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ENHANCING THE VISITOR EXPERIENCE IN MUSEUMS WITH AUGMENTED REALITY
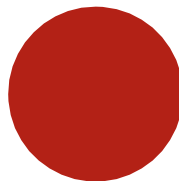
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Enhancing the visitor experience in museums with Augmented Reality

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Abbreviations and Symbols

AR   Augmented Reality

UX   User Experience

VR   Virtual Reality

MR   Mixed Reality

QR   Quick Response

Zé Book Book with the title "Zé do Saco, o Contrabandista"

Tables & Figures

Resumo

As chamadas experiências desenvolvidas para todos os públicos não se enquadram adequadamente a todas das pessoas que visitam os museus. Esta investigação demonstra a necessidade de adaptar as experiências de acordo com o público-alvo que um museu tenciona atrair. Os adolescentes são por norma os mais prejudicados porque os museus fazem uma segmentação clara entre os seus visitantes: crianças e adultos. Ao mesmo tempo, estudos demonstram que esta faixa etária é a mais desinteressada em relação ao que os museus têm para oferecer.

Este projeto ambiciona solucionar este problema providenciando diretrizes aos profissionais que trabalhem em museus. Estas diretrizes potenciam soluções que incrementam o interesse dos adolescentes por estes espaços através da integração da Realidade Aumentada.

A investigação começou na exposição "Museu das Alfândegas" do Museu dos Transportes e Comunicações. Foi desenvolvida uma experiência com uma narrativa não-linear para melhorar a experiência dos visitantes.. Esta experiência integra a tecnologia de Realidade Aumentada com narrativa e elementos de videojogos, especificamente customizada para cativar a faixa etária dos adolescentes.

A metodologia desta dissertação segue uma adaptação ao modelo de "design-based research". O processo consistiu em várias iterações: passos: a identificação dos problemas; os objetivos para uma solução; ; definição da solução e sua implementação; a avaliação por especialistas. Foram desenvolvidas duas iterações sobre o problema.

Desta forma, com uma experiência personalizada (e validada), foram desenvolvidas algumas diretrizes que indicam como a tecnologia móvel de Realidade Aumentada pode ser usada nos museus para enfatizar a experiência dos visitantes adolescentes.

Assim, esta investigação contribui para a o estado da arte relativo às experiências museológicas direcionadas ao público-alvo adolescente.

Abstract

The so-called "one-size-fits-all" experiences do not apply to many of the museum visitors and this research addresses the compelling need for customized experiences in museums contexts.

One of the audience groups that is often ignored by museums is the age group of teenagers since the segmentation is usually made between children and adults and there is little customization for the teens' generation. At the same time, studies have shown that this age group appears to be disinterested in what museums might offer.

This project aims to ameliorate this problem by providing guidelines to museum practitioners of how the interest of teenagers towards museums could be increased through the integration of AR Technology.

The investigation took place in the Customs Exhibition of the Alfândega Transports and Communications Museum. A non-linear technology-mediated experience was developed to reinvigorate the exhibition. This experience integrates mobile Augmented Reality technology with storytelling and game elements, specifically customized for the age group of teenagers.

The methodology of this thesis follows an adaption of a design-based research process model. The process in this paper consists of several steps: problem identification, objectives for a solution, design and implementation, experts evaluation. Two iterations were performed.

So, alongside with a validated customized experience, some design guidelines were developed on how mobile AR Technology can be used in a museum context to enhance the experience of the age group of teenagers.

Thus, this research will lessen the gap that exists for empirical studies in museum literature in the area of visitor experience and specifically for the target group of teenagers.

1. Introduction

1.1 Context/Motivation

Nowadays, visitors are at the heart of institutional strategic planning of the museums and their understanding and satisfaction are vital for their survival. Challenges like the drop in public funding, with the simultaneous decline in museum audiences, a new attitude towards collections and active and interactive participation, as well as the emergence of the experience economy, triggered more consumer-oriented policies. As Hein (2000) notes museums are shifting focus from being object-centered institutions towards visitor-centered institutions. This shift was followed by the emergence of the 'visitor studies'. Research into museum audiences has been providing guidelines to museums on how to develop museum spaces and exhibitions and thus diversifying and increasing their visits. Also, they helped museum practitioners to realize the museum visitors´ motivations as well as the impact of their experiences at museums.

The conceptualization of the visitor experience is quite complex as the diversity of human beings. Some of the identified factors are personal (including visitors' existing expectations and preferences), social (related to the human connections during the visit) and physical (concerning the space and the content of the exhibitions). Also, many models, of different approaches, are available for the understanding of the visitors' motivations and the factors that promote their satisfaction. The Multifaceted Model proposed by Packer and Ballantyne (2016), as well as the model of the Smithsonian institution, offer a categorization of experiences. Falk's identity model categorized the

visitor themselves in five archetypal identities, where IPOP model is a four-dimensional construct that proposes museum visitors' preferences.

The above models help us realize that the so-called "one-size-fits-all" experiences do not apply to most of the museum visitors (Falk,2009). In contrast, customization regarding teenagers is not a frequent practice for museums. Specifically, this generation is often excluded from a museum's curatorial strategies as an audience group (Tzibazi, 2013). The segmentation is usually made between children and adults and there is little customization for the teens' generation. As Napoli & Ewing (2000) state we cannot create a single message to attract all kind of visitors, especially this "net generation" flooded with new technologies. They also stress their differentiation from the previous generations regarding their beliefs and behaviors.

Besides the lack of segmentation and customization of experiences for this age group, this group itself appears to be disinterested in what museums might offer and as Tzibazi (2013) states, teenagers do not see the museums as appealing places. If this situation will not be handled properly, museums will struggle to remain relevant to future generations. For ameliorating the disinterest of teenagers towards museums, the emphasis is frequently given on the integration of technology, since teens belong to a generation virtually connected, digitally native, and socially networked (Stogner, 2009) and are more prone to embrace them, than the previous generations (Napoli & Ewing, 2000). In this dissertation, AR technology will be investigated and integrated into a case study to analyze how AR can enhance the visitor experience.

Quite recently, in 2000s, AR entered the museum landscape,but soon was recognized its value as a tool for innovation and enhancement of the visitor experience. Regarding the visitor experience, previous research clearly shows the potential of AR to create interactive and enjoyable tourism experience (Yovcheva et al., 2014; tom Dieck and Jung, 2015). Also, since the ability to learn is dependent on learners' collaborative participation in the learning process, interactive features of AR applications are able to facilitate active learning (Dunleavy & Dede, 2014). The Museum Edition of the

Horizon Report (Johnson, Adams Becker, & Witchey, 2011; Johnson et al., 2012), reinforced the potential contributions of AR to education and interpretation of exhibitions and collections, as well as for marketing and communications. Furthermore, the Trendswatch report published by the American Alliance of Museums for the first time in 2012 (Merritt, 2012), equally highlighted AR as a powerful technology capable of letting visitors handle objects in new ways, view rarely seen artifacts or images, and access richer interpretations. Modern AR applications often aim to assist navigation in the museums, supplementing the existing information on display, providing access to inaccessible collections, virtually reconstructing the past, and providing opportunities for social experiences and content generated by the users.

In relation to the teenagers, studies within museum contexts showed that teenagers related games and interactive content as appealing methods to enhance their visitor experience (Cesário et.al, 2017).

At this thesis, augmented reality technology will be integrated in the exhibition "Metamorphosis of a place: Customs House Museum " of Alfandega Transport & Communications museum so as to enhance the visitor experience specifically for the age group of teenagers.

The Museum

The Transport and Communications Museum (MTC) is a unique example of the city's built heritage, located in the 19th-century, neo-classical New Customs House Building of Oporto which has been permanently restored to receive the Museum's visitors.

Its mission is to highlight all the distinguishing elements of the characteristic architecture of a customs house, what they mean in terms of work routines and their symbolism for the direct users, the nearby population and the city and region in general.

It is important to emphasize the technology present in the museum. Not only is it immediately present in the Museum's themes (transport and communications), but it is also a key factor in its behind-the-scenes work (collection management, educational

services, document management), support for exhibition contents (audio-visual, interactive, multimedia), as well as in communication with the public through web 2.0 social networks, promoting proposals for participation and constant challenge.

The permanent exhibitions

The permanent exhibitions of the Museum are the following:

COMMUNICATE

This exhibition tries to get the visitors familiarized with the communication model and theory through multiple exhibits and metaphors.

One of the sections of the exhibition is focused on the message itself which is explored through the lens of the evolution of various forms and codes of communication as well as the processes and mechanisms that create difficulties and barriers to communication. Also, another area is focused on the five senses of the human body as the natural mechanisms of communication for encoding and decoding a message. The channels of the message are explored via an area devoted to the evolution and exploitation of the main technologies associated with various media of communication.

In other parts of the exhibition, the protagonist in the communication model is the Oporto Customs House as well as the Douro Basin. In one part of the exhibition the Oporto Customs House is represented as a metaphor for communication, as a connection enabler between the city, the region and other points in the world; but as well as a barriers factor against communication through tariffs application and its surveillance methods. The other section focuses on Douro Basin and addresses the connections between Oporto and its World Heritage Historic Centre and nine other sites classified by UNESCO found along the Douro, from source to mouth.

THE ENGINE OF THE REPUBLIC: CARS OF PRESIDENTS

This museum collection is a permanent exhibition of one of the most important collections of cars in the country: the vehicles that have been in the service of its presidents since the founding of the Republic, over 100 years ago.

This collection also reflects an awareness that the vehicles exhibited are part of a historical heritage. As such, they are no longer disposed of once decommissioned, but become part of the collection of the Museum of the Presidency of the Republic.

CUSTOMS HOUSE BUILDING INTERPRETATIVE VISIT

An interpretative visit at the Customs House Building itself as a historical visit also takes place. The Building is a rich, extensive "territory", marked physically and symbolically by elements that illustrate its history as a customs area, its daily routines, influenced not only by the different "moods of the River Douro", but also by the successive transformations of Portugal's commercial relations with the world, its professions and its relationships with the nearby community – Miragaia.

"RIBEIRA NEGRA" PANEL BY JÚLIO RESENDE

Composed of 40 panels, 3 feet high by 1meter wide, this piece is one of the greatest tests for tile panel Black Riverside, located at the eastern entrance of the tunnel Ribeira.

The original idea came from a suggestion of conductor Álvaro Salazar, at the time director of the International Symposium of Musical Workshop. Conceived in 1984, in just 10 days, and in confined working conditions, this work of art began to be exposed in the Cooperativa Árvore and then at the Mercado Ferreira Borges. In 1986, the panel in ceramic glaze on stoneware was created. The opening ceremony was on the 21st June in 1987.

The exhibition "Metamorphosis of a place: museum of customs"

This permanent exhibition is the focus of this research. This exhibition aims to explain the transformation of the building from a former Customs house to a cultural centre and a museum. This exhibition is devoted to the memory of the place, the history of the building, the transformations imposed on the land for its construction, the unique routines of customs clearance, the current role of customs and the renovation of the building for new functions.

Multiple objects are used to convey real stories and encourage the visitor to imagine and create others: record books, customs tariffs, typewriters and calculators, apprehended goods, smuggling strategies, scientific instruments used in analyzing products and substances to ensure the population's safety, symbolic furniture of the complex hierarchical structure typical of a public service, illustrative records of the building's renovation and some of the countless cultural, political and scientific events that have brought the Customs House to life since 1993. Alongside the exhibition, the Customs House Museum Library has a collection of a wide range of documents that reveal the knowledge necessary for customs activity (opened to the public on 18th May 2006 – co-financing III QCA).

The main characteristics of this exhibition are that its is quite antiquated and old-fashioned with minimal technology integration for interactivity purposes. Taking account exhibition of "Communicate" and " The engine of the republic: cars of presidents" someone could observe this exhibition is a bit neglected in terms of exhibits selection and multimedia and technology integration. However, the interior design which seems like a labyrinth could be capitalized and used as a space for a treasure hunt or other challenges staging.

The sections of the exhibition

At the following image, someone could see that every aisle is referred as a different section.

The first section is comprised by a collection of paintings of Porto, Ribeira ,and Miragaia so as to pinpoint that Porto was a city of trade and therefore pinpointing how important it was a Customs House for the history of the city.

The second section is comprised by multiple books and documents which refers to legislation and systems of the Portuguese commerce which the Customs House had to follow. The most important system for the Customs House was the Pauta Code system.

The third section and fourth section includes interesting goods that passed from the control of the Customs House and has an interesting story such as the exhibit No.71

"viola da contrabando" which is a guitar which was used to smuggle olive oil during Second World War.

Also, the third, fourth and fifth section includes objects that were used for the everyday processes of the Customs House. Some examples of such objects were balances, stamps, uniforms worn from the employees of the Customs House, the Customs House laboratory equipment and instruments, bags that were used for the correspondence in the organization, chairs used by the employees in the Customs House. Important is to note that the fifth section's main collection is the "clocks collection" which was used to stress the importance of time in the trade.

The sixth section refers to "Alfandega Nova" which is the name of the Building after its renovation and use as a modern, multi-faceted and multi-functional space and museum. Some of the exhibits are the architectural designs of the building, important publications regarding the museum, brochures from events hosted at the organization
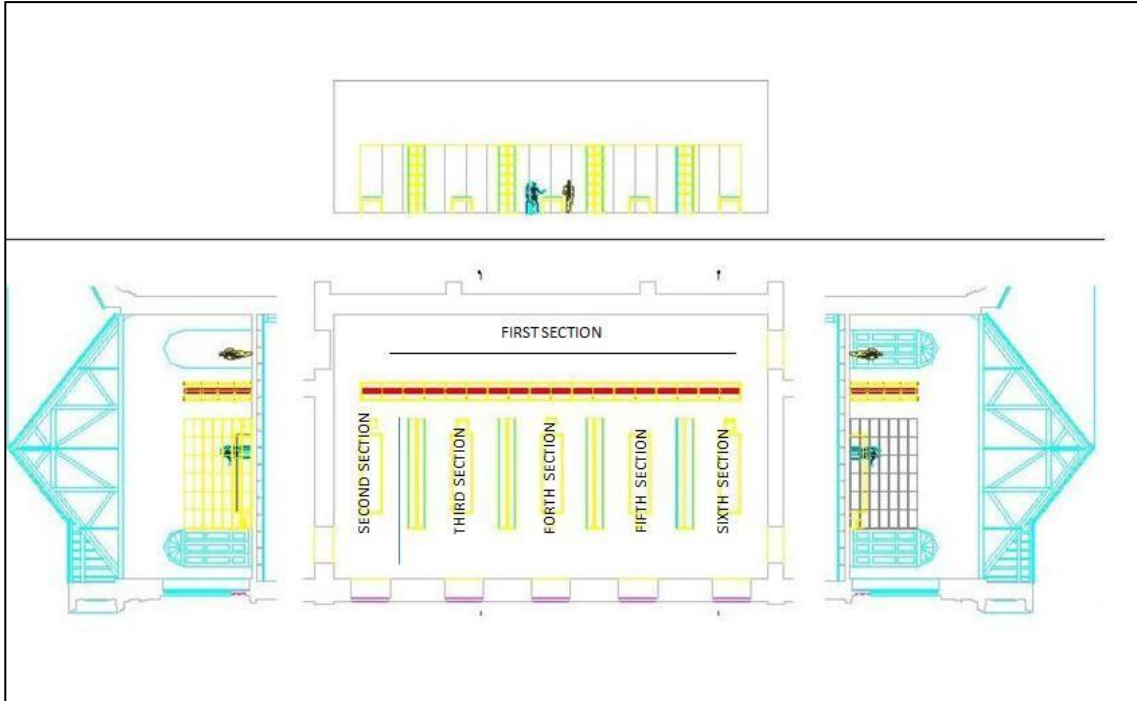
Image 1 The sections of the exhibition room of " Metamorphosis of a place: museum of customs"

1.2 Objectives

The specific objectives of this thesis are :

- the design of a non-linear story, which integrates AR technology, and enhances the experience of museum visitors, without disrupting them from the physical space of the exhibition;
- the promotion of a perspective, a way to interact for a specific context which will still be replicable in other exhibitions;
- the creation of a narrative experience for the exhibition of Alfandega museum, which will involve interactions with the real objects of the exhibition;
- the evaluation of the solution from experts;

- the creation of design guidelines regarding augmented reality experiences for the age group of teenagers;

1.3 Problem, Research Questions

The problem addressed in this thesis is related to the low interest of teenagers towards museums alongside with the lack of necessary funding/resources and specific guidelines for customized museum visits for this age group.

In this research, we will investigate if the integration of mobile AR technology with storytelling and gamification can enhance the visitor experience for teenagers and thus increasing their interest towards museums

The problem is:

- How can the integration of Mobile AR Technology, with storytelling and gamification improve the visitor experience in a museum context for the age group of teenagers?

The research questions are:

- Would a non-linear experience be more appropriate for teenagers than a linear one?
- How can a linear experience have an intuitive route?
- How should be designed the markers for an augmented reality application?
- What are the design guidelines regarding an AR platform?
- What are the limitations of a commercial AR application such as HP Reveal?

1.4 Methodology

The methodology of this thesis is based on a design-based research. Design-based research (DBR) advanced at the beginning of the 21st century and was proclaimed as a practical research methodology that could adequately bridge the chasm amongst research and practice in formal education (Anderson T. et al. 2012)

Recently, design research gaining more acceptable also in the IS research community which increases the value of design science (DS) as an IS research paradigm(Hevner et al. 2004; March et al. 1995; Walls et al. 1992).

The methodology followed is an adaptation to a synthesis of proposed design research processes models because of the lack of a generally accepted model (Peffers K. et. al , 2006). This synthesis resulted in a process with six steps: problem identification and motivation, objectives for a solution, design and development, evaluation, and communication (Peffers K. et. al , 2006).

