Interactive Mixed Reality Technology for Boosting the Level of Museum Engagement

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Abstract

Holographic immersive technology such as ‘Mixed Reality’ is nowadays extending in the cultural heritage sector to open new prospects to engage visitors in museums. This paper investigates the level of engagement in the museum space by conducting observations and time consuming at the Egyptian Museum in Cairo. An interactive mixed reality system named ‘MuseumEye’ was developed and used Microsoft HoloLens as a mixed reality head mounted display to boost the level of engagement with the exhibited antiques. This system was experienced by 171 of the Egyptian museum visitors and another observation was conducted to record their behaviours and the time they consumed next to each antique. Results of this study showed the time consumed to engage with holographic visuals and the exhibited has been increased 4 times compared to the time the visitors consumed before without using technological gadgets. The implications of these immersive technologies can be an important vehicle for driving the tourism industries towards achieving successful engaging experiences.

Keywords: Microsoft HoloLens; Engagement; Museums; Usability; Mixed Reality; Observation.

1 Introduction

Mixed Reality (MR) is trending the last few years on enhancing the museum engagement and the visiting experience when it incorporates with museum tours (Hou, 2019; Pollalis et al., 2018). Engagement is defined in different manners by different authors (Brodie, Ilic, Juric, & Hollebeek, 2013; Higgins & Scholer, 2009), such as attachment (Dwayne Ball & Tasaki, 1992), or emotional connection (Marci, 2006). Taheri, Jafari, and O’Gorman (2014) identified three drivers for engagement in tourism: prior knowledge, multiple motivations and cultural capital. Regarding engagement in museums, it enhances the visitors’ consumption experience (Edmonds, Muller, & Connell, 2006). Normally, successful engagement is measured in museums by the average time spent in the space. However, the time may be consumed in other facilities in the museum such as the coffee shop (J. Falk & Storksdieck, 2005). Therefore, engagement for museum visitors is better represented in spending time with the interpretation techniques and creative presentations (Welsh, 2005).

HoloMuse as MR system impacted on boosting the level of engagement by incorporating interactive holographic in museums that can be manipulated by hand gestures (Pollalis, Fahnbulleh, Tynes, & Shaer, 2017). Other scholars used MR storytelling on the exhibits to engage visitors (Darzentas, Flintham, & Benford, 2018). Also, MR technology has been exploited to produce multiplayer games in museums to increase the engagement with co-visitors in museum spaces (Holloway-Attaway & Rouse, 2018). Many scholars attempted to engage visitors with the cutting-edge of MR systems and headset, however very few emphasised on providing an evidence of an actual impact these technologies on the museum engagement. This study employed a series of observation studies to provide metrics that can measure the level of engagement in museums specifically after adopting MR technologies. Also, this study built a new interactive holographic MR system using Microsoft HoloLens as a headset to boost the level of engagement at the Egyptian Museum in Cairo.

1.1 Pre-study

Based on a prior interview with one of the Cairo museum's curators, it was stated that either national or international museum visitors usually spend an average one hour in the museum, including roaming and touring. Based on the nature of the museum and its number of collections and rooms, this phenomenon was unusual as it also contradicts other studies that report that the average time spent in museums varies between 120 and 180 minutes (Chia, Yeong, Lee, & Ch'ng, 2016), and between 90 and 240 minutes in the Louvre museum (Yoshimura, Krebs, & Ratti, 2016). Many factors, can influence the time spent in museums such as economic, psychological, socio-demographic, trip-related factors (Brida, Nogare, & Scuderi, 2017), entry time, exhibits and number of visitors (Yoshimura et al., 2016). This research focuses on the time spent in front of the exhibited antiques and investigates how the visual experience and information was retained during the tour. A methodological exploration action was planned to take place due to the lack of essential information that the research could acquire from the literature review.

