A Framework for Constructing and Evaluating the Role of MR as a Holographic Virtual Guide in Museums

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Keywords: Mixed Reality; Virtual Guide; Museums; Holographic System; Microsoft HoloLens.

Funding: This project was funded by Newton-Mosharafa scholarship which was managed by the British council in Egypt.

Conflicts of interest: No conflict of interest.

Authors' contributions: This paper is constructed from my PhD thesis under title "Virtual Guidance using Mixed Reality in Historical Places and Museums" in 2019. The co-authors contributed as follows:

- *Minhua Ma*; is the PhD supervisor who actively contributed text and critical analysis of the work presented in this article.
- *Ziad Al-Klaha*; he is an expert in statistical analysis and he contributed by reviewing the PROCESS statistical method to demonstrate the quantitative results in a better form.
- *Carl Strathearn*; he is a computer programmer and he helped in the technical programming issues in the Mixed Reality system; in addition, he enhanced the clarity of discussion section of the article.

Declaration: This manuscript has not been published and is not under consideration for publication elsewhere.

Ethics approval: The project was granted an ethics approval from Staffordshire university through an ethics committee as part of my PhD project in 2018. The ethics approval included revealing human figures who participated voluntarily in the study and signed the consent forms.

Abstract

Mixed reality (MR) is a cutting-edge technology at the forefront of many new applications in the tourism and cultural heritage sector. This study aims to reshape the museum experience by creating a highly engaging and immersive museum experience for visitors combing real-time visual, audio information and computer-generated images (CGI) with museum artefacts and customer displays. This research introduces a theoretical framework that assesses the potential of MR guidance system in usefulness, ease of use, enjoyment, interactivity, touring and future applications. The evaluation introduces the MuseumEye MR application in the Egyptian Museum, Cairo using mixed method surveys and a sample of 171 participants. The results of the questionnaire highlighted the importance of the mediating the role of the tour guide in enhancing the relationship between; perceived usefulness, ease of use, multimedia, UI design, interactivity, and the intention of use. Furthermore, the results of this study revealed the potential future use of MR in museums and ensured sustainability and engagement past the traditional visitor museum experience, which heightens the economic state of museums and cultural heritage sectors.

1. Introduction

With the advent of virtual reality (VR) and augmented reality (AR) in the cultural heritage domain over the last two decades (Fenu & Pittarello, 2018; Schaper, Santos, Malinverni, Berro, & Pares, 2018; Sylaiou, Mania, Karoulis, & White, 2010). These technologies have enhanced the visitor experience and reshaped the traditional physical borders with the creation of innovative windows into the past, present and future (Trunfio, Campana, & Magnelli, 2019). The application of AR in museums enhances and visualises essential visitor information and increase interaction with other technologies and multimedia elements (Antlej et al., 2018). Moreover, AR technologies propagate longer exhibit and display interactions and instigate greater visceral learning than the typical museum experience (Pujol et al., 2012).

Significantly, virtual museum guides enhance engagement and social interaction between visitors (Kopp, Gesellensetter, Krämer, & Wachsmuth, 2005b). These virtual guides can increase the attendance and attention of museum visitors (Burgard et al., 1999; Rzayev, Karaman, Henze, & Schwind, 2019), and increase the economic state of tourism as a vital source of income (Rosentraub & Joo, 2009). Typically, museums employ communication systems that include: senders, receivers, and channels of communication which facilitate the transmission of verbal and non-verbal information to the visitor (Cameron, 1968; Munodawafa, 2008). However, museums employ such systems to relay information and content indirectly, which often results in visitors missing essential information (Knez & Wright, 1970).

Therefore, the use of guiding roles such as 'Mentor' and 'Pathfinder' received a considerable amount of attention in museums and cultural heritage sites (Best, 2012; Cohen, 1985; Zhang & Chow, 2004). As a result, many studies refocused on the role of the tour guide and how to educate visitors (Best, 2012; E. Hooper-Greenhill, 1999; Horn, 1980; Mancini, 2000; Pond, 1993; Zhang & Chow, 2004). For instance, Best (2012), concluded that museum visitors prefer the AR guides to enhance the education experience. Therefore, fulfilling the visitors' needs, the evolution of the virtual guidance is classified in two components:

a) VR systems that guide visitor by re-imaging exhibits (Zuk, Carpendale, & Glanzman, 2005), support and provide customer navigation (Boland & Johnson, 1996). (Owen, Buhalis, & Pletinckx, 2005), and immerse visitors with holographical content (Kateros, Georgiou, Papaefthymiou, Papagiannakis, & Tsioumas, 2015). Moreover, mobile VR devices enhance museum guidance by adding relevant directions, information and content using the visitor's location (Damala, Cubaud, Bationo, Houlier, & Marchal, 2008; Rekimoto & Ayatsuka, 2000; Sparacino, 2002). The success of VR touring systems in museums has extended their application to outdoor cultural heritage site with guided services that integrate; navigation, information and location with 2D and 3D images, audio and video clips to personalise the visitor experience (Madsen & Madsen, 2015; Vlahakis et al., 2002).