In this paper, the steps are " problem identification and motivation, objectives for a solution, design, development, implementation or experience staging, evaluation, re-design of the experience, 2nd evaluation and the second re-design.

The communication phase was omitted since it actually consists of this dissertation as a whole. As defined the communication step is actually to communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences, such as practicing professionals, when appropriate through research publications that have a common empirical research process structure. (Peffers K. et. al , 2006).

Important at this phase is to note that after the step of "evaluation" the researchers have to decide whether to iterate back to step " design and development " to try to improve

the effectiveness of the artifact and offer a greater contribution. (Peffers K. et. al , 2006).

However, design-based interventions are rarely if ever designed and implemented perfectly; thus there is always room for improvements in the design and subsequent evaluation(Anderson T. et al. 2012)

At this research, we have developed two iterations of the process, consisting of "evaluation" and further "design, development and implementation" stated as the re-design of the experience. So, the evaluation was performed twice and each time there was a refinement according to the guidelines and observations of the evaluation. The first iteration can be found at 3.5 and 3.6 sections and the second one at 3.7 and 3.8.

1.5 Contribution

This research aims to lessen the gap that exists for empirical studies in museum literature in the area of visitor experience and specifically for the target group of teenagers and in the context of the application of technology. As the review by Kirchberg and Tröndle (2012) noted, "the bulk of museum studies literature concerns cultural, historical, or critical analyses of the museum as an institution: its societal role, its politics and management issues, its function as a place for learning, leisure and self-actualization, and its curatorial and collecting issues. Rarely are the experiences of museum visitors a focus of interest.". Also, museums mostly focus on providing different guided tours for children and adults, without having any appropriate guidelines for the teens' generation in particular. This gap in museum study literature comes across even more in the context of the application of technology in museums (Pallud & Monod, 2010), considering the breadth of applications and more recent and profound developments. Specifically, regarding AR applications, they are mostly tested for usability and are evaluated to validate internal museum goals, but rarely are they a tool in better understanding the visitors and their experiences.

2. Literature Review

2.1 Visitor Experience

Visitor Experience was only recently defined by Packer and Ballantyne (2016) as "an individual's immediate or ongoing, subjective and personal response to an activity, setting or event outside of their usual environment." (p.7). In other words, the visitor experience has four defining characteristics. The visitor experience is

1) inherently personal and subjective, and therefore not directly observable by researchers

2) responsive to the affordances of external or staged activities, settings or events, meaning that it is constructed through the personal interpretation of those external contributions and therefore can be enhanced or shaped, but not controlled by the design of the physical context,

3) bounded in time and space

4) significant to the visitor, impacting them differently than the everyday life, significantly or not, either in a positive or negative way.

As Masberg& Silverman (1996) suggested museum visitor experiences are multidimensional and complex and go beyond narrow definitions of learning. This realization by museum professionals led to another shift in museology away from a cultural transmission paradigm towards a visitor meaning-making paradigm (Rounds, 1999). The meaning-making paradigm proposed that visitors use exhibits to pursue their own personal agendas, fulfill a range of human needs, and construct meanings about themselves, rather than passively receiving the content offered by an exhibit (Rounds, 1999; Silverman, 1995).

These new findings triggered more studies on what kind of experiences are mostly sought by visitors such as the one at the Smithsonian Institution (Doering, 1999; Pekarik, Doering, &Karns, 1999).

Taking into consideration the subjective and personal dimensions of the visitor experiences, there could not exist a single experience that could satisfy all the kinds of visitors. As Doering (1999, p. 83) stated, "Visitor are diverse in their interests and are looking for these different types of experiences in museums. If museums want to be accountable to their visitors, they should at least respect and consider as valid each of these four types of museum experiences."

The results of their study proposed four categories:

1) object experiences (e.g. being moved by beauty, seeing rare/uncommon/valuable things, seeing "the real thing"),

2) cognitive experiences (e.g. "enriching my understanding", gaining information or knowledge)

3) introspective experiences (e.g. "reflecting on the meaning of what I was looking at", imagining other times or places),

4) social experiences (e.g. spending time with friends/family/other people, "seeing my children learning new things").

Another proposed categorization is the Multifaceted Model proposed by Packer and Ballantyne (2016) which captures 10 different aspects: physical experiences, sensory experiences, cognitive experiences, emotional experiences, hedonic experiences, restorative experiences, introspective experiences, transformative experiences, spiritual experiences and relational experiences.

Except of the categorization of experiences, the satisfaction in experiences can also be studied through the IPOP model; a four-dimensional construct that proposes museum visitors' preferences. These preferences could be related to:

- Ideas –concepts, abstractions, facts, reason;

- People – human connection, affective experience, stories, social interactions;

- Objects – things, aesthetics, craftsmanship, ownership, visual language;

- Physical – somatic sensations including movement, touch, sound, taste, light ,and smell.

Studies have shown that exhibitions that satisfy all the dimensions of the IPOP framework are successful with visitors since even if each visitor is being drawn to each dimension in varying degrees, in most individuals, one of the four preferences appears to be dominant. In addition, practitioners that have applied it, claim that it stimulated creativity in the exhibition design team and promoted a superior level of engagement of the visitors (Léger, 2014). As Beghetto (2014) states the IPOP framework has been considered a promising heuristic tool for exhibition designers attempting to immerse visitors in meaningful experiences by offering predictive trends upon which to design experiences.

Another way of approaching the motivations and purposes of the visitors is through Falk's identity model which explores them through an identity-related perspective. Important is to note that identity is taken to be a situational construct in the context of a given visit, rather than a fixed attribute of visitors (Falk, 2011). Falk (2006) identified five of these archetypal visitor identities:

- explorers(curiosity-driven visitors for whom museum-going is a means of satisfying their general interest);

- facilitators (visitors primarily focused on the needs of another, such as a parent accompanying a child);

- experience seekers (experience "collectors" who are influenced by an exhibition's reputation and the recommendations of others);

- professional/hobbyists (visitors with a specific motivation and interest in the museum's subject matter);

- rechargers (visitors seeking time out from day-to-day life and a space to reflect [initially described as spiritual pilgrims]).

Extra characters might be material to specific exhibition hall settings, for example, aware travelers for war dedications and group searchers for ethnic legacy historical centers (Bond and Falk, 2013).

Regarding the predictive value of the model, Falk(2009) claims its sufficiency to enable it to inform museum operations, including exhibition design. However, this claim still remains the subject of ongoing debate (Dawson & Jensen, 2011; Falk, 2011; Jensen, Dawson, & Falk, 2011).

Whatever the model to be adopted and the nature of experiences offered, it is important not to ignore the prior motivations and expectations of visitors, often referred to as entrance narratives (Doering, 1999), since it will influence what visitors will choose to engage with. In the case of Smithsonian exhibitions, Pekarik& Schreiber (2012) realized that visitor expectations tend to frame the resulting experience since there is a strong agreement between expectations and eventual experience among visitors.

In this research, the focus will be on the youthful target audience and specifically on the teenagers. Thus, in section 2.2, the motivations and preferences specifically of this target audience will be thoroughly examined in the context of a museum visit.

2.1.1 Visitor studies and visitor-centric approach

As Hein (1998) notes, visitor studies took a while to become established. The earliest systematic studies of visitor behavior can be traced to the first half of the 20th century, in particular, those of Edward Robinson and his students Arthur Melton and Mildred Porter in the 1920s and 1930s (as reviewed in Bitgood, 2013). However, it was not until after the Second World War that, for various reasons, visitor studies began to grow (Hein 1998; Black 2005).

The emergence of the 'visitor studies' can be related to the growing importance of museums and cultural institutions to understand their audiences. As Liu (2008) suggested, in order to offer exhibitions and services suitable for visitors, museums have to conduct visitor studies and systematically acquire knowledge related to visitors and apply it to planning and decision-making. Research into museum audiences has been providing guidelines to museums on how to develop museum spaces, exhibitions and programs, and thus diversifying and increasing their visits. Also, they helped museum practitioners to realize the museum visitors´ motivations as well as the impact of their experiences at museums.

This urgency of understanding the museum visitors and being more responsive to their interests became even more noticeable during the past 30 years. During the past 30 years, museums of all kinds have tried to attract and become more responsive to the interests of a diverse public (E. Alexander & Alexander, 2007; Anderson, 2012; Black, 2012; Weil, 2002). The new positioning of visitors at the heart of institutional strategic planning elicited a primary need to meet and understand audiences, their motivations to go to museums, and the factors that influence their satisfaction during a visit (Kirchberg&Tröndle, 2012; Miles, 2007; Shettel, 2008).

However, museums have not always been visitor-oriented. As Hein (2000) notes museums are shifting focus from being object-centered institutions towards visitor-centered institutions. Museums and cultural institutions, in general, were forced to adopt a more consumer-oriented policy due to challenges like:

- the drop in public funding leading to increased reliance on donor and visitor ticket funds (Ballantyne &Uzzell, 2011; Goulding, 2000),

- the decline in museums audiences (Simon, 2010),

- the accountability from professional museum associations that give accreditation and establish guidelines (Shettel, 2008),

- a new attitude toward collections, reconsidering what constitutes the best form of engagement with a museum exhibition (e.g. experiencing objects interactively versus passively) (Hein, 2007)

2.1.2 Experience Economy and Museums

Experiences have been mentioned in different ways for a long time. However, the concept of 'customer experience' came more relevantly to the fore in the 1990s by Joseph Pine and James Gilmore in their book on the Experience Economy (1998). The authors claimed that after agricultural, industrial and service economy, the economy is lately being transformed into a new economic era; a new economy sector; the "experience" economy. The focus of economy has transferred into experiences", suggesting the coming of "experience economy" (Jang& Jung, 2013). This transformation of an economy based on experiences is further confirmed by Rosenbaum-Elliot, Percy and Pervan (2011). In this economy, the 'experiences' are presented as the new economic offering as the progression of economic value, after the services are also commoditized like products. In this era of the experience economy, businesses have to adjust by offering their customers a unique, memorable and valuable experience actively in the process of marketing (Pine& Gilmore, 1998). All types of businesses will need to consider selling not only services or products, but also experiences in order to satisfy their customers in this new battlefield. (Pine & Gilmore, 1998).

Receptive to this change of the economy, museums progressively see their part as far as the visitor experience they offer (Falk and Sheppard, 2006; Kirchberg&Tröndle, 2012). As Peter Samus(2008) claims that ´the museum is not the sum of the objects it contains but rather of the

experiences it triggers." Also, Hennes (2010, p. 25) argued that "exhibits aren't actually experiences—rather they are platforms for experiences"

2.2 Teenagers and Museums

According to Falk (2009), the so-called "one-size-fits-all" experiences do not apply to most of the museum visitors. We cannot create a single message to attract all kind of visitors, especially this "net generation" (Napoli & Ewing, 2000) flooded with new technologies. This generation is very different from the previous generations regarding their beliefs and behaviors (Napoli & Ewing, 2000).

Nevertheless, this generation is often excluded from a museum's curatorial strategies as an audience group (Tzibazi, 2013). The segmentation is usually made between children and adults and there is little customization for the teens' generation. As a repercussion, this group itself appears to be disinterested in what museums might offer and as Tzibazi (2013) states teenagers do not see the museums as appealing places.

If museum professionals want their museums to remain relevant to future generations, adjustments must be made. For ameliorating the disinterest of teenagers towards museums, the emphasis is frequently given on the integration of technology, since teens belong to a generation virtually connected, digitally native, and socially networked (Stogner, 2009) and are more prone to embrace them than the previous generations (Napoli & Ewing, 2000).

Specifically, studies within museum contexts, showed that teenagers related games, interactive content, virtual reality and social media as appealing methods to enhance their visitor experience (Cesário V. et al. 2017)

Also, co-design sessions with teenagers, in the Natural History Museum of Funchal has shown that teenage audiences were particularly interested in design patterns related to "interactions", "gaming", "localization" and "social media" when it comes to interactive technology experiences in exhibitions(Cesário V. et al. 2017) Specifically, the teenagers were asked to participate in co-design sessions about the ideation of interactive museum experiences for the MNHF. As a result of these co-design sessions, and a total of 150 transcripts, several design patterns found out.
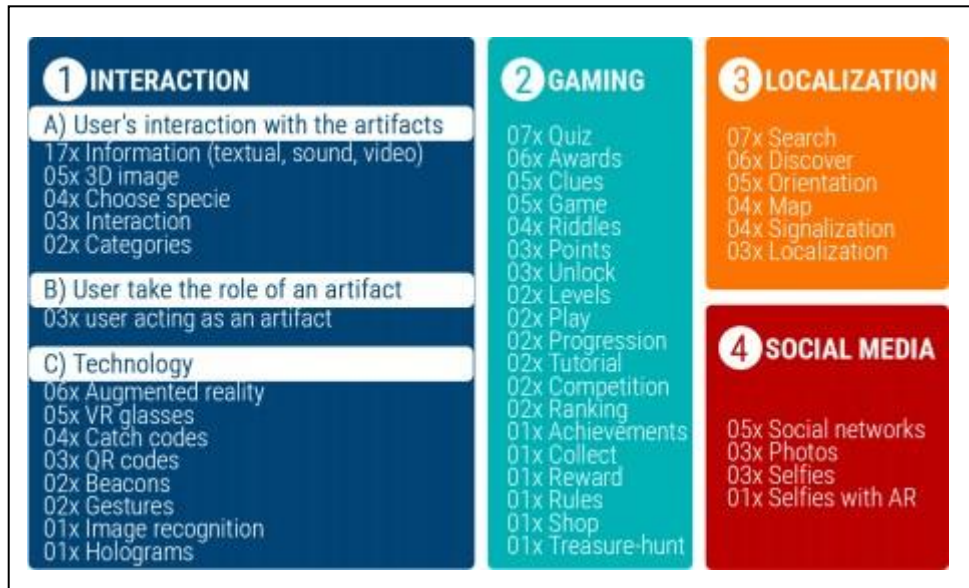
Image 2. Word categories gathered from the co-design sessions with teenagers.(Cesario V. et.al 2017)

Interaction. The *Interaction* category recalls the desire of the teenagers to have some interaction within the artifacts inside the museum. This kind of interaction could happen in three ways: by receiving information about the exhibits, by the user taking a role inside the museum instead of being a regular visitor, and also with the kind of technology that they are desiring to have those interactions. The Interaction category was the most popular category and specifically the sub-category of the user's interaction with the artifacts. It seems like having "information in several types" like textual, sound, video or image was the most preferred way of interaction and generally the most desired element among all the categories. Also, augmented reality and VR was the most preferred kind of technology for this kind of interactions.

Gaming. The second most popular category was the Gaming one with the most preferred elements to be associated with the words "quiz", "award", "clue", "game", "riddle", "point" and "unlock"

Localization. The *Localization* category relates to the desire of the teenagers to localize themselves inside the museum building and included words relating to movements within the museum as well as the discovery of artifacts. It was the third most popular category with the most preferred experience characteristics to be associated with the words "search", "discover" and "orientation".

Social Media. The *Social Media* category is related to the desire of sharing the experiences on social media channels within a mobile application. The least popular category was the "Social Media" with the most preferred way to be the connection to "social networks"

Other findings of the same survey suggested the importance of user-driven innovation. as well as that teenagers value interactive technologies when visiting museums ,especially when being driven through a playful approach.

2.3 Technology and Museums

The visitor-oriented approach led to multiple internal technological alterations. According to Marty (2007), the fluctuating demands of access and organization of data triggered the adoption of collection management systems and later through the digitization of collections. In addition, cultural institutions realized the significance of online presence and created the first museum websites in the mid-1990s (Jones, 2007). Regarding the enhancement of the visitor experience, guests run over more frequently in a scope of new media technologies, from high definition video and animation, that incorporate music and sound effects, touch screens with games and 3D modeling manipulation, and a host of other interactive experiences (Gilbert, 2016; Lohr, 2014). Furthermore, the use of social media is prominent amongst the most noticeable trends in design for museums nowadays.

The adoption of technology in museums seems to be inevitable, and as Stogner (2009) points out, "the issue is no longer whether to use media to enhance museum exhibitions, but how to use it." (p.385). Nowadays, most museums have integrated some type of interactives in their exhibitions and this makes increasingly rare for a visitor to have an entirely passive experience (Marty, 2007b). Even if the basis of most exhibitions is still the conventional tool of storytelling, visitors are pulled into the stories through multisensory digital experiences that are as much about feelings and emotions as they are about knowledge and cognition (Pallud & Monod, 2010; Stogner, 2009)

Some museums have been hesitating in the deployment of non-traditional interactive exhibit practices for various of reasons. The deployment of new technology for the design of exhibitions has also arisen a number of concerns regarding the high cost of interactive technology, the ability to generate additional revenue for museums, the contradiction with the identity and mission of museums and the disruption of the visitor experience.

In relation to the cost factor, the critic Schwarzer (2001) advocates that the high cost of implementation and maintenance of interactive technologies is unjustifiable since they do very little to bring in additional revenue to art museums.

Another arising risk is that of disruption, where visitors rely on too heavily on the technological interface and are distracted from the primary focus, the collection objects (Marianna Adams et al., 2004).

