# Extended Play at Faraday Museum

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**Abstract**

Taking advantage of augmented reality technologies this paper describes 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 constrains. 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´s 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 FM. 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 interaction 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.

## 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[13] once describe 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).

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

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

2010)[5]. 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[12].

Lanier[8] (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 and mixed reality are 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[10] (McLuhan 2003 [1964]) and disembodied technologies like mobiles and tablets.

In this sense we consider that mix reality is 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 (Birchfield et. al 2008)[6] shows that it is possible to interact with the virtual object by using two external controllers with the aspect of glowing balls. In Extended Play at Faraday Museum we will use augmented reality to enhance human-museum object interaction to further develop user/player experiences.

We can consider the usage of other technologies to enhance human-museum object 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[3] 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)[1] "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[11][4] (Barreto et al. 2014) a game that teaches children, from 7 to 9 years old, how to survive 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[5] , it's an online game with mini-games with mechanics such as dragging, solving puzzles, detecting differences between images and so on. Smithsonian American Art Museum: Meet me at Midnight[6] , it's 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[7] , it's 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[8] "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 when

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

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

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

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

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

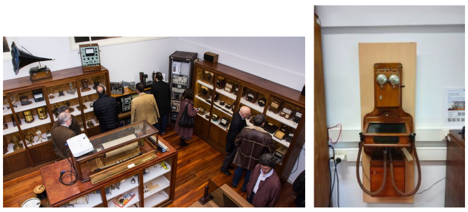
[7] http://www.sciencemuseum.org.uk/games-and-apps (accessed September 2018)

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

the fire took place. Minecraft Infinity Project[9] is a game that uses cooperation in order to build popular pieces of art. Finally, Labours of Hercules[3] (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[2] (Aparicio 2012) which overlaps digital content with the real world in order to precisely know where veins are. ATTech[4] (Chantzi 2013) was used to learn about specific biology content with the help of image marks that showed 3D models of an embryo. Augment[10] is an application where the user can upload its specific content in order to show it to clients or friends. Reblink[11] it's 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) [7] 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) [9]. 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.



(a) A Faraday Musuem room (b) Telefephone Gower-Bell

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

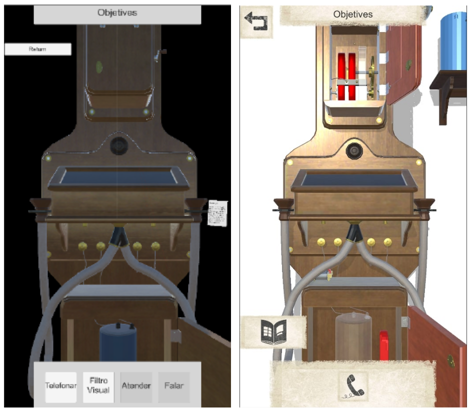
[9]http://www.biennial.com/minecraft-infinity-project (accessed September 2018)

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

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

## 3. Game Design, Metodology and Development

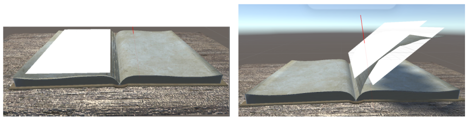
The created application, Extended Play at Faraday Museum, is an augmented reality game for a public with 12 years old and up with basic Portuguese (English option in the future) knowledge and skills. The augmented reality game asks museum visitors to create an object-oriented collection as a way to engage 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. 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.




(a) Before (b) After

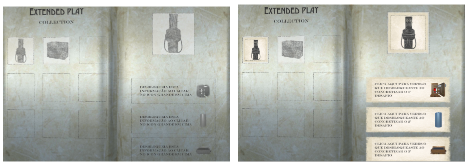
Figure 2: Different stages of the game graphical interface.

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).



(a) Telephone button (b) Smoke particles

Figure 3: Collectors book page animation




(a) Telephone button (b) Smoke particles

Figure 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 Belas Artes University and IST, were involved in the process of creating the gaming experience. The 3D work was made by Rafael Alexandre Lopes Miranda, and the 2D graphic design was done by Camila José Bettencourt da Silva Barros. The second step was to test diverse augmented reality platforms 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. For this purpose, we built a video presentation available on YouTube[12].

Few days after the national museum's day the game was tested in a public games exhibition with a cardboard replica (figure 5) made for the event.