The prior observational studies used the approach of the random time sampling technique to capture the time consumed in the room of King Tutankhamun, which is located on the second level of the Egyptian museum. The observational study captured 20 participants of the daily museum visitors via a fixed camera fitted to different locations at different times. Visitors who observed where stood next to 4 different exhibits that belongs to the King Tut. The preliminary exploratory observation concluded that forty seconds was the average duration that visitors usually spend in the museum room without using guide tools or gadgets.

The average of the time spent is = (total spent time by sampled visitors) 812 ÷ (number of sampled visitors) 20 = 40 sec.

This research adds to the snowballing body of evidence that MR technology can reshape and change the museum visitor's experience.

2 System overview

In order to measure the influence of the MR technology on the touristic engagement levels, this research embarked to create an interactive holographic MR system using

Microsoft HoloLens (Microsoft, 2015) as a holographic immersive headset that supports the mobility and hand gestures interactions for users on the spot of action. The system made to cover 10 antiques in the museum room.

2.1 Functionality

For the sake of fulfilling all visitors' needs and accomplishing the museum guide's objectives, a comprehensive list of functions – depicted in Table 1 – was formed. Some functions were adopted from previous mobile guide studies that were suitable for the nature of the system. Also, several other new functions were built to exploit the device's abilities and achieve the aim of the system.

Museum professionals were involved in discussing the proposed functions in order to evaluate them with respect to different museum exhibits. Also, software developers were invited to discuss the possibility of the proposed functions from a technical perspective.

The system functions vary according to their classification, which can define the particular action that the visitor performs while using the system. The categories were tackled as per the below descriptions. Fig. 1 demonstrates the functionality of MuseumEye next to the museum exhibits.

- 1- Visual Communication: It is necessary to achieve direct communication between the visitor's senses and the system's visual and audio sources, as part of the immersive experience. So, a set of functions were designed to enrich the experience with various forms of communication during the tour such as spatial scenery, and animated avatars.
- 2- Guidance: This involves a set of functions that involve visual and acoustical signs and cues, which guide the visitor around the museum room e.g. holographic labels, images, videos and interactive virtual replica of the authentic antique.
- 3- Interaction: This involves set of functions that utilise the headset's hand gestures to interact with spatial visuals. These functions aim to open up several ways of interaction between the visitor and the two realms; e.g. User interface (navigation and controls), interactive portals for each antique and knowledge scale game.
- 4- Communication: This is essential to create lines of communication between the visitor and the virtual guide to transfer knowledge and give instructions, using audio and visual clues. These functions are such as; virtual storyteller of the King himself, audio narration, capture images and collaborative shared experience.

Functions/ Tasks	Description	Category	Purpose
Spatial scenery	It represents historical scenes composed of buildings, antiques and representations of characters – ancient Egyptian gods – considered to have spiritual power in ancient Egyptian culture. All of these virtual items will be mapped	Visual communication	Make the visitor fully immersed in both realms.

Functions/ Tasks	Description	Category	Purpose
	and superimposed on top of the physical room including ceiling, walls and floor.		
Storytelling by virtual guide performance	<p>Stories or narrative content were synthesised from reliable sources. This content is animated and performed by the virtual guide who is the avatar of King Tutankhamun. The explanation is supplemented and synchronised by images which are augmented where the guide points.</p> <p>The virtual Tutankhamun is life-size, and his way of acting is like as a human guide.</p>	Communication	<p>Enrich the visitor with contextual information in an interesting manner.</p> <p>Providing the visitor with a customised guide so the visitor can listen and watch the explanation.</p>
Script Text	A visible script in text format, to be triggered by the user.	Guidance	It allows visitors to catch up with the ongoing explanation if part of it was missed. It provides an additional channel specifically for visitors with hearing loss.
Images	Augmented images upon visitor hand interaction. These images represented the antique's condition when it was discovered. Moreover, these images were taken by the discoverer of the exhibited item.	Guidance	Enrich the content with different layers of visual information. Moreover, most of these images are not available to visitors. Bringing these images while seeing the real antique is beneficial. It also exposes visitors to in-depth visual information if they are interested in more exploration.