Furthermore, another concern of museum professionals is that if they adopt a more interactive entertaining style in the content presentation, there will be a contradiction at the museums' identities which will be accompanied by an external confusion to the public about the museum's motives and future directions (West, 2004). Museums that unreservedly endorsed technology have been likened to amusement parks, in a contrast between high culture (museum as a temple) and popular culture (an amusement park for entertainment purposes only) (Balloffet et al., 2014)

On the other side, there is a variety of expected beneficial outcomes from the integration of new technology such as higher attendance levels, the attraction of new audiences as well as enhancement of the visitor experience. Often, using interactives is perceived as a marketing tool to appeal to certain target audiences (Marty, 2007b; West, 2004). Also, some research results (Wang Y, et al. (2009) claim that the museum experience can be boosted by an interactive and immersive environment. Visitors seem to find interactive exhibitions meaningful, perceiving in them opportunities to communicate and socialize, receive personal feedback, and actively learn in an applied everyday fashion (Falk et al. 2004) . A study on the Field Museum experience (Hanko K. et. al., 2014), confirmed that visitors were generally excited at the prospect of new digital tools within the referred experience: nearly three-quarters felt that new technologies had the potential to enhance the visiting experience, and two-thirds said they would "love" to see the museum incorporate more such technologies into its exhibitions. Moreover, a study that took place both at a science center and at a history and science collections-based museum, demonstrated that interactivity was a major expectation in the former and less so in the latter, despite the museum's effort to be more engaging and interactive (Falk et al., 2004). The study (Falk et al., 2004) additionally proved that interactives supported visitor learning and/or reinforced facts and concepts.

Also, even if some museums have been skeptical whether the adoption of interactive technology is compatible with their identity and mission, the previous study showed that in the long term, visitors that had interactive experiences in the museum, changed their existing perception of the institution as "dry and dusty" to a place that was "modern" and "looked forward".

According to Black (2016), 70% of the "core" museum audiences have no special interest in museums , and one of the main reasons seems to be the form of the permanent exhibitions retaining a didactic display, which promotes a "one-way transmission of knowledge" (Black, 2016, p.6)

Museums cannot anymore impose their content and display approaches on visitors and still grow an audience, particularly so far as younger generations are concerned. (Black, 2016) This change in the public is something that museums must acknowledge and turn to more participatory practices to engage audiences as well as move to a ´bottom-up´ approach, driven by users.(Black, 2016, p.11). Probably, these participatory practices could be enabled with the use of new technologies where visitors are turning from passive to active participants (Mancini & Carreras, 2010; Simon, 2010).

2.4 Augmented Reality in Museums

As was mentioned before, museum professionals pursue to enhance the visitor experience beyond the primary experience of viewing objects, with the use of various multimedia. Quite recently, in 2000s, AR entered the museum landscape but soon was recognized its value as a tool for innovation and enhancement of the visitor experience. In 2005, AR was considered one of the 10 most important emerging technologies for humanity (Mike Adams, 2005).

The most commonly accepted definition notes that "AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. In other words, AR combines the real and the virtual world, in a supplementing way. "(Azuma, 1997)

As Krevelen and Poelman (2010) note AR is the overlay of computerized information in the real environment.

Regarding the museum context, the application of this technology, especially to mobile devices, merges the experiential and interpretive aspects of perceiving an object in a museum exhibition to generate a singularly integrated, meaningful experience (Elinich, 2011) that is entirely dependent on the real world. This coexistence of the two realities on the display can tackle the problem of heads-down experiences and the disconnection of the visitor from the real world, as often happens with other kinds of technology. This specific characteristic of AR, led to its recognition as a tool for museum innovation (Schavemaker, 2012), as well as a promising technology for enhancing the interaction between visitors, collection objects and their contextualized information (Weng, Parhizkar, Ping, & Lashkari, 2011).

The benefits of AR technology integration in the museum context can be various. An exploratory research in Manchester Jewish Museum, showed that both visitors and employees alike felt that the implementation of this new and innovative technology could add value and AR is considered the way to move forward to preserve history, enhance visitor satisfaction, generate

positive word-of-mouth, attract new target markets as well as contribute to a positive learning experience(Jung T. and Dieck C.,2016). Moreover, the Museum Edition of the Horizon Report (Johnson, Adams Becker, & Witchey, 2011; Johnson et al., 2012), reinforced the potential contributions of AR to education and interpretation of exhibitions and collections, as well as for marketing and communications. The Trendswatch report published by the American Alliance of Museums for the first time in 2012 (Merritt, 2012), equally highlighted AR as a powerful technology capable of letting visitors handle objects in new ways, view rarely seen artifacts or images, and access richer interpretations.

Specifically, regarding the visitor experience, previous research clearly shows the potential of AR to create interactive and enjoyable tourism experience (Yovcheva et al., 2014; Tom Dieck and Jung, 2015). Telling hidden stories and enhanced content are some examples of how museums can use AR to enhance the visitor experience (Leue et al., 2015).

Also, since the ability to learn is dependent on learners' collaborative participation in the learning process, interactive features of AR applications are able to facilitate active learning (Dunleavy & Dede, 2014). Additionally, the 2016 Trendswatch report (Merritt, 2016), emphasized the important role that AR coupled with VR technologies can play in formal and informal education, conceivably changing the meaning of immersive learning.

2.4.1 Applications

The following section provides multiple examples of modern AR applications that were aiming to assist navigation in the museums, supplementing the existing information on display, providing access to inaccessible collections, virtually reconstructing the past, and providing opportunities for social experiences and content generated by the users.

Navigation

Traditionally navigation has been and still is a highly relevant area for institutions, in particular, the large ones, which actively pursue new ways to steer visitors between different points, with efficiency while meeting their needs (Tarr, 2015).

For instance, Musee du Louvre, in an effort to lead visitors to collection highlights partnered with Nintendo for the development of a dedicated software that includes an interactive map that locates visitors in real time and expands information about the collection including augmentation of some exhibits.

The Science Museum in London, launched a mobile tour in the "Making the Modern World" gallery hosted by an avatar of a well-known TV personality and science enthusiast. The application uses the Vuforia AR browser, which recognizes nine color markers that are placed next to some of the highlights of the exhibition, which is followed by storytelling and presentation of important facts about the objects by the animated augmented character.

Supplementing Reality

AR has also been used to supplement or enhance the actual collection in exhibitions; the real world. This enhancement with additional information can also direct the visitors attention to specific aspects of the exhibits and thus better meet their educational goals.

For example, at Franklin Institute Science Museum, for improving the learning outcomes of the visitors, a couple interactive kiosks focusing on the explanation of natural phenomena, were augmented so as to illustrate the related physics, in a more perceivable way. For instance, for the kiosk that was focusing on the classic Bernoulli's principle, that correlates the speed with the pressure of a fluid, an actual floating ball was used over a tube blowing air. Visitors could interact with the ball and see on a screen the augmented arrows surrounding the ball that indicate the changes in air pressure and speed.

In a similar context, the Exploratorium in San Francisco, also developed science inquiry activities. The series "Science in the City", available with the AR browser Layar, introduced stories about places, people, and themes related to natural phenomena and the built environment. With their own phones, users could superimpose an altimeter to measure the height of fog at their location, and learn how it moves to nearby areas; or explore zones of geologic interest with active fault lines where the direction of movement was virtually overlaid (Rothfarb, 2011b)

However, the applications of AR were not limited in science museums. The temporary exhibition "The Life of Art: context, collecting, and display" at the J. Paul Getty Museum in Los Angeles, also used a mobile app developed with AR technology, in a pursuit of telling in-depth stories and fostering close and mindful looking at a small number of singular objects. This iPad mobile app was used to help users focus on the details of each piece and see them from different perspectives (Checchi, 2013)

Reinvigorating Antiquated Exhibitions

One of the main reasons why technology was integrated by museums is for overcoming the need of renovation and replacement of their exhibitions, caused by their degradation and aging with the

passage of time. Especially in science museums and aquaria, the complexity and expense of such innovations make them extremely difficult in terms of costs and resources needed

Specifically, AR has been adopted as a solution to this problem, in an attempt to virtually renovate antiquated exhibitions. The Field Museum (Chicago IL) decided to revitalize one of its oldest exhibitions, the Hall of Plants of the World, with a temporary AR gaming app, which was communicating findings from a research in the botanical collection of the museum by augmenting the static and long-standing plant models that populate the exhibition (Grainger Digital Studio, 2016).

Also, in the Ayala Museum AR technology was employed so to enhance a long-established form of an exhibition in museums, the dioramas. The displays, that date from 1974 when the museum opened, depict iconic scenes in Philippine history, from the pre-colonial period to independence. Visitors can rent devices to see the "Diorama Experience of Philippine History" where animations, realistic sound effects and voice narrations augment the exhibition (Ayala Museum, 2015).

Accessing the Inaccessible

Frequently, specific exhibitions or historical places restrict public visitation because of conservation, danger or renovation reasons and AR feels the gap, by a virtual representation of the exhibits or the historical places.

When Stedelijk Museum was under a major renovation and the indoor offerings were unavailable, the collections were presented virtually at public events in order to sustain the relationship with the onsite audience (Schavemaker, Wils, Stork, & Pondaag, 2011). The "ARtours" endeavor consisted of projects of different scales, truly experimental in their conception, given the adoption of the AR browser Layar which still needed a lot of improvements. In one project, art students were inspired by the collection to create their own work that was augmented in the park outside of the closed building; another project took place at a music festival, where attendants could "borrow" pieces of artwork and virtually hang them anywhere around the venue.

The MARCH project (Mobile Augmented Reality for Cultural Heritage) in French Pyrenees offered a virtual experience in prehistoric caves since access was restricted to public visitation for conservation reasons (Choudary, Charvillat, Grigoras, & Gurdjos, 2009). A mobile AR system ran on a Nokia smartphone, recognized simple colored images placed at the corners of photographs of the cave wall engravings. Scientific drawings were superimposed onto the engravings to help visualize and interpret the figures that are faded and can be confusing.

Reconstructing the past

The reconstruction of the past is a regular theme in museum applications and according to Gervautz and Schmalstieg (2012), AR is an ideal technology to re-enact historic events without interfering with original architecture.

Reskinning and bringing dinosaurs back to life is a formula repeated across different museums with natural history collections. One characteristic example is this of the Berlin's Museum für Naturkunde in 2007 which implemented the Jurascopes, fixed look-through devices that swiveled like telescopes. Peeking through them, visitors would see the mounted skeletons in the gallery become layered, first with inner organs, then with muscles, afterward with skin, and finally contextualized in their natural habitat where they roamed, fed and hunted, all accompanied with audio effects

Another interesting example of the reconstruction of the past is this of the Museum of London which released the "Streetmuseum" AR mobile app for smartphones (Swift, 2013). At various locations in the city, users can see what a site looked like in the past through the overlapping to the actual buildings of archival photos and paintings. GPS location information not only assists user navigation on a map but also locates them at the augmented spots.

Collective Experiences

Mobile technology, that is the type of AR technology which is the focus of this research, seemed to be sometimes an obstacle to social interaction and is accompanied by the isolating effect (Hsi, 2003) and interference with conversations (Woodruff et al., 2001). On the other side of the coin, sometimes it behaves as a social interaction facilitator, as in the case of interactive kiosks which often promote sharing among visitors (Gammon, 1999). Also, mobile AR expands the possibilities of collective experiences through multi-user activities in a virtual space, where users assume different social roles that are collaborative and build mutual understanding around common goals (Reitmayr & Schmalstieg, 2001; Xu et al., 2008).

One successful example that promoted collaboration between visitors, is the mobile game "A Gift for Athena", used in the British Museum, which intended for 7-11 year-olds and involved the collaboration between young students. This application was designed to interact with the Parthenon gallery –players go through a series of challenges that involve finding sculptures, solving puzzles and playing mini-games, each set examining a different part of the Greek temple (Gamar, 2015).

Visitor Content Generation

Participatory practices are of high importance in museums nowadays, and user-generated AR content is perceived as such. In user-generated AR, in addition to receiving and manipulating digital content, the user has an active role in producing the virtual information that is superimposed onto the surrounding real world (Wither, DiVerdi, & Höllerer, 2009). Even though the technology is not yet mature to enable the Web 2.0 concept, there are AR applications that have been developed to promote content generation.

The American Museum of Natural History has implemented the approach to the historic Hall of Northwest Coast Indians, where visitors are invited to search for particular collection objects on display, color their representations on facsimile sheets, and through the AR app see and manipulate the virtual 3D object mapped with the texture they created (Joseph, 2016)

Also, at one of the Exploratorium's "After Dark" adult evening events, inspired by four surrealist artists, visitors downloaded the Junaio AR browser to track fiducial markers that gave them access to iconic elements from the artists' paintings. They could then virtually place those elements into their surroundings and augment their companions (Rothfarb, 2011a).

3. Research Design

This research is design-based so a design science methodology will be followed. The model adopted is already referred in section 1.4 and consists of the following steps: problem identification and motivation, objectives for a solution, design, development, implementation or experience staging, evaluation, re-design of the experience, 2nd evaluation and the second re-design.

However, the problem identification, motivation, and objectives of the solution are described in greater detail in the introduction chapter.

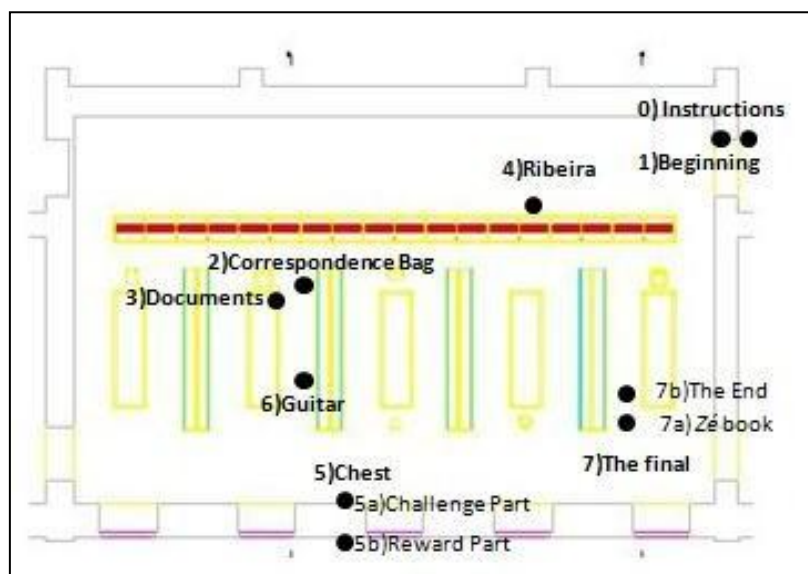**The first version of the experience**

Image 3 The position and sequence of each AR moment/episode in the floor plan

at the first version of the experience

The concept of the experience was inspired by the book with the title "Zé do Saco, o Contrabandista " written by Manuel Jorge Marmelo. This book refers to the story of Zé who was an employee in Alfandega Museum but also involved in smuggling practices.

The first experience consisted of 7 moments where the "chest" one and the "final moment" is consisted of two parts. The experience is linear and is following the sequence that the numbers depicted in the map. At the end of each moment, there is a clue of which is the next moment of the experience. This version of the experience integrated both mobile AR technology and QR Code technology. Also, the experience was in the Portuguese language.

The instructions moment consisted of a leaflet which informed the visitors of how they could connect to the wireless network of the museum, which applications they would need; a QR Code reader and HP Reveal, how to use these applications and from which trigger image they should start; the beginning sticker.

In the first moment the visitors can watch a video with Tiago, an animated character which is the narrator of the experience, who provides further instructions to the visitors, introduces them to the challenge which is to solve a smuggling case, and in the end gives them the queue to the next moment, the correspondence bag.

Image 4 Tiago, the "narrator" of the experience

The correspondence bag(2) moment informed the visitors that they should search for a similar bag which is under the table next to them since that bag includes a document which will offer clues for their case.

The documents moment(3) was about reading four documents that referred to various matters of the Customs House, scan a sticker which was behind them and check each time if they found the sought document. Three of the documents led to a video overlay which informed them that this was not the right document. The scanning of the trigger image of the right document led to a video, which informed them that they found the right document and examined more carefully the document for clues. These clues were that the most smuggling transactions took place in Ribeira, that the main suspects were Zé Lima and Sérgio Pinto, employees of the Customs House, and that there may be video recording from Ribeira from that period somewhere. At the end of this video overlay, Tiago offered a queue to moment (4), Ribeira, by stating that there they could find video recordings of Ribeira from that period.

In moment 4, the Ribeira moment, someone could see a video with a possible smuggling transaction of a chest between Zé Lima, a former employee of the Customs House. In the end of the video, Tiago, urges the visitors to find and open the chest which is the queue to moment 5, the chest moment.

The chest moment consisted of two episodes. The first was the "challenge moment" which was unlocked through a QR Code where the visitors were led to an online quiz at the platform onlinequizcreator[1], where they should answer right to at least half of the questions so as to open the chest. After the "challenge moment", the visitors that had answered right to two questions were given the trigger image which led to "the reward" moment. The "reward" moment included a video where the chest opened and a guitar was found inside. In the end, Tiago urged the visitors to try to open also the guitar to see if something is hidden inside.

The guitar moment included two small challenges; one with an "alphabet soup" where the words to be found are" jewelry, gold, coffee, documents, sugar, olive oil" and another one where they have to guess which item is hidden within the guitar. After the two challenges, Tiago appears and urges the visitors to read a chapter from a book to gather more clues. This book is the " Zé Book" moment (7a) which refers to the book of "Zé do Saco, o Contrabandista " written by Manuel Jorge Marmelo.

The final moment where the visitors actually will find out the solution to the mystery consists of two moments; the Zé Book moment (7a) and the Ending moment(7b).

The Zé Book moment is unlocked through QR Code technology which downloads a one-page pdf which shows Zé feeding his family with olive oil and includes a small paragraph, where the visitors realize who is the suspect and why he was smuggling olive oil; for survival reasons.[2]

The ending moment (7b), is a video of Tiago commenting on the solution to the mystery and wondering if he should speak to the police about the case or not. In the end, he decides to go and grab a snack since he wants time to think about it and farewell to the visitors.

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[1] https://www.onlinequizcreator.com/
[2] Check the appendix for the pdf

3.1   The awareness of the problem

Everything started with a visit to the Museum and a meeting with the museum staff so as to discuss the problem that existed in this exhibition and the possible solutions to cope with it. The museum staff stated that this exhibition is the least interesting and engaging for the visitors but one of the most important for the history of this building. So, there should be found ways to improve the visitor experience in a low-cost way due to budget constraints. In addition, they pinpointed that they would prefer focusing on the age group of teenagers since it is the least engaged group with this specific exhibition room.