b) The second stage of VR/AR progression in museums moved towards interactive head-worn devices with eye-tracking capabilities that provide greater accessibility and immersion with content than mobile phone and tablet devices (Wagner, 2007), (Sparacino, 2002) and (Damala & Stojanovic, 2012). Other smart immersive technological guide systems were created based on the visitors' content co-creation and personalisation (Antón, Camarero, & Garrido, 2018; Ardito, Buono, Desolda, & Matera, 2018).

Flavián, Ibáñez-Sánchez, and Orús (2019) conducted a study on human factors in AR, which suggests AR HCI emulates the highest levels of natural human communication. Furthermore, in a museum setting, AR interactions increase the guiding functions, which enhance the interaction between visitors and the artefacts (Edmund Ng Giap, Parhizkar, Lina Chai Hsiao, & Lashkari, 2011; Trunfio et al., 2019) and in some instances employ gesture control for natural HCI (Burgard et al., 1999). In addition, the gamification of AR guidance systems in museums increases visitor engagement and promotes active learning (Raptis, Fidas, & Avouris, 2017). However, this research found that current AR museum guides were not aligned with the role of human guides such as being mentor, pathfinder, educator, information giver and motivator (Cohen, 1985; Holloway, 1981; Weiler & Black, 2015). Most studies in this area consider AR technologies as a set of tools that support the guiding experience in museums and neglect the significance of interactivity, multimedia, user interface design, and usefulness in the context of the museum experience. Moreover, recent studies do not address the influences of interactivity, multimedia and user interface design, and usefulness on the effectiveness of the role of guidance in MR guide tools.

Thus, this study identifies a gap in current MR HCI research and explores the role of MR as a smart immersive technology to redesign the traditional museum tour guide service. In consideration, this research study designed, tested and deployed a novel spatial MR guide system called 'MuseumEye' in the Egyptian Museum in Cairo to investigate; interactivity, multimedia, user interface design, intention and usefulness of the MR tour guide system. The system was built using the Microsoft MR HoloLens and took nine months to create and deploy, including testing and fixing bugs.

2. Background and Related Work

2.1 Guidance in Museums

Museums are multidimensional environments and require a multi-perspective approach to guidance enhanced by implementing technologies such as AR, VR and MR (Raptis, Fidas, & Avouris, 2018). However, the most significant roles that museums play are in attracting people and enriching their knowledge (Doering & Pekarik, 1996). A museum guide is defined as verbal or non-verbal instructions and information that helps visitors to engage, amuse, educate and navigate (Best, 2012; Fine & Speer, 1985). Many studies focus on visitors and the aspects of communication and interactions taking place (Duffy, 1989; Hodge, D'Souza, & Rivière, 1979; Eilean Hooper-Greenhill, 2013; Yalowitz & Bronnenkant, 2009). These studies reveal that the structure of guided tours provides information that the guide can follow to foster the audiences' contributions and engagements. However, applying models of best practice is significant for interpretation services and intercultural communication (Weiler & Black, 2015). Many studies emphasise the role of the tour guide in educating museum visitors (E. Hooper-Greenhill, 1999; Horn, 1980; Mancini, 2000; Pond, 1993).

For instance; Cohen (1985) explains that the modern tour guide has to fulfil the role of a' pathfinder', to lead visitors around the museum environmen. Secondly, the tour guide is a' mentor', who provides visitors with essential information (Cohen, 1985). Furthermore, museum mentoring is a social interaction in face-to-face settings (Goodwin, 2007). For example, Best (2012) advocated: *'Museum guides use pointing and gaze at objects, as the group move to orient themselves and others to new foci'.* Thus, the mentoring role involves being a 'social mediation' and 'cultural brokerage' (Cohen, 1985; Holloway, 1981).

There are other essential guide roles such as the 'actor' to reenact information to the audience, the 'Information-giver' to exchange and impart knowledge, the 'Ambassador' as a representative of the heritage's culture and country and the 'Catalyst' to encourage social cohesion in touristic groups (Holloway, 1981). Moreover, tour guides are 'Leaders' as they show the way around the museum and act as the social leader of the tourist group (Cohen, 1985). Finally, they are the 'Teacher' and 'caretaker' as they inform tourists about the souvenirs they can buy (Fine & Speer, 1985). 'Interpreter/translator' (Almagor, 1985) and 'organiser' (K. Hughes, 1991).