Functions/ Tasks	Description	Category	Purpose
Audio narration	Audio commentaries by a narrator were produced from academic references in an interesting manner. They are synchronised with displayed images that are referred to in the commentaries for further clarification.	Communication	This function is the essence of museum guidance, is to listen to a guide and look at the antique simultaneously. It provides an effective response to one of the patterns observed among visitors, namely the tendency to read labels with loud voices. Therefore, this function is built to ease the mission of reading to others aesthetically.
Air tap/ Hand interactions	Interaction – by hand gestures such as air tapping- is possible in several ways: <ul style="list-style-type: none"> - Moving between scene - Reveal item's images - Reveal item's script text - Use the UI navigation buttons - Spin or rotate the virtual replica of the item. 	Interaction	Interactions can boost the level of engagement with visitors. As long as the user keeps interacting with the system, it means the information continues to feed into the user. Therefore, demanding information is a positive sign for knowledge retention.
Knowledge scale game	It is an interactive game for discovering secret and thrilling information about each antique. Around each antique, there are small interactive circles, which reveal secret information next to them. It reveals this information by spinning the antique via hand gestures of the user's hands.	Interaction	This educational interactive is designed to improve user engagement and information retention.
Videos	An introductory and informative video about the museum collections and the particular collection exhibited is covered in the system.	Guidance	Watching videos during the experience will add diversity to multimedia visuals. Videos have visual effects, text and images, created to be interesting for the visitor. Also, the visitor can skip the displayed video if he/she gets bored.

Functions/ Tasks	Description	Category	Purpose
Scenes portal points	Based on HoloLens' user location hotspots feature, MuseumEye provides interactive scene portals that are placed at key areas of interest. Once the user stands on top of it, it takes the visitor to the particular scene which is relevant to the item at that position.	Guidance	It is a direct and physical way to access scenes that include the particular guided methods, relevant to each exhibited antique. It is also part of the multi- scenarios design of the tour.
Orientation of Portal points	Auto-orientation occurs of the portal points that are capable of facing the visitor's position. Portal names will always face the visitor.	Visual Communication	Auto-orientation of the text is a fundamental ergonomic aspect of the system. The title of the scene informs the user of the name of the exhibited item if the user is at a distance from the item. Besides, it provides access to the scene.
Taking a photo / screenshot	The visitor can take a picture or screenshot of what he sees in MuseumEye using a voice command.	Communication	<p>This function allows the user to capture and share what he/she sees to others.</p> <p>It is a response to the museum visitors' behaviour pattern, which was discovered in the pre-study observational analysis, namely the tendency to take photos.</p>
Collaborative shared experience	It allows a group of visitors who wear the HoloLens headsets to see what the single visitor can see. It is a collaborative experience, which means all interactions are also possible for co-visitors who are in the same network connection.	Communication	This function encourages social interaction and opens prospects for open discussion between visitors. Hence, more interaction leads to gaining more knowledge about the context. This function was also built based on visitors' patterns explored in the pre-study, namely that visitors tend to walk in groups and have conversations next to the exhibited antiques.

Functions/ Tasks	Description	Category	Purpose
Animated characters	As part of the scene design, each character performs a particular animation to compose an epic and a harmonic glimpse of ancient Egyptian lifestyle.	Visual Communication	This results in more influence on the sense of immersion in the mixed realms environment.
Tap to Place portals	<p>A hand gesture to interact with the scene portal and place them next to the relevant antiques. It is a protected function for museum curators who can access it through a combination of a keyword and hand gesture.</p> <p>Also, 'tap to place' is utilised when the scene opens in front of the physical item. It gives the user the possibility to place the scene wherever he/she wants.</p>	Interaction	Working remotely with the museum guidance system was not easy to allocate the scene portals by the system creator. So, once the system creator places these portals in their right places, they will be allocated at these pointed forever. This function is also protected from the user but not protected for the museum curators if they want to change the exhibited items' locations. Once the user accesses these scene portals, they would see an entire scene with a set of visuals that can facilitate the needed guidance for the exhibited item.
Interactive virtual replica of an original item	Large-scale replicas of the authentic exhibited items were created to display virtually next to the physical one. It is also interactive to explore the virtual replica from different angles and observe details that are not possible to perform in the real museum.	Guidance / Interaction	To add partially the sense of controlling the object by 3D interaction as the user controls the authentic item. Hence, visitors can rotate and move the virtual replica as a sort of compensation for touching constraints that the visitor face towards the authentic one.
User Interface (Navigation and Controls)	It is a wide and curved user interface that faces the user in the antique's scene, where the authentic item is placed next to the visitor.	Interaction	The user interface provides the user with various types of controls that lead to the growth of the visitor's interactions skills. It also provides the user with the freedom to enter or leave the scene whenever he/she wants.