The solution proposed was an augmented reality experience with storytelling elements which could "enhance" virtually the exhibition. Regarding the storytelling elements, there was offered a tour in the exhibition room so as to present the space, the exhibits and also interesting stories of selected exhibits which could be the basis or part of the story created for the augmented reality experience.

3.2   Conception of the experience & Experience Design

The main design patterns used in this experience design were inspired by the study in the Natural History Museum of Funchal (MNHF) as described in section 2.3. In this study, it was found out that teenagers find gamification, interaction with the artifacts, augmented reality and the "localization" aspect such as the "go and seek" moments very appealing in interactive experiences within museum contexts. Following these design patterns, this experience will focus on providing the preferred interaction of users with artifacts which is the offer of "information in several types" like textual, sound, video or image. Furthermore, it will include some of the most preferred game elements such as quizzes, awards, clues, games and points. In addition, it will offer moments where the visitors should search within the museum and discover clues which are correlated with the localization category as described in the referred study in MNHF.

The approach of the narrative was that the exhibition was the "Storyworld" and every selected exhibit from the museum would give one episode of the story. In the first version of the prototype the narrative followed a linear structure and at the second and third version a non-linear one.

As the museum staff proposed, the concept of smuggling could be used in our narrative since it is a prohibitive concept which could appeal teenagers and also there was a lot of interesting stories and content regarding smuggling incidents. Also, there was a book written for the Customs Museum exhibition with the title "Zé do Saco, o Contrabandista " written by Manuel Jorge Marmelo, which already had a smuggling story that hypothetically took place in the museum when it was still used as a Customs House.

So, because of the existing content we decided to create a story around a smuggling case which would use the main character of the book, Zé, as well as some other elements from the book. Then, the exhibits that could have a connection with smuggling practices were selected and then through fictional storytelling all the AR episodes were included in the story in a coherent and organic way. For example, the exhibit of "viola da contrabando" was included in the story because it was used for smuggling food during World War II between Spain and Portugal.

Image 5 The "viola da contrabando" exhibit, of the
"guitar" moment

Other exhibits did not already have a connection with smuggling practices but they were quite eye-catching and through fictional storytelling this connection could be created.

After the selection of the exhibits and that would be included in the story, the script of the story was written. When there was not easy to create an AR episode for a selected exhibit, more information was gathered for this exhibit so as to get inspired. Except of the content and information that was already provided during our first visit at the museum, more content about the exhibits or the history of the building was collected either through personalized tours at the exhibition from the staff at the Customs Museum or exhibit catalogs.

The experience and the narrative were designed multiple times according to the feedback of the supervisors of this project.   The output of this phase was a script where it was described as the main concept of the experience, its moments as well as the spatial experience design. After the validation of the script by the supervisors of this thesis, the development process followed.

3.3 Development

The augmented reality platform selected for the experience is HP Reveal [3] . For creating an augmented reality moment someone needs to add a marker as well as an overlay, which is the content which will be unlocked through the scanning of the marker.

Overlays Development

Then, the visual content was created with the help of Prezi[4], Powerpoint[5], Renderforest[6], Windows Movie Maker[7], Google Forms[8], Google Documents [9]and illustrations. The audio content was edited with the help of Adobe Audition CC [10]and Goldwave.[11]

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[3] https://www.hpreveal.com/
[4] https://prezi.com/?gclid=EAIaIQobChMIzNSFkOmm3AIVyfZRCh2opAdZEAAYASAAEgKi7vD_BwE
[5] https://office.live.com/start/PowerPoint.aspx
[6] https://www.renderforest.com/
[7] https://www.topwin-movie-maker.com/
[8] https://www.google.com/forms/about/
[9] https://www.google.com/docs/about/
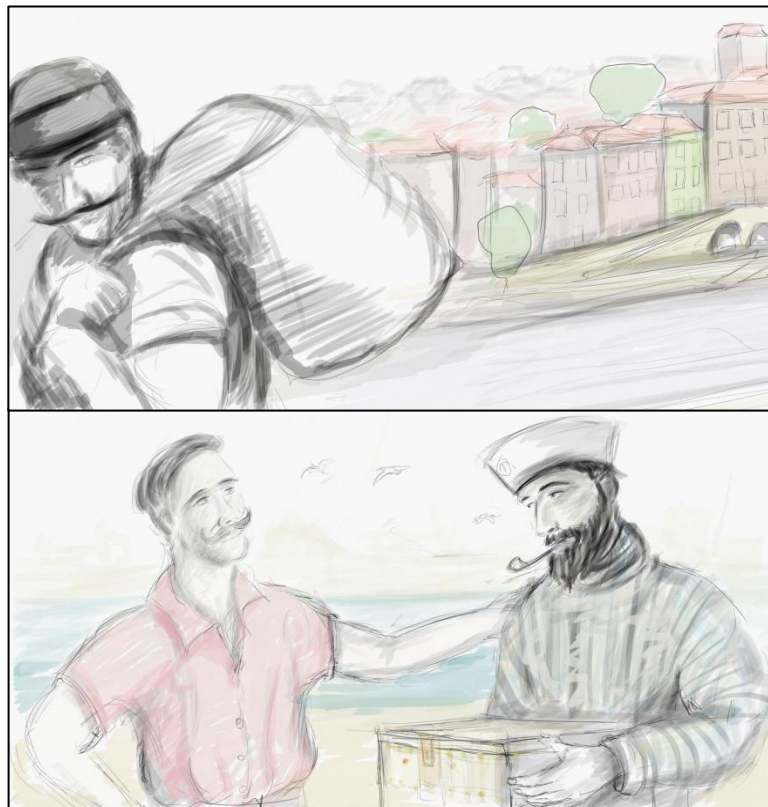[10] https://www.adobe.com/products/audition.html
[11] http://www.goldwave.com/

- Prezi was mainly used for the "guitar" moment.

Image 6 The overlay of guitar moment which was created with Prezi software

- Illustrations were created from a concept artist for the "Ribeira" moment as well as for the "Zé Book" moment.

Images 7,8 The illustrations that were used for Ribeira moment

Image 9 The illustration that was used for the "Ze Book"
moment

- Windows Movie Maker was used as a video editor and for the narration recording of the
  moments.

- Renderforest was selected for including some simple animations and graphics in the videos.
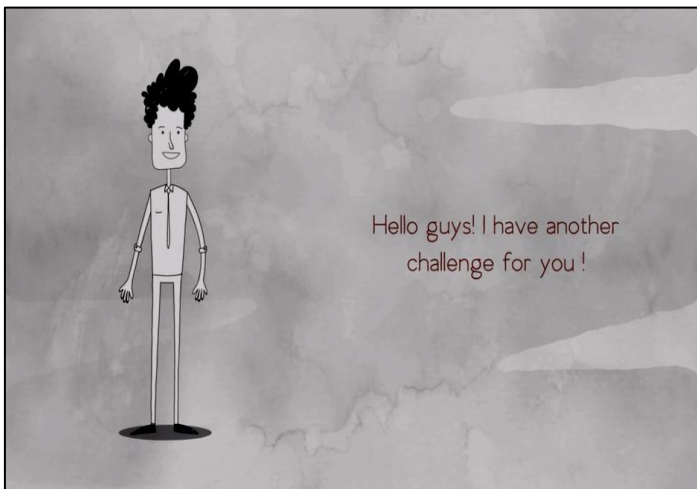

Image 10 The design of the most used overlay in the
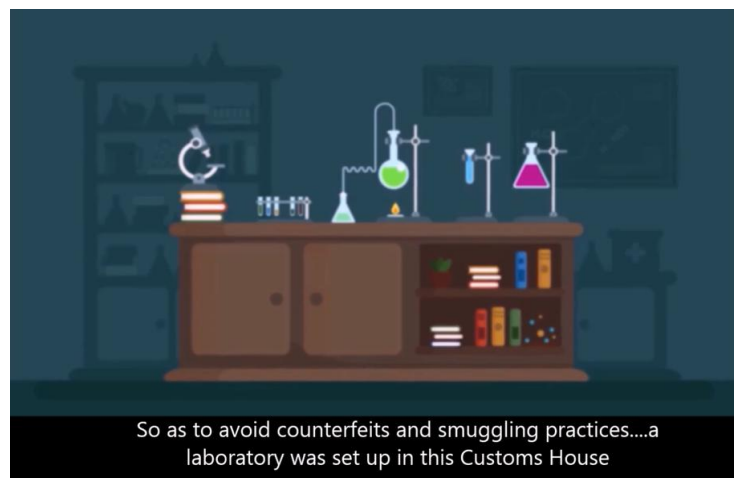experience, created with Renderforest software

Image 11 The overlay of the Lab moment, created with
Renderforest software

- Google Docs software was used for the " Zé Book" moment where people have to read a pdf of chapter 8 from " Zé do Saco, o Contrabandista" book.
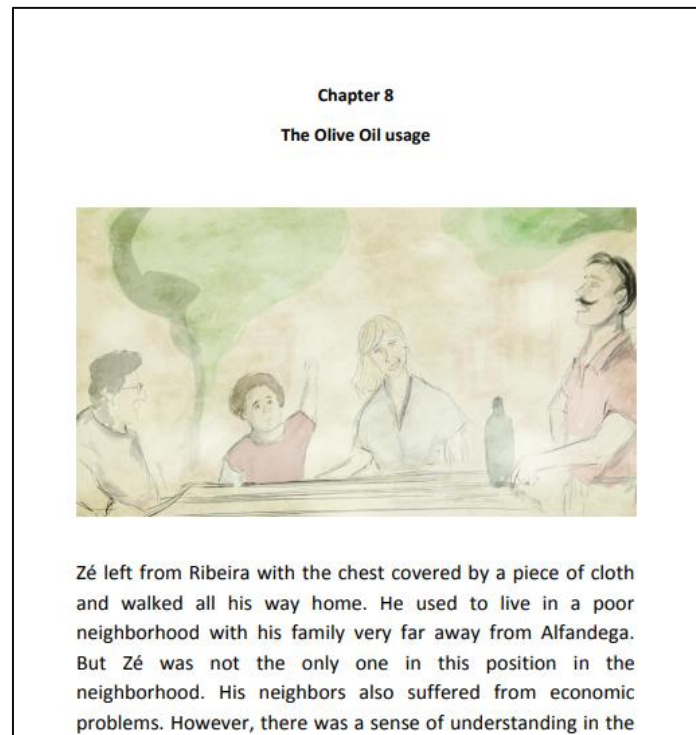

Image 12 The pdf of the "Ze Book" moment

- Google Forms software was used for the creation of the quiz for the challenge for opening the chest.
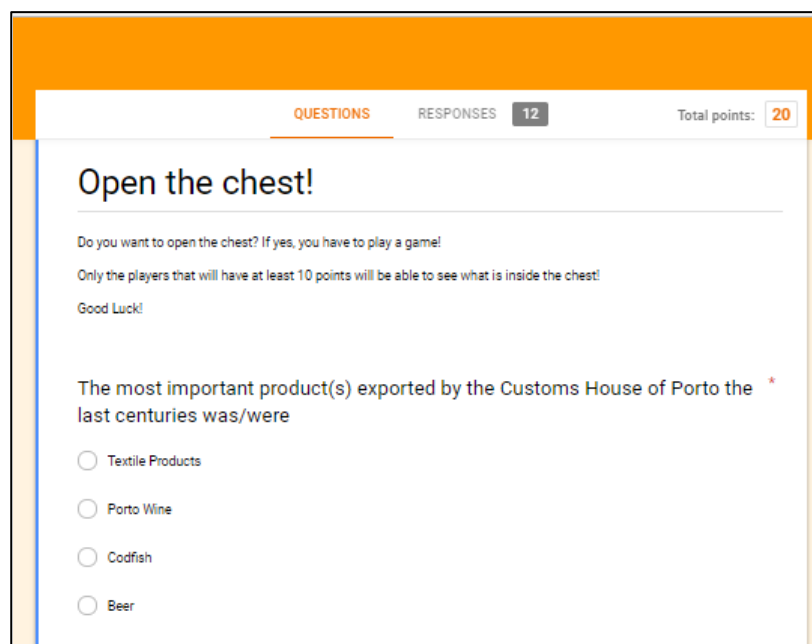

Image 13 The googleform used to create a quiz for the "chest challenge" moment

- Abode Audition CC and Goldwave audio editors were used

The output of this process was 2D animated videos with audio, presentations exported as videos, pdf files, and online quizzes.

Design Science follows an iterative process until the artifact is tested and evaluated multiple times. Accordingly, the content was redesigned multiple times according to the advices from the supervisors as well as the expert's evaluation.

Markers/Trigger Images Development

It is often advised to prefer using small pictures of the exhibits than the exhibits themselves as markers (trigger images in HP Reveal) [1]since the changes in lightning can affect the result of scanning in HP Reveal application. Small pictures are less affected by the lightening factor as well as can be placed in the most appropriate position in the exhibition room and facilitate the scanning process.

In the first iteration, the trigger images depicted similar objects to the exhibits but in the second ones they depicted the actual exhibits as advised by the experts. An important detail of the design of the stickers is that in the corner the logo of HP Reveal was placed so as to facilitate the recognition of them as part of the multimedia experience.

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[1] In the rest of the paper the markers will be referred with the term "trigger image" which is the term used in HP Reveal app

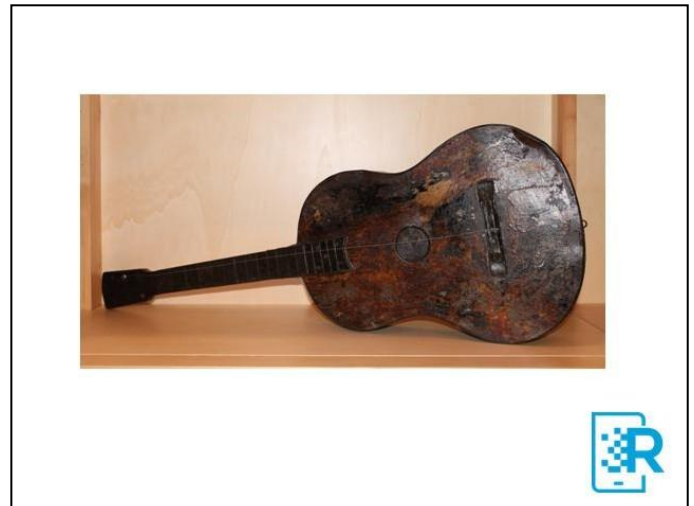Image 14 Trigger image depicting an imitation of the actual exhibit

Image 15 Trigger image depicting the exhibit

3.4 Implementation

HP Reveal Software will be used for the integration of augmented reality technology. To make easier the comprehension of the implementation process we will first present briefly the main characteristics of the HP Reveal app.

HP Reveal application

HP Reveal is a free augmented reality platform, appropriate also for people who do not have a technical background. It is available as a free app for iOS or Android-based mobile devices.

HP Reveal's image recognition technology uses a smartphone's or tablet's camera to recognize real-world images and then overlay media on top of them in the form of animations, videos, 3D models and web pages.

So, an AR experience has a trigger/marker that generates an overlay or aura. A trigger/marker could be, for example, a photograph, poster or an object. For the creation of an AR moment, someone should upload a specific trigger image and then on top of that an overlay (known as aura in HP Reveal). Also, to share the moment to the public someone should share their "auras" in public. After the creation of the moment, when the user points the camera at the trigger/marker, the overlay displays superimposed on the marker/trigger.

Usually, the auras work better when they are created at the HP Reveal Studio which someone can access at the URL's website and not from the mobile application itself.

The prerequisites for this application is a smartphone or tablet with a camera as well as internet connection. Also, someone could access the content of a specific channel only if they follow the channel as well as its public content.

The Implementation Process

- Creation of Auras at the HP Reveal Studio

After the development phase, the content was uploaded at the augmented reality platform HP Reveal. So, firstly the markers were uploaded and then the overlay videos and thus each "aura" was created. Also, in all the moments, it was integrated the action of making an overlay fullscreen after the overlay had started. Specifically for the "chest" moment , after the video overlay the user will be directed to a url with an online quiz. So, for this moment also the action of " open a url at a native browser" was added at the moment/aura.

Then, the created moments were shared for public use so that anyone that would follow our channel to be able to access them.

- Trigger images placement and testing in the exhibition

As it has been already mentioned for every exhibit, which has to be scanned with the AR program, there will be a sticker next to it, so as to indicate which exhibits are part of the AR experience.

So, the markers were printed and placed next to the exhibits as well as tested for the readability from the viewfinder of HP Reveal. The stickers which could not be read by the HP Reveal app were redesigned.

- "Documents" moment staging

For the "documents" moment a similar bag to the "correspondence bag" was placed near the "correspondence bag" as well as documents within it.