2.2 Virtual, Augmented and Mixed Realities in Museums

With the advent of the new technologies and devices which produce multiple realities, it is significant to redefine the difference between AR and VR systems in the MR (MR) spectrum. In consideration, Bray (2018) proposed a new taxonomy of MR, as depicted in Fig. 1.

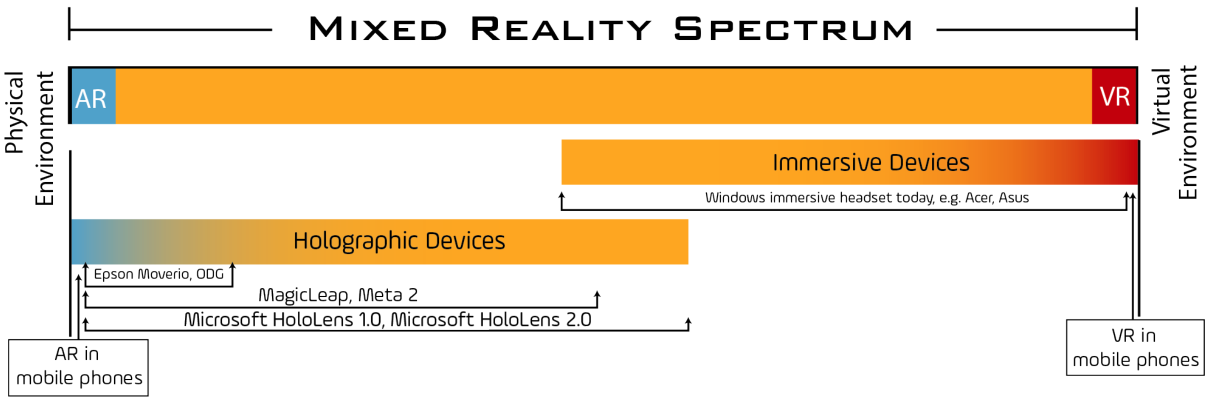

Fig. 1. MR Spectrum concept developed from Bray (2018) and the allocation of holographic and immersive devices

The technology present in AR devices expanded the application of VR thanks to advances in sensors and control, which amalgamate and minimise the gap between the physical environment and virtual spectrum. Holographic devices, such as Microsoft HoloLens 1.0 (Microsoft, 2015), Microsoft HoloLens 2.0 (Microsoft, 2019), Magic Leap (Magic Leap, 2018) and Meta 2 (Prasuethsut, 2016), have the ability to place virtual content in the physical environment (Bray, 2018). Conversely, VR devices construct a sense of presence by replacing the physical environment with virtual content (Bray, 2018). Examples VR devices include the Oculus Rift (Rift, 2020), Acer headset (Warren, 2018), ASUS headset (Allison, 2018), and Dell Visor (Atkinson, 2018).

Jaron Lanier created the term 'Virtual Reality' in 1980s, and it was described as "*a human computer interface that simulates realistic environment while enabling participant interaction, as a 3D digital world that accurately models actual environments, or simply as cyberspace*" (Gorman, Meier, & Krummel, 2000, p. 124). On the other side, AR is now sees as *"Augmented reality is a medium in which information is added to the physical world in registration with the world"* (Craig, 2013, p. 15). However, MR is an inclusive term which can embrace the two different worlds; the virtual world and the real world which differ in their nature (Milgram, Takemura, Utsumi, & Kishino, 1994). The two terms AR and MR, are used interchangeably in the literature, especially in studies that involve holograms observed by Microsoft HoloLens. For instance, the term AR is used in studies that employ the Microsoft HoloLens system (Hockett & Ingleby, 2016) and, MR to describe the same device (Hurter & McDuff, 2017; Kress & Cummings, 2017). Furthermore, Extended Reality (XR) is a new term which arose recently to include AR, VR and MR under one umbrella. Moreover, XR represents a broad variety of virtuality levels to increase the level of immersion by all types of sensor inputs. This term included AR, VR and MR under one umbrella (Alizadehsalehi, Hadavi, & Huang, 2020).