Table 1.0 List of MuseumEye functions

Fig. 1. Participants are observed while using the MR museum guide - MuseumEye

2.2 System architecture

The MR system developments always be constructed by creating 2D and 3D assets and gesture interactions that can fulfil the designed functions.

The creation and development of the MuseumEye system took four stages as depicted in Fig. 2:

- 1- User Interface: Designing the system's user interface requires the creation of UI design elements and UI interaction design.
- 2- Spatial Content Design: This process involves creating the interactive portal points which were designed to be placed in front of the exhibited items to open interactive scene to the particular antique. Also, it includes the creation of the location design of holographic objects.
- 3- Antique UI Panel: This stage involves creating all visual communicative functions such as images, videos, and 3D holographic of the antiques' replica.
- 4- 3D Content Design: This stage includes creating 3D characters and 3D environment assets and all required assets for the narrative scenes.

We used Unity with HoloToolKit for developing the MR system with the 3D software packages such as Maya, zBrush and Substance Painter. Also, Microsoft Visual Studio has been adopted for deploying the application on the headset.

Fig. 2. MuseumEye content creation

3 Method

The observation method has been frequently in museums to understand visitors' behaviours (Bollo & Dal Pozzolo, 2005; Lanir et al., 2017; Thrun et al., 1999). The observation method aims to record visitors' behaviours in the actual environment regarding the antiques exhibited. These behaviours include their movements, time spent next to/ in front of the antique, and how they react. The other aim of using observation is to conduct a critical comparison between the human behaviours in the current state of museum guidance and these same behaviours after applying the research solution. This comparison can visually demonstrate the differences in the engagement level and highlight the significance of using MR gadgets in museum tours.

171 of the daily museum visitors participated and observed in this experiment. This sample size was equal to the study conducted by Rubino, Xhembulla, Martina, Bottino, and Malnati (2013). Many museum studies relied on specific measurements to assess how people were attracted to exhibits such as '*Holding Power*' (Bollo & Dal Pozzolo, 2005; Hooper-Greenhill, 2006; Lanir et al., 2017; Serrell, 1997).

'*Holding Power*' is measured by calculating the total time spent in front of an exhibit, and is used to measure the visitor's interest. This measurement informs the preliminary

idea of the power of an exhibit to hold the interest of a visitor (Bitgood, 2017).

Fig. 3. Participants are observed while using the MR museum guide - MuseumEye

4 Results

After observing the 171 participants during experimenting MuseumEye next to the targeted antiques, it was found that:

Time spent on exhibited items: the average time a visitor spent in front of each exhibited item was 177 seconds ($\approx$ 3 minutes).

In order to get the “Holding Power Index”, the utilisation time necessary is needed to be defined. According to several interviews with experts and curators who work in this museum room, the antiques adopted for observation require from 1 to 2 minutes (90 seconds) as sufficient time to stay next to each of them for gazing and reading labels. This value represents the ‘*utilisation time necessary*’, which is required for the later observation analysis.

$$\text{Holding Power index} = \frac{\text{Average stopping time}}{\text{Utilisation time necessary}} = 177 \div 90 = 1.96$$

This measurement informs the preliminary idea of the power of an exhibit to hold the interest of a visitor (Bitgood, 2017).