- Instructions

A sheet of instructions was placed at the entrance of the exhibition room which explained which application has to be used, which channel has to be followed, how to scan every sticker and other useful   information   regarding   the   multimedia   experience.
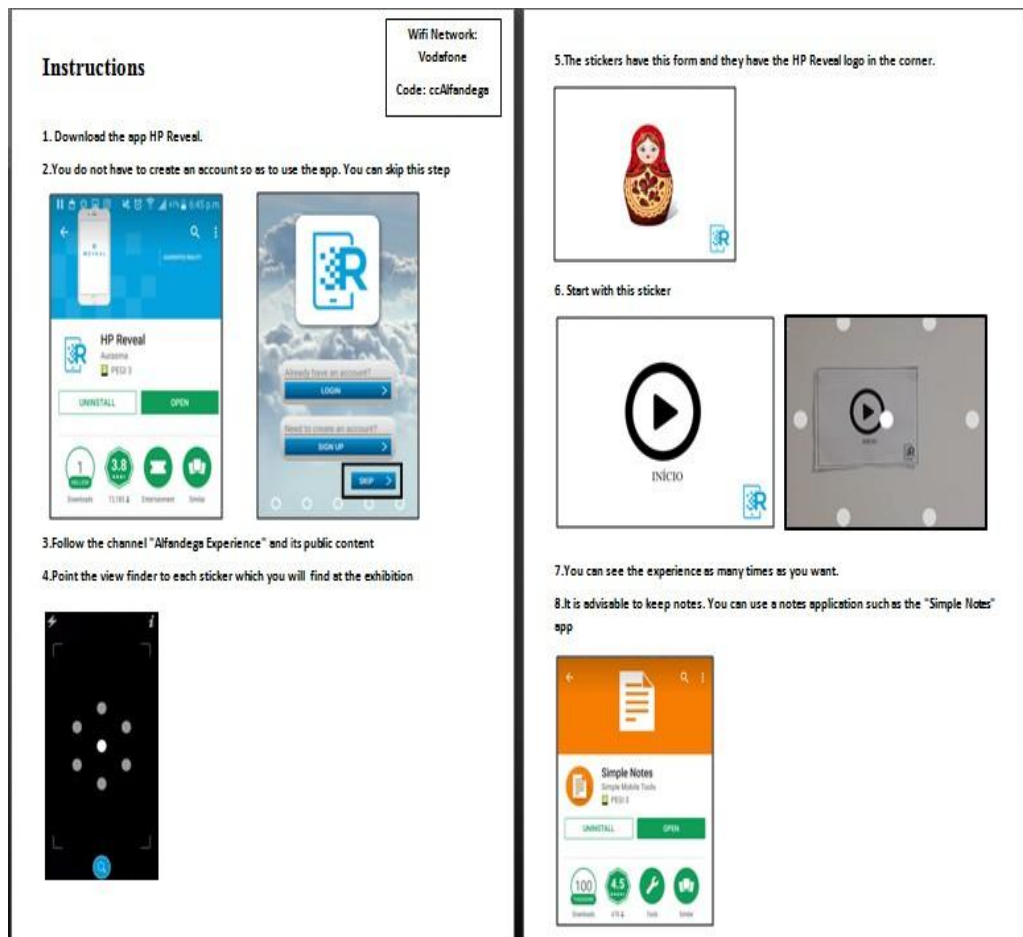

Image 16 The instructions

3.5   Evaluation/Testing of the Prototype

The evaluation of the first prototype of the multimedia experience was performed through the method of the experts' evaluation. This method seems to be one of the common user experience evaluations methods especially in the early phase of product development (Roto, Virpi & Obrist, Marianna & Väänänen, Kaisa., 2018)

The participants were five academics and practitioners in the areas of user experience design, museum studies and digital media. The first testing took place to the exhibition of Alfandega where the participants were called to participate in the experience and give feedback in real time.

The data collection method was through a form of a "free discussion" where notes had been kept and then validated by the experts. The main data/points that occurred after the first testing are the following :

VISITOR EXPERIENCE

- Players will cheat if they can do so. So, if some stickers are very close to each other, the visitors will scan both of them without caring about the indicated sequence.
- If there is sequence in the exhibition room, the route has to be intuitive. Regarding this project there is a problem when it comes to the route that visitors have to follow. For example, it is problematic that moment 3 is in the aisle right in front of the entrance while moment 2 is after someone having passed this aisle.
- It is hard for teenagers and kids to be focused and follow a specific procedure. They get lost very easily and that's why non-linear storytelling would be more appropriate for this age group.
- There is no need for QR Code Technology to be used since HP Reveal application can also load URLs which are needed in the " Zé Book" moment as well as the "chest" moment.

NON-LINEAR STORYTELLING

- Non-linear storytelling will solve a lot of the above problems and result to a more pleasant experience. Visitors should be able to explore and experience the space around them without having to follow a path.
- It should be advised to them to keep notes during the experience.
- Also, it is very important to "safeguard" the final moment somehow. One possible way is placing a warning sign next to the trigger image/sticker for the final moment which will inform the visitors that if they scan this sticker earlier than it should they will ruin the experience. A sticker with information about "Spoiler Alert" could fit at this case.

LINEAR STORYTELLING

If the experience will not be adjusted to a non-linear route as advised and the sequence will be maintained it is possible all the problems referred to arise as well as it is very important to take some precautions.

- The sequence should be indicated in the trigger images
- A map could also be shown at the end of each video so as to help the visitors navigate to the next sticker they have to scan.

INCREASE OF THE EDUCATIONAL VALUE/ LEARNING OUTCOME

- The results of a multimedia digital experience in a museum setting should not be only the entertainment of the visitors but also the increase in their knowledge.
- Adding interesting facts of educational value in the story could be a way to increase the educational value of the experience. Another way is to include some secondary moments in the experience.

FEEDBACK REGARDING THE CONTENT

Exhibits

- You should include at least one exhibit from every aisle/corridor in the story

- Include the collection of vintage clocks in the story

Trigger Images/ Stickers

- Stickers should not be placed on exhibits
- Stickers should have the image of the actual object/exhibit they refer to
- QR Code Stickers should also include the image of the exhibits they refer to

Documents Moment

- The bag used at this moment should be as close as it can be to the actual exhibit of the correspondence bag**.**
- The documents should seem old through handwriting as well as through coffee techniques that can make a paper seem old.
- The trigger images on the documents should be on the front side.

Videos

- Audio has to be included
- Scenes of videos are too-fast for reading
- The character font needs to be bigger
- Changing of the background to white or "wooden" one
- In the video of "correspondence bag" moment it should be made clear that the similar bag in moment "documents" includes four documents and only one of them is related to the mystery.
- In the alphabet soup in the "guitar" moment should not include hidden words diagonally since it is quite for them to be found.

Quiz in Moment "Chest"

- There is a problem with the translation in Portuguese in some parts (intro and first question)

Pdf in Moment 6

- The length of the text is too big. You could possibly add audio narration
- The pdf file is too big. It needs compression

3.6 Re-design of the experience

The expert's evaluation phase was followed by the re-designing of the experience.

NON- LINEARITY

The storytelling will mainly follow a non-linear path with only some linear moments which are intuitive for the player.

One of the moments which should have a specific order in the experience is the beginning moment whose trigger image is at the entrance, it has the indication "the beginning" and at the meantime it is advised in the instructions page to start from this trigger image.

Image 17 The trigger image/marker of the
beginning moment

The other moment which needs to be in order is the ending moments which consists of the "Ze Book" moment as well as the "final moment". Next to the markers of these moments it will be placed a warning sign that the players will have a "spoiler" if they do not unlock this moment only in the end. Also, it will be explained to them that they should firstly access the "Ze book" moment and then the final one.
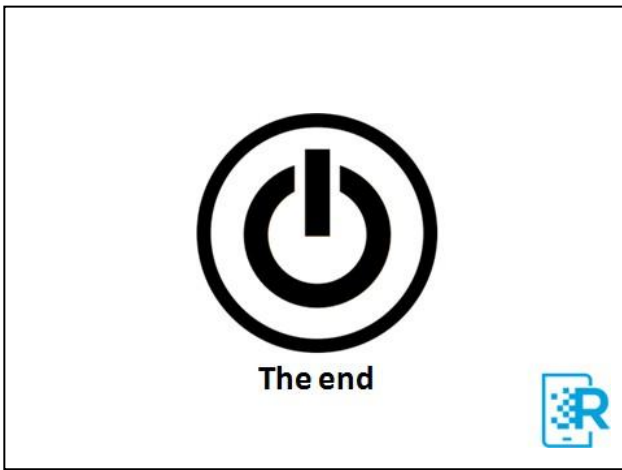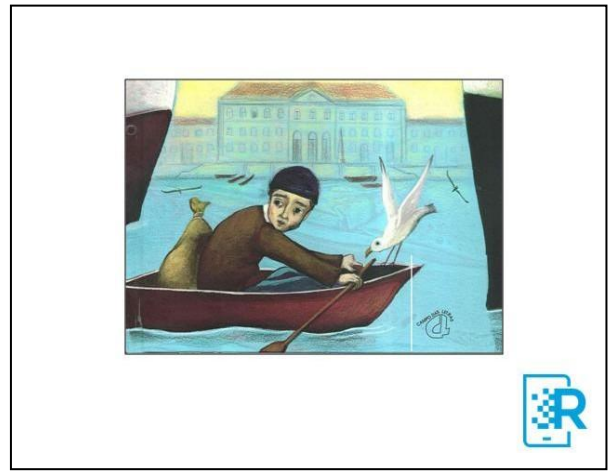
Image 18 Trigger image of the ending moment(7b)

Image 19 Trigger image of the "Ze Book" moment(7a)

Image 20 Leaflet with "spoiler" warning and instructions for the ending moments

The other moment which has a sequence is the "chest moment" which consists of a challenge and then a rewarding part for those that succeeded in the challenge. Only during the challenge part the position of the "reward" sticker will be revealed, which will be hidden behind the chest exhibit.

In addition, there are other two moments which are connected; the "correspondence bag" moment and the "documents" moment which because of their local proximity it is assumed that they will be played in a sequence. However, it is not obligatory to be played sequentially.

ADDITION OF THREE SECONDARY MOMENTS

Three additional moments were included so as every aisle in the exhibition room to have one augmented reality touchpoint. The moments that were created include interesting facts about the Laboratory of the Customs House, a challenge with four chairs, and another challenge with a focus on the clocks collection. These secondary moments share interesting facts about the exhibition and thus increasing the learning outcome of the visit. Also, one of the secondary moments includes the clocks collection which was advised to be included in the experience by experts in the first testing.
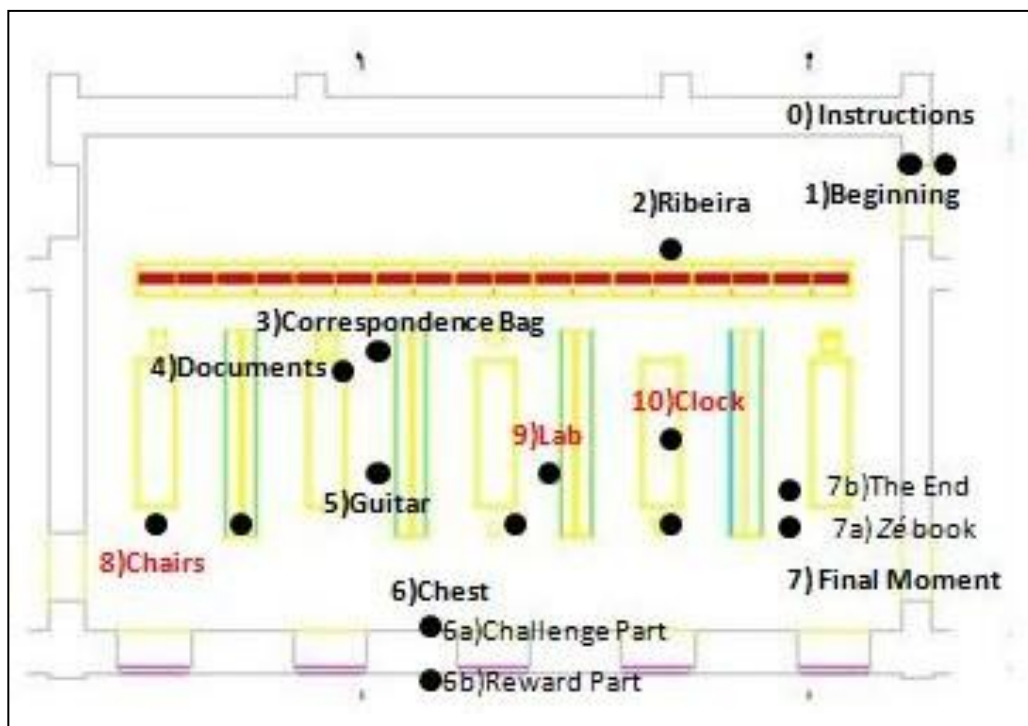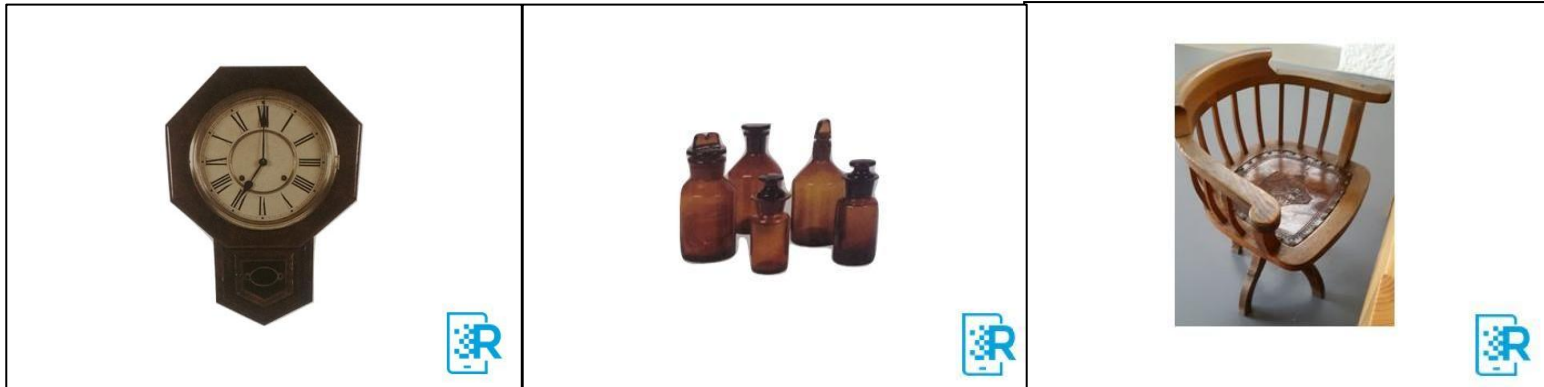

Image 21 The position of the trigger images of each moment in the
exhibition room as depicted at its floor plan. The red captions refer to the
secondary moments and the black ones at the key moments

Images 22,23,24: The trigger images of the additional moments

MARKERS

The markers that refer to a real object of the exhibition will depict the exact image of this object

Images 25,26 Trigger images representing specific exhibits as designed at the first iteration

OTHER CHANGES

- Audio was added to all the overlays. Also, the duration of the scenes of the overlays were increased. Furthermore, the font size will be increased when it is needed.

- The prototype of the experience will be in English and only the final experience will be translated in Portuguese since the author of this dissertation lacks fluency in Portuguese and external help should be asked

- The pdf of the "Ze BooK" moment will be available without the need of downloading from the users . The players will be able to access this document through GoogleDrive. Also, the length of thetext in this pdf was reduced .

- The quiz was done at Google forms since it was able to handle more features than the initial platform of the quiz "onlinequizcreator" which had limited options for free accounts. One of the features that changed was that the player now can play only once the quiz.

- QR Code Technology was excluded from the experience.

- The documents were handwritten and then soaked in coffee for making the paper seem old.

- The bag in the "documents" bag was handcrafted again to seem like the "correspondence bag"

- At the instructions part it was included the advice to the visitors to use a Notes app during the experience

- Alphabet Soup no diagonals

3.7 Second Evaluation

The evaluation of the second prototype of the multimedia experience was performed in a Laboratory in University of Porto where the main changes/improvements were presented.
The participants were the same individuals that participated in the first evaluation of the prototype.

Semi-structured interviews took place after the presentation of the second version of the prototype. The questions that were asked are the following:

Q1. Do you think that this version misses any improvements as discussed in the first iteration? Are there any other improvements which you would suggest for this prototype?

Q2.How do you find the experience? Could you make a SWOT analysis?

Q3.What elements do you like the most and which the least?

Q4.Do you think that this experience can be engaging for the age group of teenagers?

Q5. Do you think that this experience can enhance the visitor experience with disrupting him with the collection?

Results

Q1: Improvements

Improvements are fine compared to the first testing. However, there are some further improvements advised for this version of the prototype.

General improvements

Regarding the videos, there should be a clear sign that the video is ongoing like for instance the hands of the clock to move when there is timing in a challenge. Also, at the end of each video, there should be an indication when the video is over and that they should "double-tap" to exit the video and return back to HP Reveal application. In addition, removal of the "marble" background was advised since it is not relevant to the content and also thus the size of the videos will be reduced.

Chairs Moment

At the "chairs" moment the visitors should be able to scan every chair, in the same logic with the "documents" moment, to see which chair is the right answer. Also, the pace is different for every person so it would be nice to be adjustable. If the pace is too fast for someone it can make him get lost, and if it is too slow it can make him feel bored.

Feedback Moment

At the end of the experience, the visitors should be able to provide feedback in a digital way.

Instructions Leaflet

At the instructions leaflet the "Russian doll" image should be replaced because cultural elements should be avoided.

Beginning Moment

At the beginning video include the information about the duration of the experience; the minimum and the maximum since many visitors have a time constraint while visiting a museum.

Clocks Moment

You should overemphasize each possible answer at the quiz scene where the appearance of the text should be synchronized perfectly with the narration.

Documents

The trigger image of the documents are the documents themselves. Also, the handwriting should be of a higher scale and the pen should be different.

Guitar Moment

The scale of the "alphabet soup" should be higher

Q2: SWOT Analysis

Strengths:

- One of the main strengths of this project is its non-linearity since this can result to multiple types of experience since it is subject to each players' behavior. Another strong point is the replicability of the experience in other museum exhibitions.
- Another strength is the real context of the experience which is the physical space of the exhibition. This experience provides a different way to tell stories and approach the collection of the exhibition. There is a connection with concrete real exhibits which the visitors can face right in front of them. This connection is even stronger in this second version of the prototype since the trigger images depict the exact objects and not similar images to them.
- One more advantage of this project is it is not just a game. The game is the mediator/the facilitator and the content is important.