Many studies in different disciplines adopted these immersive technologies and it was found that it can result a significant impact in the needed outcomes. XR technologies showed an obvious potential in the architecture, engineering, and construction industry particularly on the efficiency of designing (Alizadehsalehi, Hadavi, & Huang, 2019), building (Sampaio & Martins, 2014), operating and monitoring phases (Alizadehsalehi et al., 2020; Rahimian, Seyedzadeh, Oliver, Rodriguez, & Dawood, 2020). In the medical sector, hybrid worlds creates the experience for immersive e-therapy (Gorini, Gaggioli, & Riva, 2008). MR helped to save lives (Siebert et al., 2017), and MR glasses were efficient in forensic science (Albrecht, Folta-Schoofs, Behrends, & Von Jan, 2013). XR technologies are very promising in the medical health field as they have a significant effectiveness on the medical training and education and can increase the level of diagnosis and treatments (John & Wickramasinghe, 2020). In the education sector, VR and MR technologies revealed a significant effectiveness on enhancing the learning attitude for secondary students; moreover, MR was proved to be better than traditional teaching methods (Tang, Au, Lau, Ho, & Wu, 2020).

Recently in the cultural heritage sector, many museums have implemented AR and VR, MR technologies to take over and substitute the roles of human guides to navigate and providing visual and auditory information to guests on the spot. In the last decade, the installation of AR, VR and MR on mobile and wearable devices permit users to navigate museum environments naturally without significant restriction. The social presence of these technologies was interpreted by Jung, tom Dieck, Lee, and Chung (2016) into four classifications: educational, aesthetics, entertainment, and escape experiences. Hence, the following literature demonstrates how immersive technologies fulfil visitor needs in museums and cultural heritage places.

According to (Brůha, Laštovička, Palatý, Štefanová, & Štych, 2020; Clini, Quattrini, Frontoni, Pierdicca, & Nespeca, 2017; Hain & Hajtmanek, 2019), VR systems allow museum visitors to interact, navigate, explore virtual reconstructions of lost heritage. Thus, VR is one of the most appealing and interactive technologies to emerge in the museum sector (H. Lee, Jung, tom Dieck, & Chung, 2020; Mihelj, Novak, & Beguš, 2014) and in virtual museums (Fevgas, Fraggogiannis, Tsompanopoulou, & Bozanis, 2014; Guerra, Pinto, & Beato, 2015; Loizides, El Kater, Terlikas, Lanitis, & Michael, 2014; Sylaiou, Kasapakis, Dzardanova, & Gavalas, 2019). However, Carrozzino and Bergamasco (2010) argue that it is uncommon and costly to equip museums with immersive VR installations and (Zuk et al., 2005), explain that VR is more suited to visualise temporal 3D archaeological data and gaming approaches for educating and entertaining visitors (Antoniou, Dejonai, & Lepouras, 2019; Lepouras, 2004). VR technologies can virtually reconstruct and rebuild a ruined heritage to provide visitors with an insight into the past (Cantatore, Lasorella, & Fatiguso, 2020; Pujol, 2004).

However, VR systems do not support mobility features, which is a critical role of the museum tour guide. Accordingly, researchers developed a portable AR tour guide (Damala et al., 2008) to provide real-time routing tailored to the visitors' position in the museum (Van Hage, Stash, Wang, & Aroyo, 2010). Subsequent studies deployed mobile AR headsets in the Louvre museum's Department of Islamic Art for guidance and information provision (Miyashita et al., 2008). Another interactive AR installation allowed visitors to change the colour of paintings (Ryffel et al., 2017). Similar studies examined the use of personalised storytelling alongside artefacts (Muñoz & Martí, 2020; Pujol et al., 2012; Roussou, Katifori, Pujol, Vayanou, & Rennick-Egglestone, 2013) and overlying information via AR (Keil et al., 2013; Sugiura, Kitama, Toyoura, & Mao, 2019; Xu, Stojanovic, Stojanovic, Cabrera, & Schuchert, 2012) across different platforms such as; smartphones, tablets and smart glasses (Pietroszek, Tyson, Magalhaes, Barcenas, & Wand, 2019; Serubugo, Skantárová, Nielsen, & Kraus, 2017).

Thus, MR technologies have contributed towards enhancing the visitor experience in the museum and cultural heritage sector. For example, one AR project extends the exhibition space with virtual visualisation of ancient sea life (C. E. Hughes, Smith, Stapleton, & Hughes, 2004) and the 'HoloMuse' MR application engages users with archaeological artefacts through gesture-based interactions (Pollalis, Fahnbulleh, Tynes, & Shaer, 2017; Wang & Xia, 2019). Another MR project enabled an immersive interactive experience to explore the potential of MR in museums (Cortana, 2017). Gesture recognition techniques were applied to an MR guide system by a smartphone application to gather user facial expression data (K.-F. Lee, Chen, Hsieh, & Chin, 2017) and create a virtual character for HCI (Avramova, Yang, Li, Peters, & Skantze, 2017), (Raptis et al., 2018). MR technology has transformed the way humans interact with each other as the immersive technologies can transcend physical barriers (Kim, Park, & Xu, 2020; Sylaiou, Kasapakis, Dzardanova, & Gavalas, 2018) as self-guided tools to ease learning (Bekele, Pierdicca, Frontoni, Malinverni, & Gain, 2018) and increase the perception and enhance the real world (Choi, 2014; Vo, Boettcher, & Draschkow, 2019).

