto Superior Técnico (IST) and Faculdade de Belas-Artes (FBA), both from Universidade de Lisboa, were involved in the process of creating the gaming experience. The 3D work was made by Rafael Miranda, and the 2D graphic design was done by Camila Reis. The second step was to test diverse augmented reality APIs such as ARToolKit+, Kudan, Vuforia, ARCore e Wikitude. The next step involved several meetings with the artists and the museum curators in order to debate ideas and see if the development of the game was going according to the curator's ideas and concepts. Low fidelity 3D model prototypes were made in order to test game mechanics until one of the artists ended the 3D model. The next step was to show the game, still in development, at IST Alameda in the national museum's day at May 18th, 2018 in Portugal.

Few days after the national museum's day the game was tested in a public game's exhibition at IST-Taguspark with a cardboard replica (figure 5) made for the event. After that event some interface and interaction problems were solved considering the constructive feedback we received. Next step was to try different techniques to detect the player's location in relation to the position of where the 3D object will appear. In this phase we tested the use of image targets, multi-image targets, scanning real world objects and using CAD information to detect real world objects. For this purpose, we used the following software: Game Engine, plugins and APIs Game engine – Unity[13] using C# language; SDK – Vuforia.[14] The choice to use Vuforia was inspired by a study done by Marto (2017). For the creation of the 2D graphic interface environment we used Photoshop[15] and Gimp.[16] In terms of 3D Software, we used Blender[17] to make all the 3D objects, including the first prototype.

The development and implementation process took several steps. First, we did a low fidelity prototype where we could test mechanics such as grabbing the telephone doors and dragging objects to the correct places along with the first challenge that the player would face and the visual particles that would be used to send visual feedback of where the problems in the telephone reside.

The second stage was making the low fidelity interface in order to test it later in the public event (fig. 6) and knowing how to export it to an Android platform. Then, we exchanged the low fidelity telephone prototype into the final version made by the artist along with its textures (Color, Specular and Normals). We also ended mechanics concerning answering the phone along with the first version of particles to simulate electricity passing through places where it is supposed to pass and the sound that would pass in the earphones.

After the public event, we changed the in-game interface according to the feedback received in 28 usability and player interaction questionnaires (please cf. conclusions and future research for further information about this questionnaires) and we ended the beginning screen and the low fidelity collection book. This book has the

[13] https://unity3d.com/pt (accessed September 2018).

[14] https://developer.vuforia.com/ (accessed September 2018).

[15] https://www.adobe.com/pt/products/photoshop.html (accessed September 2018).

[16] https://www.gimp.org/ (accessed September 2018).

[17] https://www.blender.org/ (accessed September 2018).

tutorial in its two first pages and the player can turn pages left and right, finding different objects to play inside the museum (figs. 3 and 6).

Our next goal was altering the low fidelity visual interface with the final version, where the position of the interface is right, and finding a way to save data between scenes and even after the game has been turned off. This was made with the use of an XML file that has information about each object. This file can be changed by the museum curators if they need to do it without an external programmer.

Then, we started building the second challenge of the game and the final version of the collector's book by exchanging the low fidelity version by all the work done by the artists. We changed the visual aspect of the interface inside the telephone game and we ended the final version of the electricity, where we used 3D models to show an animated texture instead of a Bézier curve with particles.

Finally, we did the third game challenge and worked in code optimization like reducing the number of calls of certain expensive methods per frame. We proceed with visual optimization like having big images with different images inside it or having different images for each different image, in order to reduce draw calls, making a shadow catcher to simulate shadow in the museum wall. Since this is an augmented reality game, the 3D object will be overlapped with reality, since the real object is in a museum wall, this will turn the experience even more realistic.

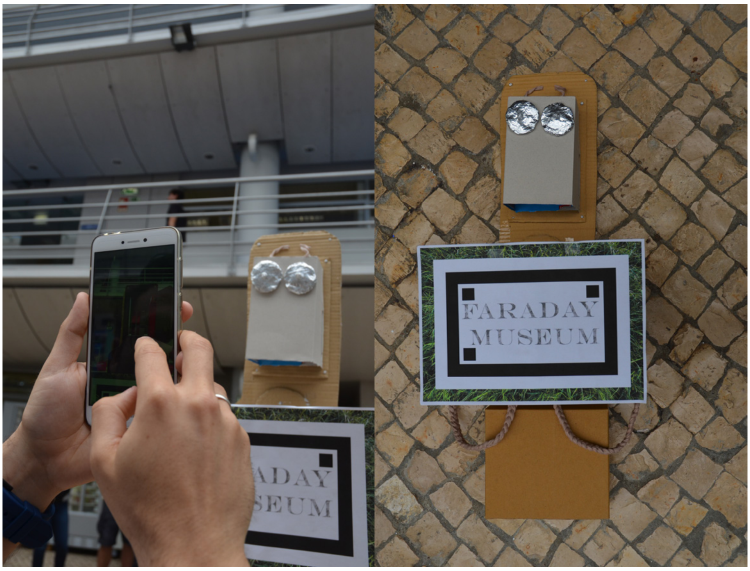

Fig. 5
Cardboard replica of the Gower-Bell telephone for usability tests at public game exhibition, May 2018.