Weaknesses

- The visuals of the videos are not so good and graphic skills are needed. The prototype is still unfinished, unrefined. However, the documents are very good for a prototype.
- Also, the app HP Reveal imposes some limitations. For example, there are some limitations regarding the interactivity of the experience since someone cannot stop a video, move it forward or backward, and make the pace of the experience adjustable to him.
- The project does not have user testing with the target group of the experience.

Threats

- The space is not big enough so as to let people wander. However, there is no control of this factor.

Opportunities

- This project promotes a perspective, a way to interact, which can be engaging for people
- The approach is replicable to other museum contexts

Q3:Liked and disliked elements

I liked the most...

- Articulation with real objects and context
- Go and find moments, Visitor is seen as an explorer
- Playing in a physical environment

I liked the least....

- timing and pace. The pace should be adjustable to every individual. The pace of each individual should be respected
- Certain parts of the video
- The "marble" background of the videos

Q4:Age group

The structure of the narrative could work for the teenagers, where visitors are approached as "explorers" which fits well to this age group. However, the visuals of the videos should be improved drastically for this age group since it is an age group quite demanding when it comes to the visuals.

As it is, it seems more appropriate for pre-teens and especially in cases of family visits where pre-teens would play together with their parents or their grandparents.

Q5:Disruption

At this iteration, where the trigger images depict the actual exhibits , the experience is not disruptive to the visitor experience.

3.8 Re-Design and Final Experience

The improvements that were performed were less compared to the first iteration. Most of the proposals for further improvements were taken into account. However, it was not feasible to make all the improvements proposed because of time or media platform constraints. The main changes for this iteration are the following:

- The documents were created again with a bigger font and with a different pen
- The recording was performed again for some videos
- Alphabet soup image at "guitar" moment was scaled up
- Substitution of "russian doll" trigger image
- There will be animations as an indication that the video is ongoing
- At the end of each video there will be the indication that the video is finished and that if someone wants to exit from the video should tap twice
- An additional moment will be added, so as the people to be able to provide feedback for the experience
- The instructions leaflet will also inform the visitors which is the minimum and which the maximum time they need to complete the experience.

- At the chairs moment, there will be added trigger images at each chair which will inform the visitors if they found the right chair or not. The logic will be exactly the same as the "documents" moment.

- At the clocks moment, at the scene with quiz the narration will be perfectly synchronized with the appearance of each answer. Powerpoint will be used for it.

4. Enhancing the visitor experience in museums with augmented reality technology

This project aims to enhance and improve the experience of the museum visitors, especially for the age group of teenagers through the integration of mobile AR, storytelling and game elements.

The concept of the experience was inspired by the book with the title "Zé do Saco, o Contrabandista " written from Manuel Jorge Marmelo. This book refers to the story of Zé who was an employee in Alfandega Museum but also involved in smuggling practices.

So, the concept of the experience is about a smuggling case in the Customs House where Ze is the main suspect. This smuggling case was never solved and the visitors will be asked to help find clues for it. During this "mission", Tiago, will be the narrator of the story and will be helping the visitors to figure out what each clue means as well as giving instructions of how to unlock the content.

The experience will consist of several moments which some of them requiring active participation on behalf of the visitors and some not. In some moments, the visitor has to solve a challenge to unlock the "content". The challenges presented in these moments will be either physical ones, or digital ones. In the passive ones the visitor will unlock videos with information relevant to the story/mystery.

The visitors have to use the HP Reveal app and scan the stickers which they will find within the exhibition room and thus unlock a clue each time relevant to the mystery. It will be advised to them to use a notes app such as the "Simple Notes" which will help them gather all the evidence which needed to solve the mystery.

The storytelling mainly follows a non-linear structure except some specific moments where the linearity is stated or is intuitive. More information about the moments that have a sequence within the experience and the ways this linearity does not confuse the visitors can be found in section 3.6.

4.1 The Spatial Experience

Each bullet in the following image represents where each AR moment takes place in the exhibition room. All the moments are unlocked by the scanning of a respective sticker except the instructions moment, which actually has to do with the reading of some instructions about the multimedia experience as well as the documents moment where the trigger images are the objects themselves.

The moments which are written in black are the "key moments" while the ones in red the "secondary" ones. The "key moments" offer valuable information for the mystery solution while the secondary moments serve other purposes which will be discussed in section 4.2.2.

Someone could also observe that there is at least one sticker to be scanned in each corridor. This was not the case from the beginning but rather being purposed by the experts during the first evaluation.

Also, most experts believed that the intuitive route, in the beginning, will be in the corridor all front from the entrance with the paintings collection and the ending one at the final corridor.
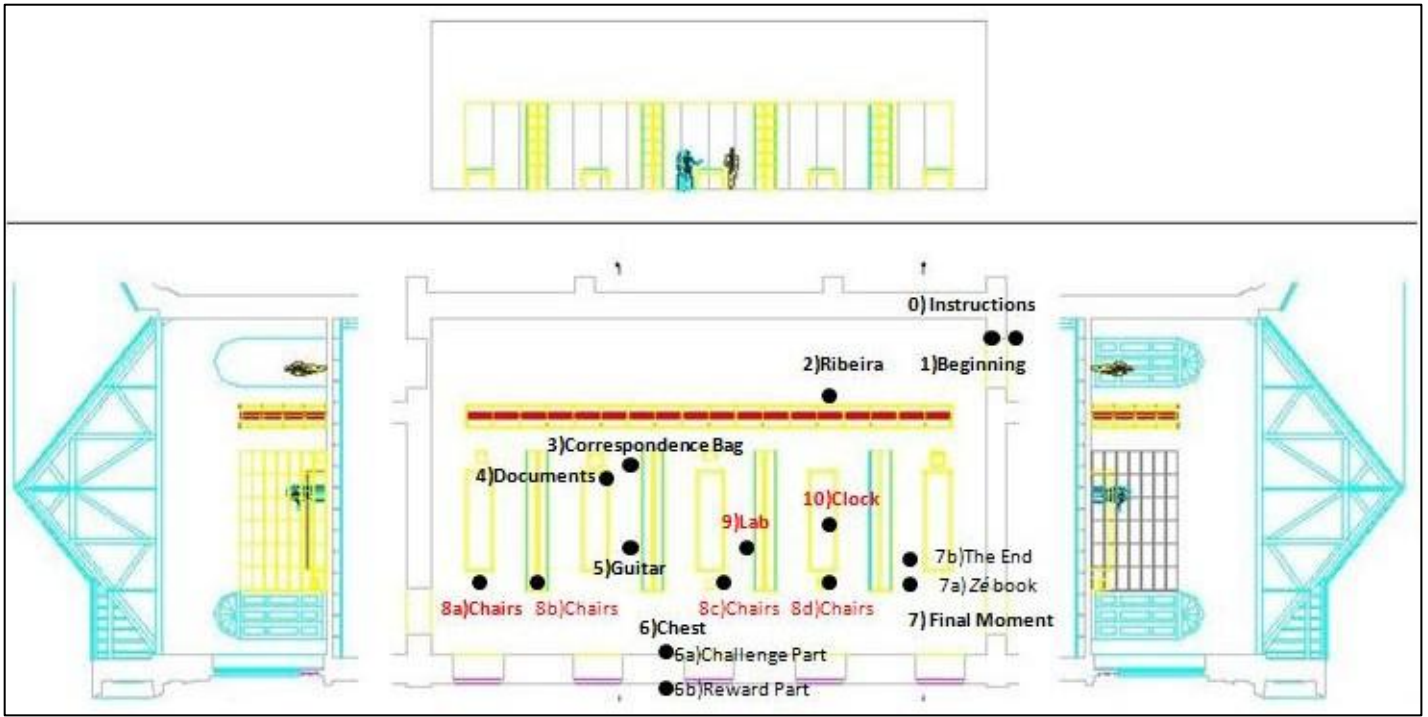
Image 27 The position of the trigger images of the secondary moments (captions in red) and of key moments (captions in black) in the exhibition room
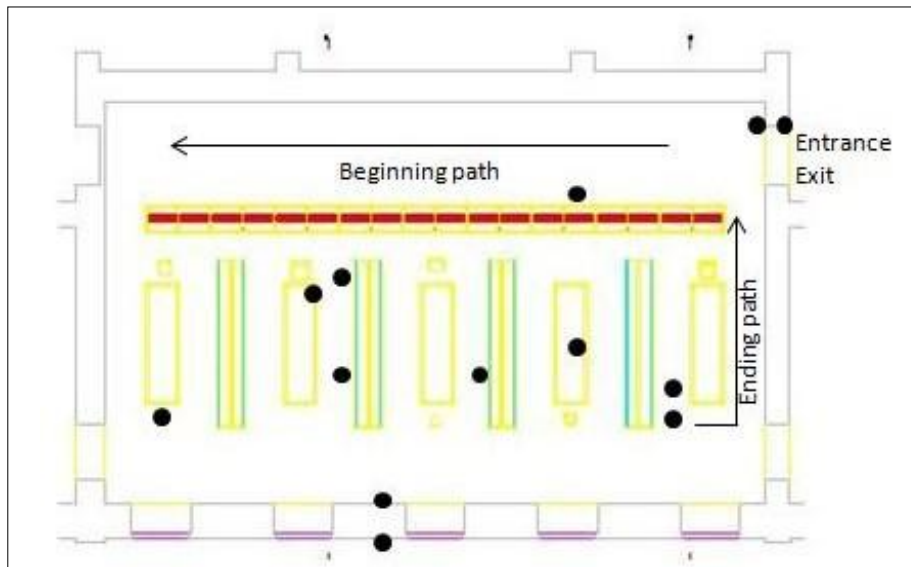

Image 28 The assumed most common beginning and ending path

4.2 The moments of the experience

There are moments that are considered "key moments" since they offer useful information for the mystery solution while others of them are "secondary" and serve other purposes such as increasing the learning outcome of the experience as well improving the spatial experience of the visit.
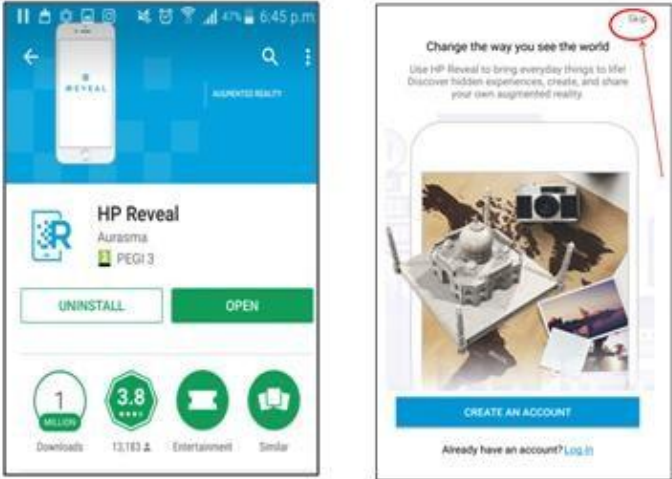
4.2.1 The key moments

0) Instructions:

The visitors will find an instruction leaflet [2] at the entrance. These instructions will refer to which application they have to download, how to connect to the wi-fi network, how to use it at the exhibition to unlock digital content, which sticker to scan first and to other useful information. After reading the instructions, they are advised to start from the moment 1.

---

[2] For the instructions leaflet check the Appendix

Image 29 The first page of the instructions leaflet

1) The beginning moment:

The visitors will have to scan through HP Reveal a sticker with a "starting button" image which symbolizes the start of the experience. After the scanning, they will be able to watch a video of Tiago, the narrator of the experience. Tiago will welcome the visitors to the museum, introduce the challenge regarding an unsolved smuggling case to them and motivate them to participate in this experience.

Image 30 Trigger image of the Beginning moment

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2) "Ribeira"

The visitors will have to scan the sticker with a painting from Ribeira which is located in Section1.

Then they will watch a video which consists of two scenes and narration from Tiago. The first scene will show 2 men at Ribeira talking with one of them holding a chest in their hands. Also at the first scene, Tiago will inform the audience that one of the men in the scene is Zé and he is a former employee of Alfandega.

The second scene will show leaving Ribeira with a bag at his back. The narrator Tiago will assume that there was a smuggling transaction between the sailor and Zé and that Zé hides the smuggling item, the chest shown in the first scene, in his bag.

Tiago will assume that the treasure chest is a smuggling item and urge the visitors to search what is inside the treasure chest to find more clues about the case.

Image 31 Trigger image of Ribeira Moment

3) "The Correspondence Bag"

After the scan of the respective sticker, the visitors will watch a video of Tiago who will tell the visitors that the exhibit has some useful documents about the case but they cannot access them since the exhibit is protected by glass.

Then, he will explain to them that they can find copies of these documents in a similar bag which is under the table. Also, he will inform the visitors that even if there are 4 documents in the bag only one of it offers useful evidence for the case.

Image 32 Trigger image of "The Correspondence Bag" Moment

4) The Documents

All of the documents will have stickers on them and the visitors are called to scan the document that they think that it is more relevant to the case.

The right document addresses the smuggling case pinpointing the main suspects as well as proposing a video surveillance system at Ribeira whereas the most smuggling transactions take place. If the visitors scan the right document, they will watch a video which will explain to them that this is the right document and will analyze the evidence it offers.

The other documents will refer to some other practical everyday matters in the Customs House such as some changes in the legislative framework of fish taxation, additional codes in PAUTA code, and a new registration at the Employees book. If the visitors scan the "wrong" documents, they will see a video which will inform that they selected the wrong document and that they have to try again until they find the right document. Important is to note that only in these case the trigger images of the objects will be the objects themselves.
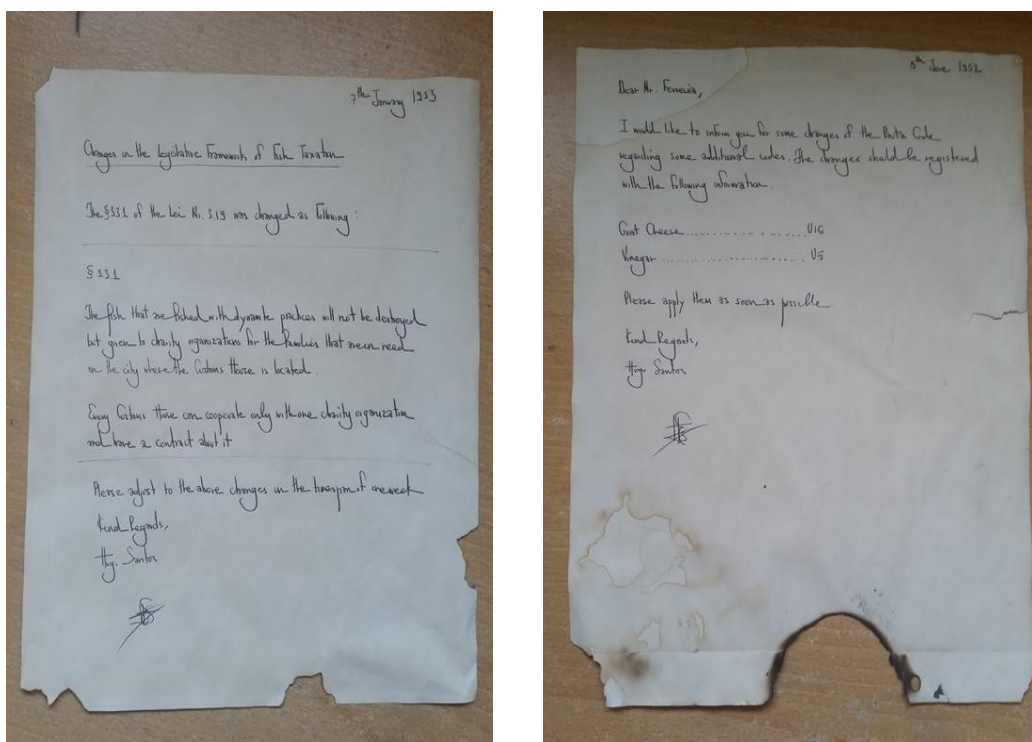

Image 33 Sample of the documents which will be placed within the similar bag to the "correspondence bag".

5) The guitar

Then visitors will scan the sticker with the image of the guitar exhibit and will watch a Prezi presentation which includes two small challenges. The first is about an alphabet soup where they are asked to find 6 words in one minute. The second challenge asks from them to select one of the items that represent these words as the smuggling item which is hidden within the guitar. After they have selected one item it will be revealed the smuggling item; an olive oil container.
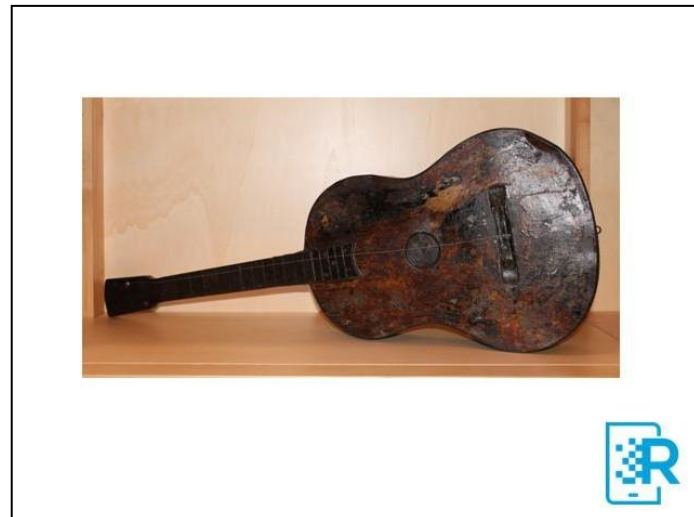

Image 34 Trigger image of the "guitar moment"

6) The Chest

These moments consists of two parts. The first refers to a challenge and the second can be accessed only if the visitors will have a satisfactory performance in the challenge. If they do not have a satisfactory performance they can try another challenge, the clocks challenge, to gather the points they need.