Moreover, MR technology needs to be tailored to visitors' needs and expectations (Weiler & Black, 2015) and should be aligned to the museum guide roles (tom Dieck, Jung, & Han, 2016). According to Falk and Dierking (2016), there are three overlapping contexts that constitute the museum experience and interpret the museum visitor needs; personal context, sociocultural context and the physical context. Therefore, this research attempts to redefine the role of the museum guide and provide visitors with a self-guided, immersive, engaging and educational experience.

3. MuseumEye – an MR Tour Guide

The MR application 'MuseumEye' developed in this study proves the potential of MR guidance by giving museum visitors a glimpse of what it was like to live in ancient Egypt. Adding virtual characters and objects overlaid with music and sound effects created an interacting and engaging MR experience. MuseumEye introduces a virtual guide who speaks to the visitor and provides various types of visual information such as videos, images and 3D visualisations of artefacts. The advantage of 3D virtual rendered objects over physical artefacts is that visitors get a closer and unrestricted look at exhibits outside of the glass case and observe objects from different angles. The MR application emulates ten antiques from the Tutankhamun exhibit with three storytelling scenes. The MR avatar guide walks alongside the museum visitor from the very start of the tour, and the experience lasts between 30 to 40 minutes.

3.1 Structure of the MR guide model

The MR guide system was designed after considering the three main contexts that constitute the museum experience defined by Falk and Dierking (2016), in addition to the defined roles of tour guides introduced by Cohen (1985), Holloway (1981) and Fine and Speer (1985). The roles of the tour guide and visitor needs were analysed and linked to museum experience constructs from a side and connected to conceptual functions from the other side as demonstrated in Fig. 2. These functions were mapped and bridged to technical operations that can be achieved using the MR device. This systematic approach prioritises the main roles of the guiding service delivered by humans, machines, tools or gadgets and ensures that the concepts that fed to the structure of the system not vice-versa.