As mentioned earlier, the preliminary observation studies measured the average of the time spent is 40 seconds.

$$\text{Holding Power index} = \frac{\text{Average stopping time}}{\text{Utilisation time necessary}} = 40 \div 90 = 0.4$$

The observation included the consuming of the content as the participant kept watching the virtual guide from 10 to 100 seconds, with an average of 36 seconds. Also, the spent from 1-8 minutes on the storytelling scenes with an average of 6 minutes.

The observation captured six different patterns on behaviours. The first pattern was that some participants seemed to be hesitant in using the MR system, especially with performing the hand interactions. Therefore, they asked for assistance during their tour. Regarding the second pattern, the observational camera and the written notes captured that some of the participants were smiling before, during or after their tour. The third pattern was that there were some participants who seemed familiar and confident with the system during the tour, as they did not ask for assistance and kept walking freely. The fourth pattern revealed a group of participants who had the same attitude of exploring the environment and keeping moving around themselves to discover the surrounding virtual world. The fifth pattern exposed a group of participants who accidentally faced crowds in front of their faces. This might obstruct the spatial visuals or cause issues with interactions’ functionality, however, they seemed stable and engaged with the storytelling demonstrations. Furthermore, the sixth pattern represented a group of participants who were witnessed talking and smiling to their peers as they were trying to inform them what they could see.

5 Discussion and Conclusion

Time has been adopted as a robust and unobtrusive measure of museum visitors’ attention (J. H. Falk, 1982; Serrell, 1995). The aim of designing MuseumEye and employing it in the Egyptian Museum in Cairo was achieved which extends the time

that visitors spent in the museum. When comparing the results between the observation of the exploratory study and during the usage of the guide system, the Holding power increased from 0.4 to 1.96 respectively (from 40 seconds as an average to 177 seconds). According to Bollo and Dal Pozzolo (2005) "*The closer it is to 1, the greater the ability of the element to hold the visitors' attention will be*". Therefore, the system was able to draw visitors' attention to the visuals seen around the exhibited antiques and the interaction they had to perform to gain more knowledge. Also, MuseumEye as a guide system can draw the attention of the three types of museum visitors: the greedy visitor, the selective visitor, and the busy visitor, which were categorised by Sparacino (2002).

Comparing the outcomes of the observation's statistics of this study with other studies that adopt technologies to extend visiting time, it was concluded that MuseumEye could extend the time much higher than other studies did. This study increased visiting time by 440% compared to the time visitors used to stay in the same room. When reviewing other studies, it was found that a study was conducted by Proctor and Tellis (2003), who were able to extend the time spent from 45-minutes using portable audio to 55-minutes using a multimedia tour pilot. Another study also extended the time from 49.6 minutes without using guides to 59.3 minutes with using a museum guide (Lanir, Kuflik, Dim, Wecker, & Stock, 2013). Moreover, an old study (Robinson, 1928) aimed to extend the time spent using a pamphlet guide, which increased from 17 minutes (unguided) to 28 minutes (guided). Another project could extend the spent time from 5 minutes to 10 minutes using a mobile guide (Wang et al., 2009). A mobile application used to boost the engaging time in museums for students from – as an average - 92 seconds to 117 seconds compared with the usage of worksheets (Cahill et al., 2011). AR tools also has been used to expand the time of interacting and learning in museums from 133.28 to 206.74 seconds (Yoon & Wang, 2014). Another study calculated the time consumed by visitors who used the guidebook as it resulted 20,57 seconds compared to who did not use it which resulted 13.26 seconds.

If MuseumEye was adopted by the museum and scaled to include numerous collections of the museum antiques, visitors could spend many hours, which could result in days' worth of exploration, instead of approximately one hour in the regular visits.

5.1 Future work

Based on the adopted approach, many activities can be held in museum rooms to boost the attraction levels in museums (Smith, Gomez, & Cortes-Rivera, 2019). Interactive holographic games can be designed to be played within the museum, based on quests that can be requested from visitors e.g. collect relevant relics or shooting historical villains.

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