[12]https://www.youtube.com/watch?v=icJ8lwK5fLc &feature=youtu.be (accessed September 2018)

During the public game exhibition we did 28 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 questionnaire. 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 event some interface and interaction problems were solved considering the constructive feedback we received.

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.

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 SDK´s Game engine – Unity[13] using C# language; Plugin – iTween, used to make Bezier curves with nodes in the 3D world to translate a particle system along its line; SDK – Vuforia[14] , was the augmented reality platform, unity compatible, used, in order to make the game.

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. 5) 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

[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).

and Normals). We also ended mechanics concerning answering the digital 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 and we ended the beginning screen and the low fidelity collection book. This book has the 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 Bezier curve with particles.

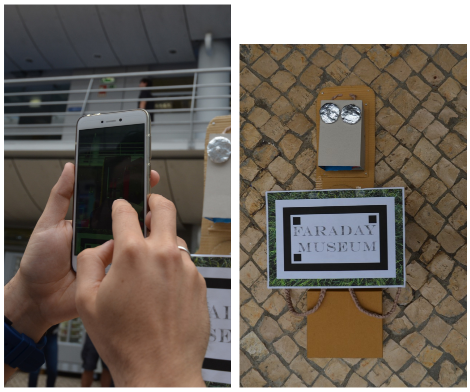
Finally, we did the third game challenge and worked in code optimization like reducing the number of calls of certain expensive methods per frame.

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 the reality, since the real object is in a museum wall, this will turn the experience even more realistic.

## 4. Results

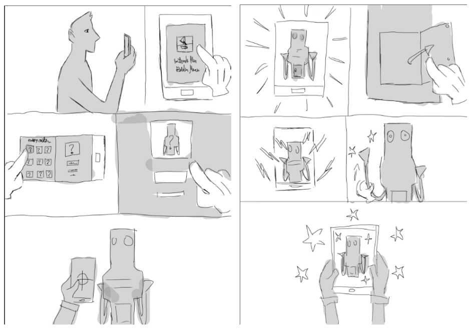
A few months after the MOJO event, the game had a final test. This test involved 30 persons, 19 were masculine and 11 were feminine. From this group, 15 had age in the range between 18 and 25, 9 had more than 50 years, 1 between 35 and 50 years old and 5 had age between 26 and 35 years. Every user filled Two questionnaires, the first one was to test the knowledge acquired and some personal opinions about this game. The second was a usability test.

In the middle of the time in which the game was being tested, it was decided to make some changes according to the feedback obtained from the first 21 users, because almost every user told that the visual feedback was no very clear.




(a) Telephone button (b) Smoke particles

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



(a) First page(Before) (b) Second page(Before)

(c) First page(Final) (d) Second page(Final)

Figure 6: Storyboards for the game tutorial animation

These problems were, not knowing when it was possible or not to drop the component in the right place,in order to solve this, when the player is dragging the component, if it turns greenish,as shown in the fig. 7 it means that he can drop the item.

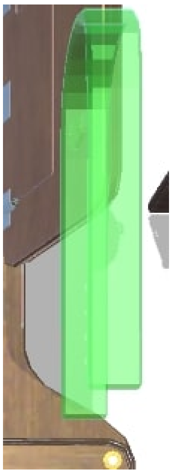


Figure 7: Visual feedback

Another problem was that it was not obvious where the object was supposed to stay. This problem was solved by putting the same object that was supposed to stay in that place, transparent,as shown in the (fig. 8) this way the user can see that it is missing.

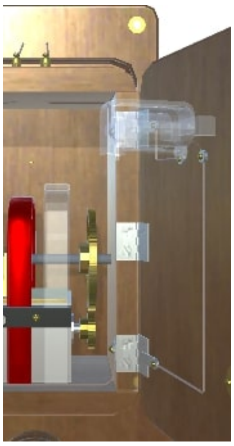


Figure 8: Transparent visual feedback

Another problem that arouse was when info appeared in the screen, some of the users did not know how to make that information go way(the way it went away was by clicking in any point of the screen), so in order to solve that a X button,shown in the (fig.9) was inserted in the interface, and now the information goes away only if it is clicked in the X.

The next problem solved was how the user knew which components he could interact with, it was already implemented a color animation in these components, however the subtle change in color was not enough, so in order to solve this a more blunt approach was implemented, like changing from the object color to red as shown in the (fig. 12).