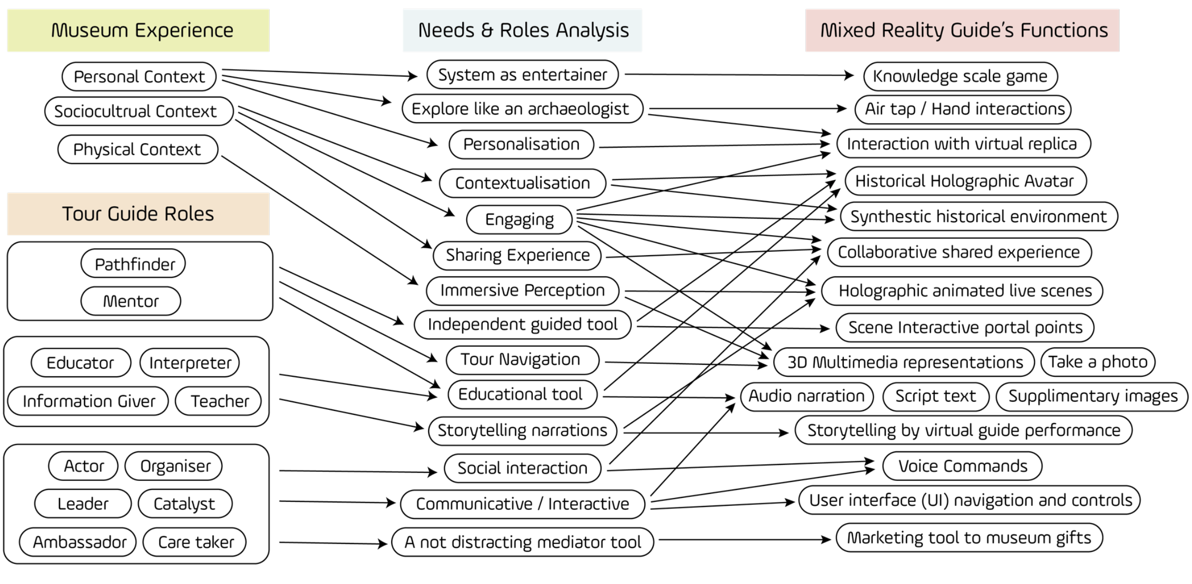

Fig. 2. Bridging museum guide roles and visitor needs to MuseumEye functions

The application incorporates a game named "Knowledge Scale game" that encourages visitors to discover hidden secrets and clues in the virtual relics. To further engage the visitor, the system has a historical MR avatar with corresponding scenes and to engage visitors in the ancient Egyptian Era. The utilisation of 3D images, text, 3D virtual antiques, holographic floating UI with hand interactions– as depicted in Fig 3 - and spatial sound effects provided visitors with essential information on the spot. The system implements' voice commands' to personalise HCI, this function makes the system communicative and responsive to questions, assigned tasks and to convey the sense of being led by a trusted program to ensure the maximum engagement and entertainment. Furthermore, the system is designed to engage multiple users simultaneously in a collaborative shared experience for sustainability and ease of usage.

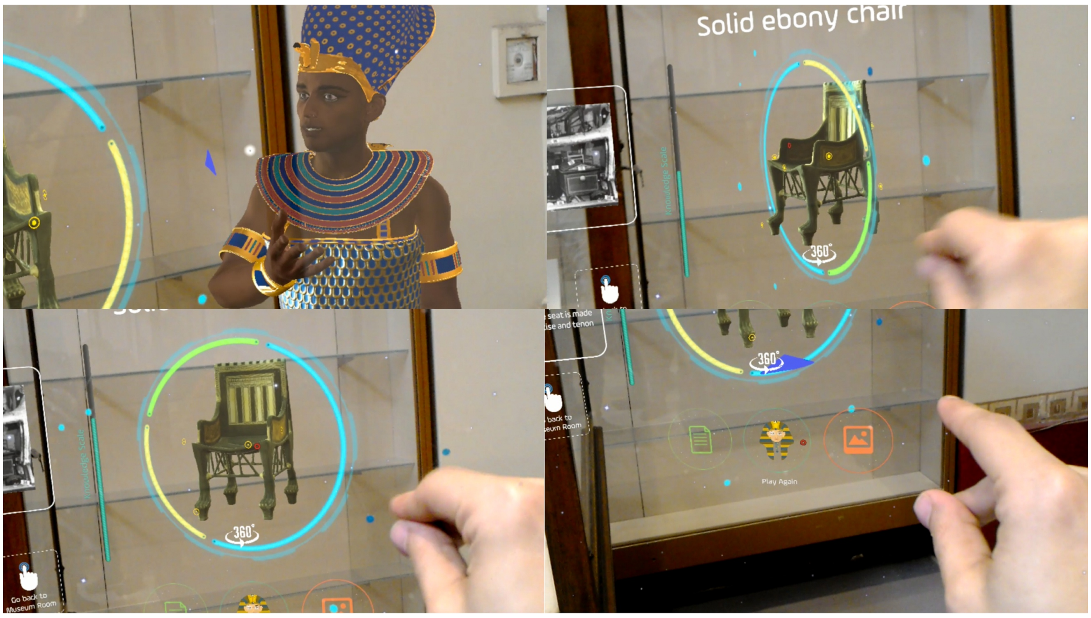

Fig. 3. Floating UI of MuseumEye with hand interactions

3.2 The Concept of the Interactions in MR Guides

The system provided five levels of interaction, depicted in Fig. 4. Firstly, the visitor in front of the exhibited item will interact with the physical environment. Secondly, interacting with the physical item. Thirdly, interacting with the virtual guide and watching his demonstrations and facial expressions. Fourthly, interaction and manipulation of the virtual artefact. Fifthly, with the UI which include buttons and triggers (Hammady, 2019). Thus, the more interactions the visitors perform, the information they receive. This interactive environment raises the level of concentration and knowledge consumption for museum visitors and motivates the visitors' cognitive ability, which reflects on the impression that visitors can feel at the end of the tour. The UI has a set of buttons, one for showing related images, another for showing the script that the guide narrates from and another for the guide surrounded by floating relics. There are further buttons for going between scenes and quitting the app.