6a) The challenge

The visitors will scan the sticker with the picture of the chest and will be linked to an URL (https://goo.gl/forms/Os2ZXqX0AveA9Xtx2) which will present an online quiz with 4 questions Those who will answer right to at least half of the questions and therefore gather at least 10 points will be rewarded with a "winners sticker".

For those who will not have a sufficient score there will be the chance to gather these 10 points through "the clocks" challenge, which is referred at the next pages.

Image 35 The trigger image of the chest challenge

6b)The reward

The "winners sticker" will unlock a video which will show what is hidden inside the chest; a guitar. This clue is very important for the solution of the mystery.
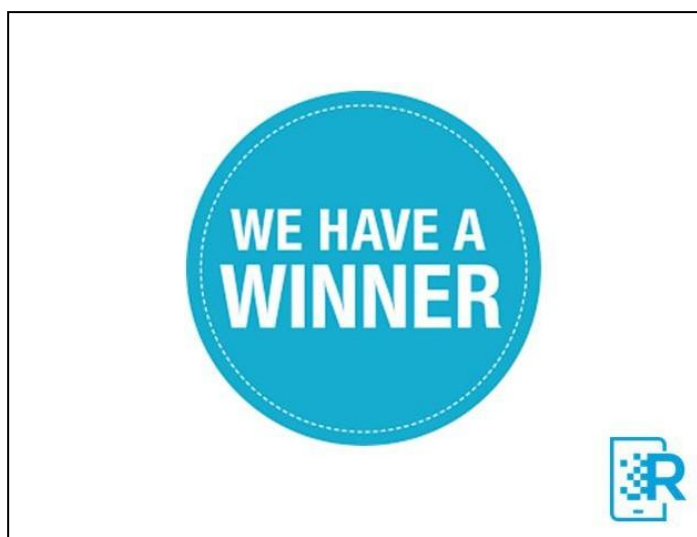

Image 36 The trigger image for the "reward part " of the "chest challenge"

7) Final moment

The final moment is consisted of two moments; the Zé book moment and then the "The End" moment.

Image 37 Leaflet with "spoiler" warning and instructions for the ending moments

7a)Zé book

A sticker with an image from the cover of the book that refers to the story of Zé " Zé do Saco, o Contrabandista " will lead to a pdf with a chapter from the book. In reality, it is not a chapter from the book but a chapter written by the designer of this experience so as to fit with the rest of the moments.

In this pdf, it will be explained that Zé was smuggling olive oil as a means of survival for him and his family. There will be also an image which will show Zé and his family using the smuggled olive oil container for their dinner.

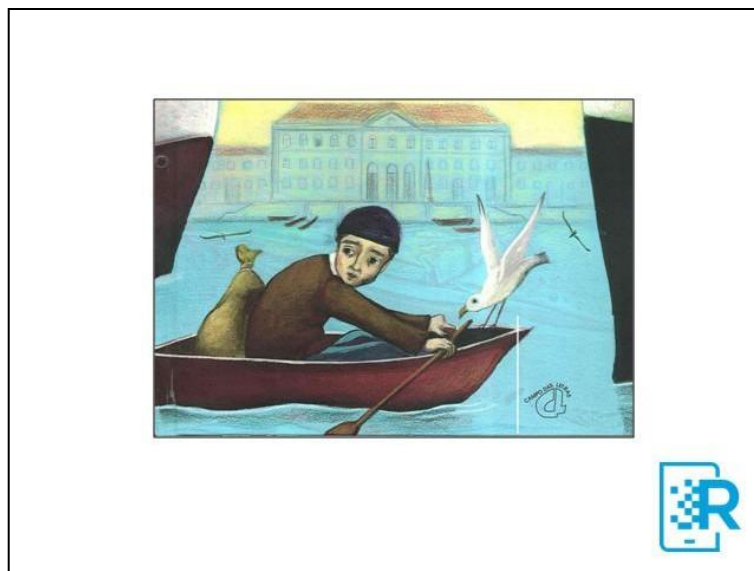Image 38 Trigger image of " Zé Book" Moment

7b) The Ending moment

A sticker with a "power off" image will unlock the final moment of narration from Tiago.

Tiago will explain who is the culprit in the mystery, his smuggling method, his motives and the smuggled item and thus present the solution of the mystery. In the end, he will farewell the visitors with the excuse that it is time for a snack for him.
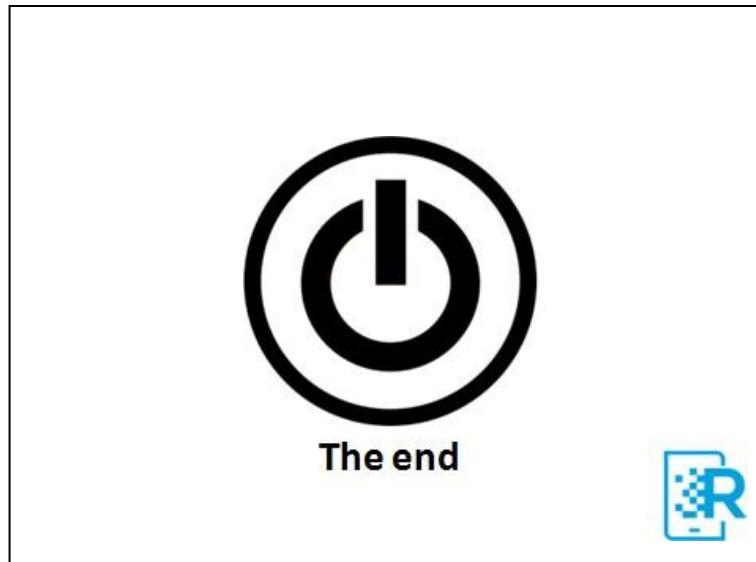
Image 39 The trigger image of the "final moment"

4.2.2 The secondary moments

These secondary moments were added after the first testing of the experience according to the feedback given from the experts. The experts advised to have an AR moment in each aisle/corridor/section of the exhibition since some corridors integrated three AR moments while others did not have any. Therefore some aisles would remain unexplored by the visitors. In addition, they propose to include the clocks exhibition at the experience since it could be quite engaging. Also, these moments were included to increase the learning outcome of the experience thus containing information of educational value.

8) The chairs challenge

The marker in Image 39 will unlock a video whereas the narrator urges the visitors to search which of the rest of three chairs that are in the exhibition room belongs to the director of the Customs House; Mr. Moreira.

The trigger images of the two chairs at image 40 and image 41 will inform the players that they did not find Mr.Moreira chair.

The marker at image 42 will inform the visitors that they have found the right chair and arise their

curiosity if the clue that Mr. Moreira was the director of the Customs House is useful for the mystery solution. In fact, this moment is not very useful for the solution of the mystery but it offers a small help to the visitors for the "documents moment". The information that Mr. Moreira is the director of the Customs House emphasizes the importance of the "right" document whereas the recipient of the document is Mr. Moreira. Thus it helps to be selected by the visitors in the documents challenge.
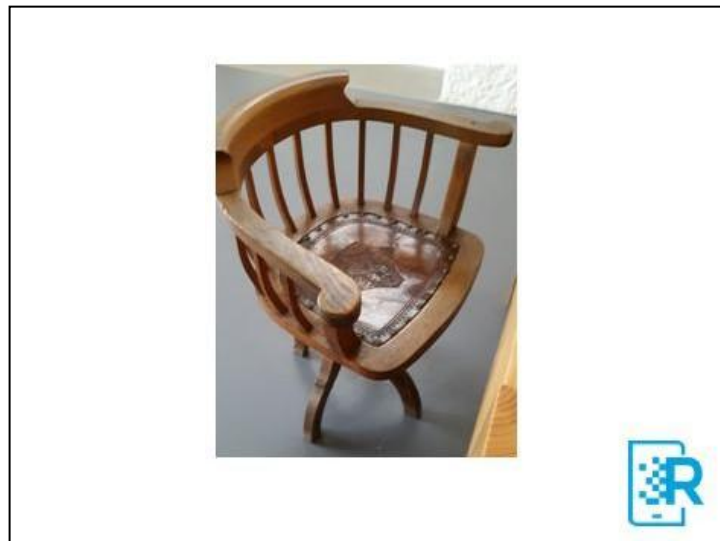

Image 40 The trigger image of the "chairs" moment at point (8a in the map)

Images 41,42 The trigger images of the "wrong" chairs (8b,8c in the map)

Image 43 The marker of the sought chair (8d position in map)

9) The laboratory

In this moment, it is stressed the usefulness of laboratories in Customs House so as to avoid counterfeits and smuggled products through some interesting examples. One of the examples presented is that without chemical testing, someone cannot distinguish a powdered baby formula from a milk protein concentrate, a substitute made with glucose syrup and colorants from natural honey or modified starch for industrial use for wheat flour.

The link of this moment with the main storyline is through the smuggling concept where at this moment possible smuggling techniques are investigated.
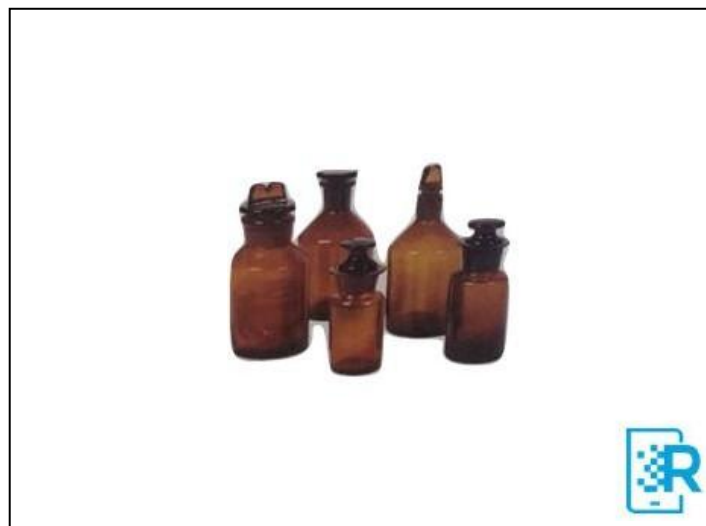

Image 44 The trigger image of the "Lab" Moment

10) The clocks challenge

This is a secondary moment and does not offer so useful information for the mystery solution. It serves as a second chance for the players that failed at the "chest challenge". Also, it was included in the experience after the first testing with the experts where it was advised to include the clock collection in the experience since the experts' pinpointed it as an eye-catching collection.

So after the scanning of the respective sticker the visitors will watch a video where they will be asked to assess a clock image and find what is weird about it. Afterward, it will be revealed to them that the number 4 on the clock is not written according to the Roman Numeral and they will be asked to guess why this is happening. Those who will answer right they will be given 10 points. In this way we make sure that everyone will be able to access the reward part of the chest moment.

Regarding the educational value of this moment, it offers information of why clock makers preferred to use **IIII** instead of **IV** and the most possible explanations of this incidence.

Image 45 The trigger image of the "clocks" moment

5. Discussion

In this chapter, the main design principles and the limitations will be discussed as resulted from the expert's evaluation as well as from the whole design procedure through the "trial and error" process

- Linear & Non-Linear Storytelling

Regarding the linearity and sequence in an augmented reality experience in a museum context, a non-linear route seems to be more appropriate for a number of reasons. During the first testing of the prototype with the experts, it was stated that visitors especially in the age of teenagers, like to wander, explore a space and have the freedom to behave and play in the way they feel like. Also, the visitors' route cannot be controlled since there are many paths that someone could follow within the space. Someone for example, could go from Section 2 to Section 5 and avoid passing through sections 3,4 (image1). So, a more flexible structure and narrative would be more pleasant for the visitors as well as more appropriate for this exhibition room where the exhibits have a fixed location within space. A non-linear structure would give more freedom and flexibility to the designers since they do not need to take into account the route of the visitors within space. Thus, they could connect the exhibits in any order. For example, a designer who would create an AR experience based on a linear storytelling should not have the touchpoint 1 at the fifth section, then touchpoint 2 at third section, then touchpoint 3 at the fifth section and then touchpoint 4 at the third section because it would be tiring for the visitors. Alternatively, with non-linear storytelling, the visitors would be able to access touchpoints 1 and 3 and then touchpoints 2,4 with only an one-way route from one section to another.

If however, the augmented reality experience follows a linear path it should be intuitive for the visitors. This could be accomplished if the trigger images will be placed in a sequence which would follow an easy route within the space, if the sequence is indicated at the trigger images, or if an interactive map will be provided which will help the visitors to navigate.

- Storytelling vs. Information Sharing

As stated by of the supervisors of this project, storytelling can be much more engaging than the mere sharing of information and facts related to the exhibits. In addition, it was emphasized that the storytelling should be organic and coherent. However, even if storytelling is a common practice in museums, when digital technologies are used the message tends to be in the form of information and data about the history of the object. This can be exciting and serve the learning objectives but the relationship to the artifact or place remains objective and distant. Storytelling can create a more intimate, subjective and emotional connection and allow the visitor to feel empathy with history and characters. Storytelling is considered the first, and most essential form of human learning (Bruner 1990). The dramatic interpretation can allow the museum visitor to be connected with, 'a knowledge that is felt than rationally understood' (Witcomb, 2010)

- Educational and Learning Outcome

During the first iteration, it was also stated that while designing a digital multimedia experience for the museum, someone should have in mind not only impressing and entertaining the visitors but also increasing their knowledge. The learning outcome of multimedia experiences that take place within museums is very important since the mission of a museum lies in the knowledge promotion. Education is one of the key activities of museums, together with keeping, research ,and presentation of museum objects. (Skyrda Maryna et.al 2012) Generally, there is a tension between the requirements for pedagogical outcomes and making the heritage more impressive through virtual and augmented reality technology (Kenderdine, 2010). Museums need to find the right balance between authenticity of the historical information and the need to tell an entertaining story (Ioannidis et.al.2013). However, this tension somewhat eases, when the interpretation takes the form of a quest or a game or interactive digital storytelling, which applies to the content and structure of our project.

- The pace

The pace of each player/visitor should be respected. If the pace of an experience is too fast for an individual, they may be lost, and if it is too slow it can be boring for them. Thus, the pace of the experience should be adjustable. However, this is not feasible in HP Reveal platform and maybe an interactive application would be more efficient to solve this problem. Falk and Dierking (2008) also claimed that the physical context of a museum exhibition can only enhance the visitor experience if individuals can personally tailor the visit, which in a technology-enhanced context includes customizable mobile tools.

- Time Constraint

The time constraint should be taken into account in such experiences since every visitor has a different availability in terms of time. Therefore, he/she should be informed what is the minimum and what is the maximum duration of every multimedia experience of this structure.

- Markers

In relation to the markers for the augmented reality platform HP Reveal, it seems like the exhibits themselves are not often a good option because the change of the lightning or the reflections of their display cases makes them hard to be recognized from the application. The same limitation was faced by the "Riot 1831@ Nottingham Castle" project which is also based on AR technology. As stated, because the historic objects require protection from excessive light, restricting where they could be placed within the gallery restricted the range of museum objects that could be used. (Patel R. & Tuck D.2014) On the contrary, using small pieces of paper depicting images of similar objects or the very same objects can result in a much better performance of the AR application in terms of image readability and recognition. This happened since someone can place them in the position with the best lightning, avoid reflections, change their scale, the resolution of the images depicted, even the images themselves and thus select what works better for the application through "trial and error". One way to always make a "trigger image" in the form of a paper more easily and faster recognized by the HP Reveal application is to add a title along with the image since it seems that words along with images are more easily read from the AR object recognition systems of the application. Also, as observed at the Riot 1831@ Nottingham Castle' project high contrast images work better than low contrast ones. (Patel R. & Tuck D.2014). One important detail regarding the trigger images in the form of a paper is that the trigger images should never be placed upon the exhibits for preservation reasons.

- Markers and Disruption

There are cases where the visitor's mental model discords with the design of the exhibition that they are interacting with (Norman, 2013), changing the focus from the experience into the design itself, interrupts the flow (Csikszentmihalyi, 1998); which eventually leads to frustration and negative user experiences.

For avoiding this phenomenon, it was pinpointed at the first iteration from the experts that the trigger images should depict the exact image of the objects and not similar objects since this could confuse the visitors.

- User Feedback

Also, during the second evaluation, the experts claimed that feedback from the visitors/user is very important for experience design since it can result in further iterations and improvements. Thus, it is proposed a feedback moment be included in the end of the experience ideally through the platform of the application. In HP Reveal, this could happen if after the final "overlay" people will be led to an online query through a URL.

- Guidelines for HP Reveal

Regarding the video overlays, when such an overlay is accessed through HP Reveal, there is not a bar at the video where someone can check if the video is ongoing. That's why there should not be long periods of still images because the user may think that the video is over and terminate the moment. Also, it is important to add an indication at the end of each video overlay that the video is finished and if someone wants to exit the video should tap the screen twice .

In addition, during the creation of "auras" where the overlays are uploaded at the platform HP Reveal it was observed that if there is not an action added like for example to make the overlays full screen, the visitors should keep the mobile phone exactly in front of the trigger image until the end of the overlay, so as not to lose the digital content. This can be very problematic since it is not realistic to expect from the visitors to not move their hands at all. So, it is strongly recommended to use the actions "make overlay full screen" or "make overlay full screen with camera open" or other actions which will overcome the above problem. However, the result when the overlay is superimposed on the trigger image is much closer to the definition of an augmented reality experience.

5.1 Limitations

The main limitations of this project are imposed by the platform HP Reveal, the limited human capital and therefore the limited skill set for a multimedia project, the lack of funding, and the time constraint.

The Platform HP Reveal

In regards to the platform HP Reveal, there are many limitations which affect negatively the interactivity of the experience. As already mentioned someone do not have the control to stop a video, move it forward or backward, check the duration of the video and adjust the pace/speed of the experience to their preference. This can result in dissatisfaction, quitting, or boredom.