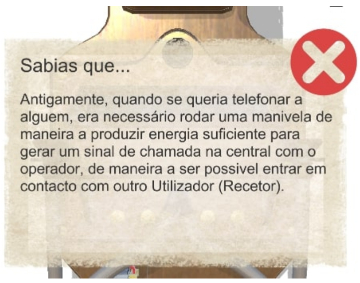
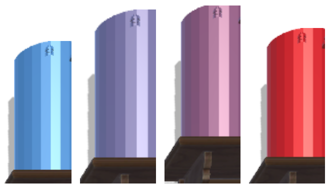



Figure 9: X Button added to info



(a) (b) (c) (d)

Figure 10: Possible to interact animation

Another problem that was seen, was the fact that the users did not know what to do in the beginning of the game. The objective here was only one, clicking on a button, however, the users did now find that button, so in order to force the attention to that specific place, the background was darkened as shown in the (fig. 11).

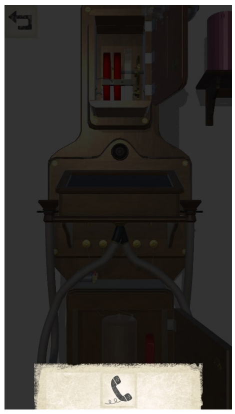
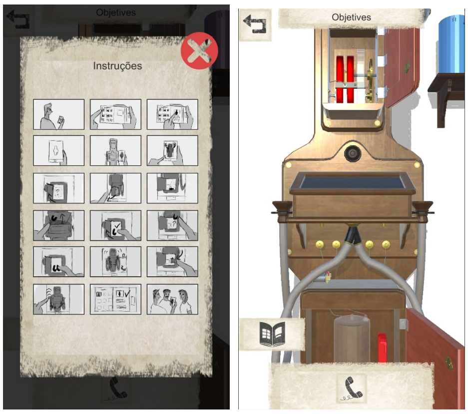


Figure 11: Background darkened

The final problem that was solved was changing the purpose of the button with a book icon. Every user that clicked there thought that it was an instruction menu, but the initial purpose was to return to the Book menu, so, the change was exactly putting what the users were after, shown in the (fig.

12(a)). And to return to the book another button was introduced(top left corner of (fig. 12(b))




(a) Instructions (b) Return Button Top Left corner

Figure 12: Instructions and the return button

After these changes, the last 9 users that used the game played really well without the same issues of the first 21 users.

### 4.1. Knowledge Acquired

In order to test if this game was a good way to teach information about this object, it was asked the users to make auto-guided visit in the museum, specifically for the Gower-bell telephone, then fill 5 questions about the telephone. After this, the player would play the game and then after playing it, he would answer the same 5 questions again in order to compare.

The questions were,

1. If you had this telephone at home, and lived in the XIX 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 u answer the telephone?

The results were as shown in the (tab.1), where Before means the number of users that answered correctly before playing the game, the After has the number of users that answered correctly and the Changes had the difference between Before and After.

Even if some changes are low, for example in the question 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

Table 1: Knowledge questionnaire results

| Question | Before | After | Changes |
|---|---|---|---|
| Question 1 | 0% | 77% | 77% |
| Question 2 | 10% | 77% | 67% |
| Question 3 | 73% | 93% | 20% |
| Question 4 | 13% | 47% | 34% |
| Question 5 | 43% | 90% | 47% |
| Mean | 27.8% | 76.8% | 49% |

Change´s mean results also tell that the results were good because we had an 49% overall increase in knowledge acquired.

### 4.2. User Opinion

After the knowledge questionnaire, it was asked some opinions such as the following,

1. How much desire do you have to visit more museums with this kind of technology?
2. What is your opinion about the utility of this kind of interactive technology in museums?
3. What is your opinion about the use of this technology in order to comprehend and interact with the object?
4. What is your opinion about your experience with this game?

Table 2: Results of the user opinion questionnaire

| Ascendent Value | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Question 1 | 0 | 0 | 0 | 2 | 10 | 6 | 12 |
| Question 2 | 0 | 0 | 0 | 1 | 2 | 9 | 18 |
| Question 3 | 0 | 0 | 0 | 1 | 1 | 4 | 24 |
| Mean | 0 | 0 | 0 | 1.33 | 4.33 | 6.33 | 18 |

In the (tab. 2) it is great to see that the values 1, 2 and 3 were not chosen, and the great majority of the users chose the values of 6 and 7, which is a positive indicator that the game has aroused interest in them.