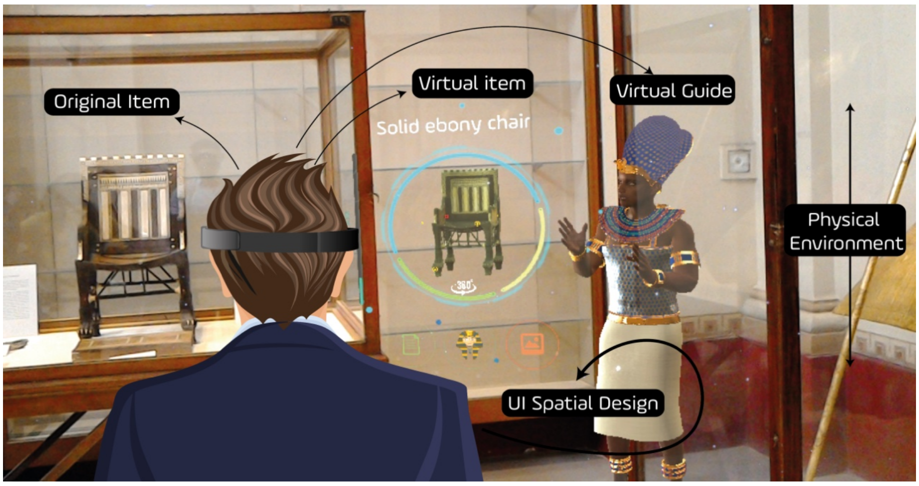

Fig. 4. MuseumEye – the MR virtual guide system and levels of interaction

3.3 Hardware

The MR HMD Microsoft HoloLens – depicted in Fig. 5 - utilised in this research is a wearable computer system and implements the Intel 32-bit (1GHz) processor, accelerometer, gyroscope and magnetometer. It also equipped with 2 GB RAM, and battery for 2-3 hours of active use and Windows 10 (Microsoft, 2015).

Fig. 5. Microsoft HoloLens –Source: (Microsoft, 2015)

4. Research Method

Technology Acceptance Model (TAM) introduced by Davis (1989) is a theory of reasoned action (TRA) that suggests that human's behaviour is determined by a person's intention to perform a certain behaviour (Ajzen & Fishbein, 1980) (Fishbein & Ajzen, 1975). This perceptual intention is a function of a person's attitude and behaviour from the subjective norm. As the attitude towards a certain behaviour can propagate positive or negative feelings, the subjective norms can evaluate the social pressure on the person either to do or not to do the behaviour. For many years, TAM has been used to measure the adoption of new technologies by users in information technology (IT) and immersive technologies in museums. For example; the TAM model investigates public acceptance of MR (Rauschnabel & Ro, 2016) or the applicability in different disciplines such as MR in education (Rasimah, Ahmad, & Zaman, 2011) and the role of the AR guide in museums (Haugstvedt & Krogstie, 2012).

As presented in Fig. 6, the basic TAM model by Davis (1989) shows the usage of IT manifested by intention, determined by the user's attitude towards acceptance. According to the TAM model, the perceived usefulness and the perceived ease of use are the predictors of the users' acceptability. Moreover, the perceived usefulness and the perceived ease of use can be influenced by several external variables. However, there are five constructs of TAM; for the purpose of this research attitude towards using IT was excluded. Previous studies demonstrate a direct relationship between the intention to use and the actual usage without connecting them with the attitude towards using IT (Ducey, 2013; Shang & Wu, 2017). Many TAM researchers extend the model using additional external constructs or external stimulus. For instance; Ayeh, Au, and Law (2013) emphasised on the significance of using context-specific external constructs within TAM study model to ensure the suitability within different technological contexts.

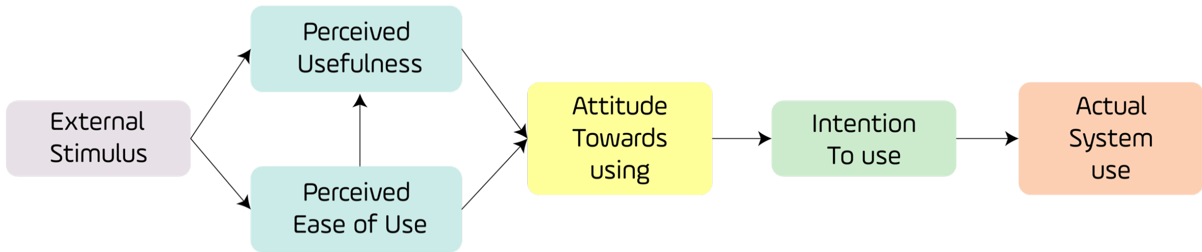

Fig. 6. TAM model introduced by Davis (1989)

Numerous studies explore the understudy variables with museums/locations and the technology involved, as presented in Table 1. The table encompasses the literature of the previous system that was applied and evaluated in museums in terms of indicating the aspects that were measured. Although some technologies in the literature were different from HoloLens, these aspects still needed to be explored for a comprehensive evaluation.