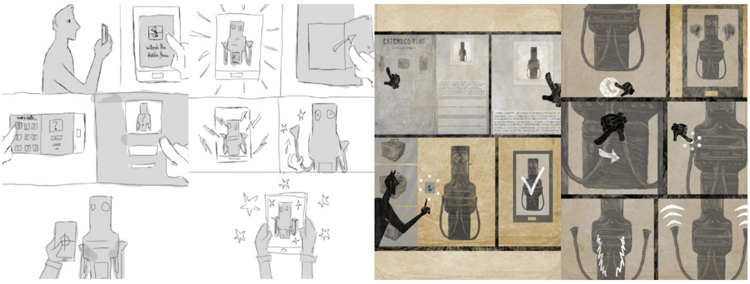

Fig. 6
Storyboards for the game tutorial animation.

A few months after the MOJO event, the game had a final test. This test involved 30 persons, 19 male and 11 female users/players. This test had the purpose of finding if the users/players felt a deeper connection with the Gower-Bell Telephone in terms of interaction. We also wanted to find if this game is a possible solution for acquiring knowledge about this object. In order to know if the interaction was good, a usability test was done. The usability test used was the UEQ.[18] This test evaluates the game in six dimensions, attractiveness, perspicuity, efficiency, dependability, stimulation and novelty. According to the authors of the UEQ, a positive value is > 0.8 for the mean, and if we watch the mean results, every scale was positive however, the perspicuity had a standard deviation of almost the mean value, and the confidence interval shows that this scale has a lot of values < 0.8. But the other results were good, the best one was the attractiveness, stimulation and novelty, which means that the users liked this game a lot.

Users were asked to make an auto-guided visit to the museum, specifically for the Gower-Bell telephone, in order to test if this game was a good way to teach information about this object. Then they had to fill five questions about the telephone. After this, the player would play the game and then, after playing it, she/he would answer the same 5 questions again in order to compare the acquired knowledge.

[18] https://www.ueq-online.org/ (accessed November 2018).

UEQ SCALES	MEAN	CONFIDENCE INTERVAL
Attractiveness	1,872 ± 0,603	1,657 to 2,088
Perspicuity	0,933 ± 0,912	0,607 to 1,260
Efficiency	1,367 ± 0,923	1,036 to 1,697
Dependability	1,317 ± 0,512	1,133 to 1,500
Stimulation	1,858 ± 0,694	1,610 to 2,107
Novelty	1,917 ± 0,744	1,651 to 2,183

Table 1
Usability test results

The questions were:

1. If you had this telephone at home, and lived in the 19th century, how would you dial to another person?
2. Where is located this telephone's microphone?
3. Does this telephone need any battery to work?
4. Is the battery needed to any component? if so, which one?
5. How can you answer the telephone?

The results were as shown in the table 2. "Before" means the number of users that answered correctly before playing the game. "After", the number of users that answered correctly. Finally, "Changes" means the difference between "Before" and "After"

QUESTION	BEFORE	AFTER	CHANGES
1	0%	77%	77%
2	10%	77%	67%
3	73%	93%	20%
4	13%	47%	34%
5	43%	90%	47%
MEAN	27.8%	76.8%	49%

Table 2
Knowledge acquired results

Even if some changes are low, for example, in questions three, four and five. This happens because the "Before" result was already high. So, it is also important to see the "After" column because it shows a great 76.8% of knowledge acquisition. The "Changes" also tell that the results were good because we had a 49% overall increase in acquired knowledge. Users' opinions about the overall experience were consistent, as one said, "The game revealed a level of interaction with the equipment that would be impossible (or rather unlikely) given its condition that, even if it were well maintained, would be impossible in real situations. I have to say that I enjoyed it, it is a promising and modest beginning that keeps your ideas not only in learning important pieces in the history of telecommunications but also, in its conservation for future generations of visitors."

5. CONCLUSIONS AND FUTURE RESEARCH

During the public game exhibition (MOJO), we did 28 users/player interaction questionnaires to evaluate user or player experience with the Gower-Bell telephone augmented reality application *Extended Play at Faraday Museum*. Ten female and eighteen male players fulfilled the questionnaires. Twenty players found the game easy to understand but eight found it difficult to manage. The majority of players said they would go more often to a museum if they could interact with similar devices. After that iteration it was possible to enrich the application to enhance users/players experience and to continue our technical research in terms of future achievements. The gaming application was also tested by the museum curators at Faraday Museum and in informal gatherings of higher education student groups. After these tests we did major and minor changes to the game and we did a final *in situ* game test at Faraday Museum. Users/players played the game while aiming with a smartphone to the real Gower-Bell Telephone. The results, in terms of interaction showed that the way the game presents the objectives to the player could be improved. However, players really liked the game, and everyone played it till the end without much effort. The results also showed that this game was a good solution for learning museum content, but we did not used other means of acquiring knowledge to compare with. In this context, the only conclusion we can get is that this is a possible solution to acquire museum content in a playful way. Users opinions and observations also demonstrated that this was a good solution to interact with an object in a museum environment. The development of this game will be continued, and it is predicted that it will have more 8 objects to interact inside the museum with different ways of interacting with them. It might be possible to take photographs with the augmented reality system and use the game at home after acquiring the object inside the museum in users/players smartphones. It is important to say, that this is a starting point to be extrapolated to other museums.[19]

[19] Final video presentation available here: https://youtu.be/sCwpNK1iZfo (accessed November 2018).

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