The answers of the fourth question were, in the majority, positive and constructive feedback, like the following answer,

> ”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”

This feedback almost answers to the problem of this thesis which is the lack of interactivity between man-museum objects. And the rest of the users also answered something similar.

4.3. Usability test

The purpose of this usability questionnaire was to test this game in terms of its Attraction(If the public likes the product or not), Transparency(If its easy to understand how the product works), efficiency(If the user can solve the tasks without much effort), control(If the user feels in control of the product), stimuli(If the game is fun, exciting and motivating) and innovation(if the game is creative and can attract the user´s interest).

The values of the results are between -2 and 2. Values superior to 0.8 shows a positive evaluation[18].

Table 3: Scales´s confidence interval and means

| UEQ Scales | Mean | Confidence Interval |
|---|---|---|
| Atractiveness | $1{,}872 \pm 0{,}603$ | 1,657 a 2,088 |
| Transparency | $0{,}933 \pm 0{,}912$ | 0,607 a 1,260 |
| Efficiency | $1{,}367 \pm 0{,}923$ | 1.036 a 1,697 |
| Control | $1{,}317 \pm 0{,}512$ | 1,133 a 1,500 |
| Stimulation | $1{,}858 \pm 0{,}694$ | 1,610 a 2,107 |
| Innovation | $1{,}917 \pm 0{,}744$ | 1,651 a 2,183 |

The results in the (tab. 3) show that every scale had a positive evaluation, however a 0.933 value with a deviation of 0,912 for transparency shows that the game can be greatly improved in that area because it shows that we cannot take into account this result, and the confidence interval shows that 95% of the results are between 0.6 and 1.2 which means that some values are behind 0.8 which is the value of reference for a good result. To test if the answers of the each scale are consistent, Cronbach´s alpha coefficient and Guttmans´s lambada were calculated, and the results are shown in the (tab 4).

Table 4: Difference between both methods

| Scales UEQ | Alfa | Lambda |
|---|---|---|
| Attractiveness | 0.84 | 0.83 |
| Transparency | 0,84 | 0.84 |
| Efficiency | 0,80 | 0.79 |
| Control | 0,21 | 0.22 |
| Stimulation | 0,67 | 0.71 |
| Innovation | 0,51 | 0.57 |

The results demonstrate that the scale Control and innovation have user answers that are not consistent, since the alfa/lambda is inferior to 0.7 which is a rule of thumb used. This indicates that the Control and innovation scale results shown in the (tab 3), can not be taken into account very seriously, which is a bad result because the innovation had a great mean overall of 1.872. On the other hand, the Transparency which has a inferior result of 0,933 has a great alfa/lambda of 0.84, meaning that the answers of that scale can be trusted.

Overall the result was good, since only 2 scales have a bad alfa/lambda result and 1 inferior result in the mean/deviation/confidence table which means.

4.4. Results Conclusion

In conclusion, in terms of knowledge acquisition, this game has improved it considerably considering that most of the users responded correctly to the questions, obtaining an average of more 49 % of correct answers. The initial average, demonstrated in the (tab.1), of correct answers was 27.8 % and after playing the game that average increased 49 % to 76.8 % after. According to the results obtained in the usability questionnaire, the game was quite attractive, innovative, stimulating, efficient also making the user feel in control of the application. However the game could be more transparent in terms of knowing the goals (which was improved in the second phase of testing). Regarding the main question, on whether people were able to interact with the digital replica of the object similarly to what they might have actually done if allowed to the real object, it was possible to verify that from the questionnaires answered by the users, they felt that they were able to interact with the telephone in a positive way in the process. It is possible to conclude this by taking into account the number of people, 80 %, who selected the maximum value of 7 and 4 selected the value 6 of the questionnaire making a total of 93 % of very positive responses. In addition, what was observed was that users really enjoyed interacting with the digital replica, however, this interaction was greatly improved after the changes that were made at the end of the first phase of the tests, and it was observed during the second phase of tests that the 9 users who experienced the game after the changes, had a much higher performance than the first phase, making them able to feel that they were interacting with the digital replica like the real one. Furthermore what the 30 users wrote about their opinion about the interaction revealed that they really felt they were interacting with a museum´s object.

## 5. Demonstration of the final game

To see the full demonstration of the game please go to the link[19] where it will show a Youtube video.