Also, regarding the challenges that someone could perform through the platform there are some important limitations. HP Reveal does not include the option of performing a quiz through the platform which means that someone should stage a challenge through a URL in a native browser or find other indirect ways. Also, the application fails to perform two overlays at the same "aura" even if this option is available at the platform. So if someone desires to stage a digital challenge with an introduction overlay and one after the challenge cannot have everything in a single aura.

As already mentioned, there are "entry barriers" for accessing the content such as the download and the creation of an account. Other platforms allow users to sign up through other accounts like Facebook, Googledrive or Instagram account which requires less effort from the users.

In addition, the application HP Reveal undergoes a lot of updates which make the platform not unavailable for many days which makes the platform unreliable as a platform of the experience for this period. Also, the mobile application is not perfectly synchronized with the web application.

Budget, Human Capital and Time

This project was implemented only by the author of this dissertation who did not have any prior experience with graphic design, 2D animation, video editing, audio editing and recording. Also, the narration part should be performed by a native English speaker actor which the lack of funding could not allow it. This fact along with the time constraint allows the above skill set to be developed only at a beginners' level. The budget constraint did not help in either hiring some people performing specific tasks or using software which could cover the skills shortage. The Renderforest software was used so as to tackle the 2D Animations skill shortage but without a paid subscription the resolution is too low, at 360 pp. Also, the graphic design and 2D animation skills could be "covered" through the Prezi program which also requires a paid subscription.

Time was also a limitation since the implementation finished in May and from May till July there were not scheduled any school visits at the museum so that an experiment with the targeted audience group to be conducted.

6. Conclusion & Future Work

This research was designed to address the compelling need of the modern museum to understand its audiences, their preferences, behaviors, and responses to technology-mediated experiences.

The focus of this research is how the use of mobile AR technology can enhance the visitor experience. The main objective is to provide design principles and guidelines which will help practitioners to design mobile AR experiences which will effectively enhance and improve the visitor experience in a museum context without disrupting the main focus from the physical space itself. The audience group of teenagers will be the focus of this research.

The main points that have been answered are the following research questions :

- Would a non-linear experience be more appropriate for teenagers than a linear one?
- How can a linear experience have an intuitive route?
- How should be designed the markers for an augmented reality application?
- What are the design guidelines regarding an AR platform?
- What are the limitations of a commercial AR application such as HP Reveal?

For answering the above research questions a project with mobile AR technology integration, storytelling and gamification took place in a permanent exhibition of the Alfandega Transport & Communications museum. This exhibition is named Metamorphosis of a place: museum of customs , and it focuses on explaining the transformation of the building from a former custom house to a cultural centre and a museum.

Regarding the linearity of the experience, it is strongly recommended a non-linear structure for the experience for the age group of teenagers. The age group of teenagers is not a group which would like to follow a specific route and would like to "explore" the space in their own way. However, if the experience will follow a linear structure it should be accompanied by an interactive map, an intuitive route in the space and stated sequence on the trigger images or other ways to make the route easy for the visitors.

In regards to the markers that will be used at HP Reveal, it is strongly advised to use images of the actual exhibits at the form of a paper/sticker and with a title on them if the image is hard to read. The exhibits themselves should not be the trigger images because someone should find a very specific angle, having very good lightning which is not always the case, and it could be proved cumbersome. Very important is that the trigger images/stickers should never be placed on the objects themselves for preservation reasons and also be placed in the best possible location in terms of readablity/recognition from the AR platform.

When HP Reveal is used someone should not try to upload two overlays at the same moment, select markers that are fastly and easily recognized, warn users/players that when the overlay is over they should tap twice to exit the video, finding a way to indicate that the video is ongoing.

As already mentioned at the discussion chapter, the main limitations of this project are imposed by the platform HP Reveal, the limited human capital and therefore the limited skill set for a multimedia project, the lack of funding and the time constraint.

In regards to the platform HP Reveal, there are many limitations which affect negatively the interactivity of the experience. As already mentioned someone does not have the control to stop a video, move it forward or backward, check the duration of the video and adjust the pace/speed of the experience to their preference. Also, regarding the challenges that someone could perform a quiz directly through the platform. Also, there are "entry barriers" for accessing the content such as the download of the account. In addition, the application undergoes a lot of updates which make the platform not unavailable for many days which makes the platform unreliable as a platform of the experience for this period. Also, the mobile application is not perfectly synchronized with the web application.

Other limitations resulted from the lack of budget, the human capital and the limited time span. This resulted from the fact that all the development and implementation parts of the project should be performed by the same person, which means that there was no expertise in every area. A multimedia project should be run from a multimedia team especially when there is no budget for contractors hiring. Also, the limited time span resulted in the failure of the conduct of an experiment with subjects from the audience group of the study which will however be conducted in the future.

Regarding future iterations of the project, there will surely be a user testing with the audience group of teenagers. Also, the visuals and the resolution of the overlays, as well as the narration, will be improved significantly. Also, in the next iteration the whole experience will be translated in Portuguese to be in the native language of the main audience in the Alfandega Museum.

Regarding future work, other AR platforms could be researched and compared with HP Reveal to conclude if they impose fewer limitations to the designer and offer a more personalized and interactive experience, have less "entry barriers" to access the content , offer challenges with answer selection within the platform or the option to add two overlays at the same "moment". In addition, other promising reality technologies like MR and VR could be integrated and be compared to AR in relation to their effect on visitor experience in museum contexts. Also, VR is the second most preferred interactive technology for teenagers in the context of museums (Cesario et.al, 2017)

Regarding the significance of this study, this research lessens the gap that exists for empirical studies in museum literature in the area of visitor experience when there is technology integration and specifically AR technology. As the review by Kirchberg and Tröndle (2012) noted, "museum studies literature rarely focus on the experiences of museum visitors. This gap in museum study literature comes across even more in the context of the application of technology in museums (Pallud & Monod, 2010). Specifically, regarding AR applications, they are mostly tested for usability and are evaluated to validate internal museum goals, but rarely are they a tool in better understanding the visitors and their experiences.

Also, this research offers a replicable non-linear solution which integrates AR technology and can enhance the visitor experience in museum contexts. It also offers design guidelines for augmented reality experiences which involve actual objects and take place in a physical space. Furthermore, this research offers important guidelines of how HP Reveal platform could be used and how its limitations could be overcome as resulted from the expert evaluation and the phases of development and implementation of the experience.

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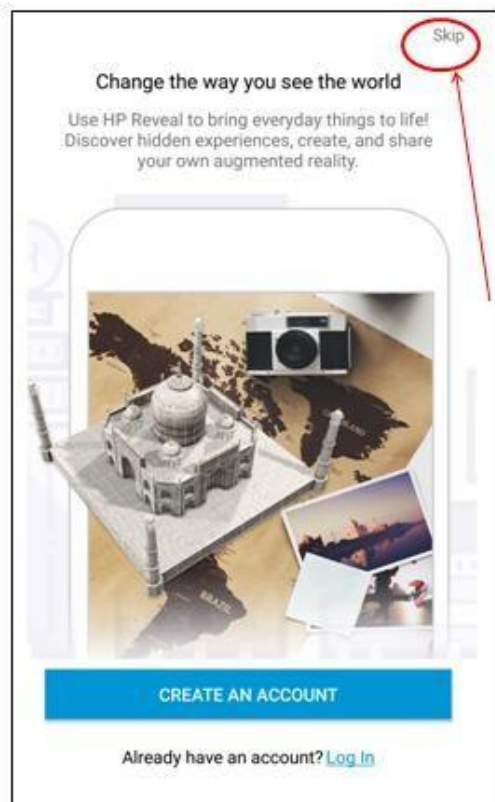
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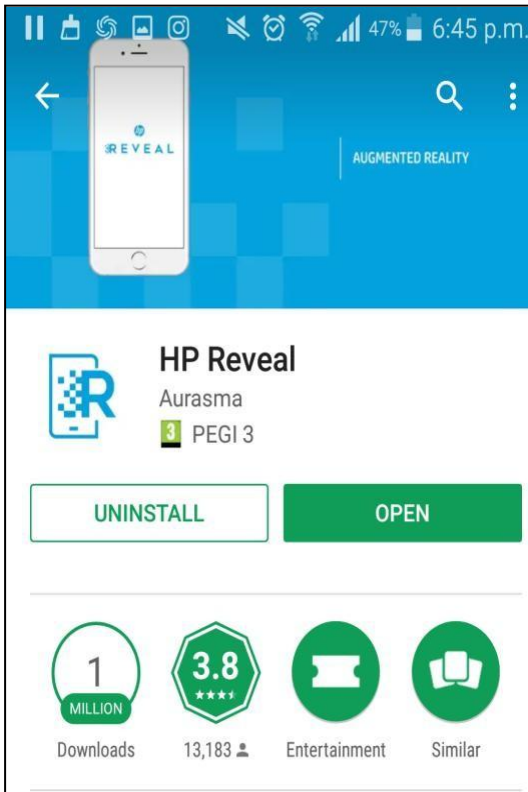
8. Appendix

8.1 The instructions leaflet

Instructions

1. Download the app HP Reveal.

2.You do not have to create an account so as to use the app. You can skip this step.
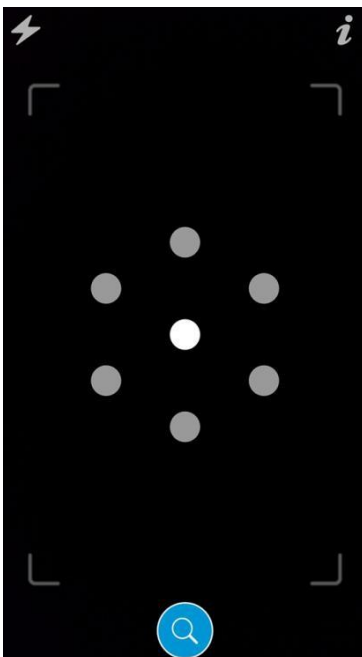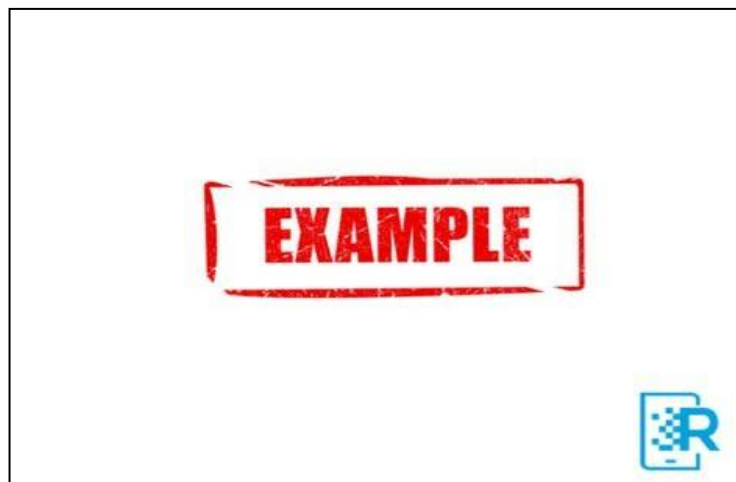
3. Follow the channel "Alfandega Experience" and its public content

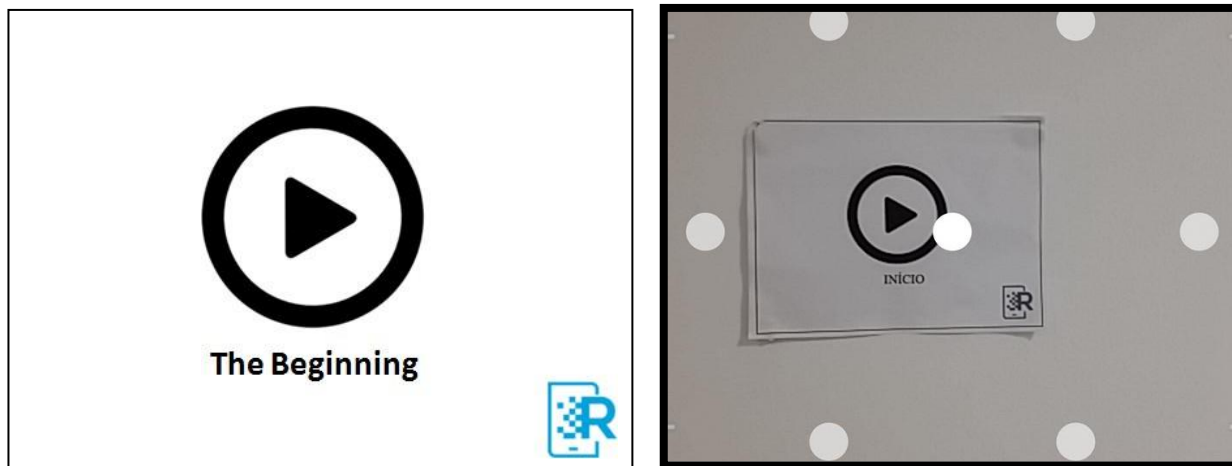**4. Point the view finder to each sticker which you will find at the exhibition**

**The viewfinder
mode of HP Reveal**

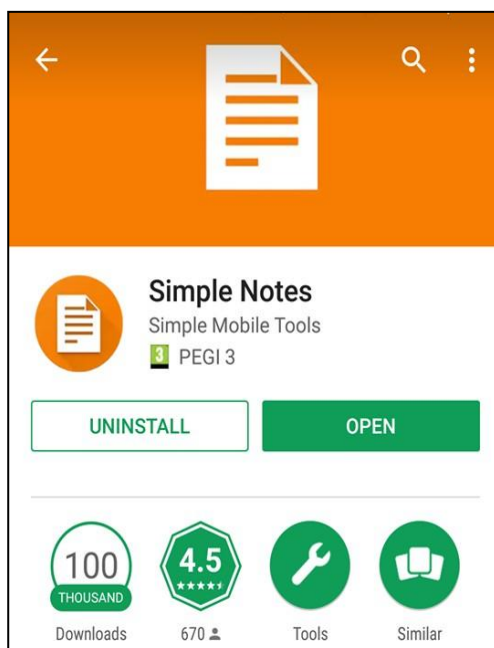**Example of how the stickers
look like**

6. Start with this sticker

7.You can see the experience as many times as you want.

8.It is advisable to keep notes. You can use a notes application such as the "Simple Notes" app

9. The experience can last from 15 to 45 minutes. When you feel you have figured out the solution to the mystery you can check if you are right, here.

You are here

The answer/solution
to the mystery
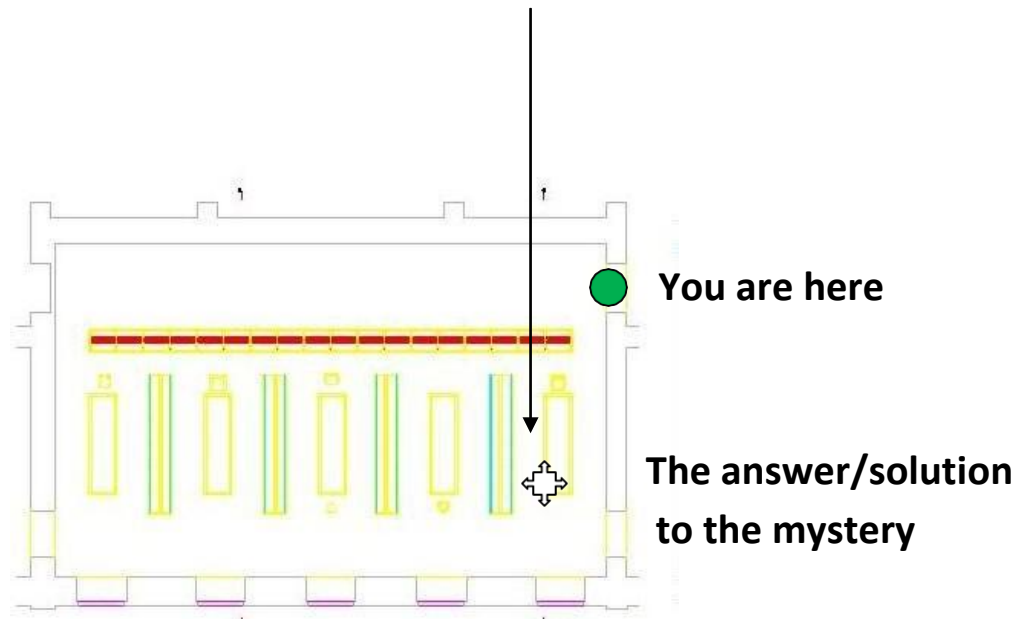
8.2   The Chapter from Moment " Zé Book(7a)"

Capítulo 8

O uso do azeite

O Zé deixou a Ribeira com o peito coberto com um pedaço de pano e caminhou até à sua casa. Ele costumava viver num bairro pobre muito longe da Alfândega numa casa que recebeu de herança do seu pai. A casa era centenária e com graves problemas resultantes de longo tempo sem manutenção adequada, mas eram problemas que o Zé não podia resolver com o pouco que auferia. A comunidade local partilhava o mesmo sentimento de luta. Devido a isso, todos partilhavam e ajudavam no que podiam. O Zé era conhecido por contrabandear comida e todo o excesso que tivesse que não fosse para a sua família, trocava por outros alimentos de maior ou igual necessidade, ou até utensílios. Para o Zé, e outros membros da comunidade, não viam com mal o que faziam. Para eles era uma questão de sobrevivência e não havia espaço moral para questionar o civismo ou até a legalidade das suas ações quando eles próprios e as suas famílias sofriam de estômago vazio. Havia um entendimento entre os comerciantes e os pescadores com o Zé, não propriamente para explorar gananciosamente a situação, mas para ajudar aqueles que mais precisavam contornando a lei.