## 6. Conclusions and Future Research

The purpose of this project was to solve the interaction problem between user-museum object, and in order to solve this problem, a augmented reality game was used. After the first public test in the MOJO event, 20 players found it easy to interact

[18] https://www.ueq-online.org/

[19] https://youtu.be/sCwpNK1iZfo

and 8 difficult. By having the visual results and user opinion, the game was enhanced in order to solve the problems pointed by them. After the second public test(this time inside the museum), the results demonstrated that there was 0 users that disliked the application, the users were also from a great range of ages from 18 to 50 and beyond. And the results for the 50 and beyond was great, they did not have that much skill, but handled the game tasks really smooth. The other users also had similar comfort using the game. So in terms of interaction, it was a good result. Some users felt that they were really interacting with the real object, and learned a good amount by playing the game, the information retention after playing the game was 76.8% and before playing it was 27.8%. However, the game can still be enhanced in terms of visual feedback because 2 persons still had some doubts of what to do in certain tasks.

The next step of this game is making more minigames associated to objects, some of this games, can contain fun ways of seeing the objects, for example, pointing the telephone to an object an see its interior. Every object, after finishing the mini game in the museum, can use augmented reality in their house to show to their family and friends. The collection book can have a zoom implemented, because this was something that the users wanted to see in the game.

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**References**

[1] Andreas Alexiou, Michaéla Schippers, Illan Oshri. "Positive Psychology and Digital Games: The Role of Emotions and Psychological Flow in Serious Games Development". *PSYCH Journal*, pages 1243–47, 2012.

[2] Andrés Aparicio, Francisco Vela, José Sánchez, José Montes. Analysis and application of gamification. *Proceedings of the 13th International Conference on Interacción Persona-Ordenador. ACM*, 2012.

[3] Angeliki Antoniou, Jamie O´Brien, Tiphaine Bardon, Andrew Barnes, Dane Virk. Micro-augmentations: situated calibration of a novel non-tactile, peripheral museum technology. *ACM Proceeding of the 19th Panhellenic Conference on Informatics*, 2015.

[4] Athanasia Chantzi, Charikleia Plessa, Lason Gkanas, Dimitrios Tsolis, Athanasios Tsakalidis. Design and Development of Educational Platform in Augumented Reality Environment using Gamification to enhance Traditional, Electronic and lifelong Learning Experience. *Local Papers of the Balkan Conference in informatics In http://ceur-ws.org/Vol-1036/ Education (accessed November 2018)*, 2013.

[5] Chris Christou. Virtual Reality in Education. *ResearchGate In https://www.researchgate.net (accessed November 2018)*, pages 228–243, 2010.

[6] David Birchfield, Brandon Mechtley, Sarah Hatton, Harvey Thornburg. Mixed-Reality Learning in the Art Museum Context. *Proceeding of the 16th ACM international conference on Multimedia*, 2008.

[7] Irene Rubino, Claudia Barberis, Jetmir Xhembulla, Giovanni Malnati. Integrating a Location-Based Mobile Game in the Museum Visit: Evaluating Visitors Behaviour and Learning. *ACM Journal on Computing and Cultural Heritage*, Volume 8 Issue 3, 2015.

[8] Lanier, J. Dawn of the New Everything, A Journey Through Virtual Reality. *The Bodley Head, London*, 2017.

[9] Luís Costa. A realidade aumentada aplicada ao conceito de caderneta de cromos. *https://sigarra.up.pt (accessed November 2018)*, 2015.

[10] McLhuan, Marshal. Understanding Media, the Extensions of man, (ed.: by W. Terrence Gordon). *Ginko Press, Corte Madera, CA*, 2003.

[11] Pedro Barreto, Rui Prada, Pedro A. Santos, Mónica Amaral Ferreira, Hugo O'Neill, Carlos Sousa Oliveira. Treme-treme - A serious game to teach children earthquake preparedness. *Proceedings of Videojogos 2014 - Sétima Conferência de Ciências e Artes dos Videojogos,Portugal*, 2014.

[12] Ruben Carvalho, Rui Raposo. Proposta de uma visita virtual 3D ao claustro do museu de Aveiro. *Ria, Repositório Institucional da Universidade de Aveiro. In https://ria.ua.pt(accessed November 2018)*, 2013.

[13] Weibel, Peter. It is Forbidden Not to Touch: Some Remarks on the (Forgotten Parts of the) History of Interactivity and Virtuality. *I In MediaArtHistories. Ed.: Oliver Grau. Cambridge, Mass.: MIT Press*, 2007.