Table 1
The explored constructs in the literature of previous studies

Projects/Studies	Museum/ Location	Technology - Device	Evaluation Aspects
(Damala et al., 2008)	Museum of Fine Arts in Rennes, France.	AR – Mobile device	• Ease of use • Navigation • Content quality: audio and multimedia
ARCO (Karoulis, Sylaiou, & White, 2006)	Victoria and Albert Museum and SussexPast, UK	Virtual Museum and AR – Mobile and website or kiosks	• Usability • Content: terminology suitability, logical order • Reliability • Multimedia
ARCHEOGUIDE (Vlahakis et al., 2001)	The archaeological site of Olympia, Greece	AR – Mobile units (laptop, pen-PC, palmtop-based)	• Ease of use • User satisfaction • Multimedia • User Interface • Content • The willingness of future use

Trondheim historical streets (Haugstvedt & Krogstie, 2012)	Trondheim historical streets, Norway	AR – Mobile device	• Usefulness • Ease of use • Enjoyment • Behaviour attention
Hypermedia Tour Guide (Bellotti, Berta, De Gloria, & Margarone, 2002)	Genoa's Costa Aquarium Museum, Italy	Handheld guide - palmtop computer	• Usability • Information presentation • User satisfaction • Content
MR Sea Creatures experience (C. E. Hughes, Stapleton, Hughes, & Smith, 2005)	the Orlando Science Center's DinoDigs exhibition hall, USA	MR experience - see-through video HMD	• User reactions • Usefulness • Enjoyment • The willingness of future use
Agent *Max* (Kopp, Gesellensetter, Krämer, & Wachsmuth, 2005a)	The Nixdorf Museum	AI (artificial Inelegance) – Flat Screen	• Interactivity
ARCO (Sylaiou et al., 2010)	Victoria and Albert Museum and SussexPast, UK	Virtual Museum and AR – Mobile and website or kiosks	• Enjoyment • Previous computing experience • User satisfaction
(Carrozzino & Bergamasco, 2010)	*the Virtual Museum of Sculpture* (*VMS*) of Pietrasanta	Virtual Museum – VR gadgets	• Interactivity • Immersion • Content

5. The Proposed Model and Hypotheses

This section develops the hypotheses based on the literature review in order to develop a theoretical explanatory model as depicted in Fig. 7. This theoretical model integrates the social and technical constructs of the literature review with the TAM model for exploring the perceived usefulness and perceived ease of use are considered cognitive responses, and the intention to use. The technical constructs are represented in interactivity, and multimedia and UI. This model involves three interrelated constructs covering, 'the perceived usefulness', 'the perceived ease of use' and 'the intention to use'. In the other side, the constructs; 'the perceived enjoyment' and 'the role of guide'.

Firstly, this framework investigates the relationships between these variables towards defining the intention to use the MR guide. Secondly, the study investigates a new variable constructed through the literature review, which is the 'Role of Guide'. This construct is explored among the other constructs in relation to the intention to use the system. Finally, this research explores how the role of the guide influences the other constructs in this context to highlight the sustainability of using this system in museums.

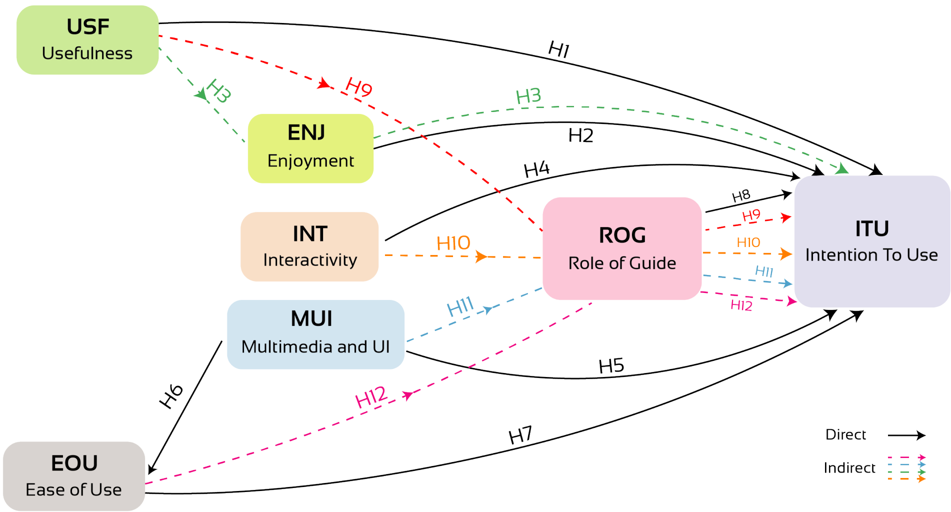

Fig. 7. Proposed theoretical model

5.1 Perceived usefulness and intention to use

Usefulness (USF) is one of the fundamental factors to predict user acceptance by measuring the effect of behaviour over usage (Davis, 1985, 1989). The perceived usefulness has a significant effect in the Intention To Use (ITU) AR in museums (Chung, Han, & Joun, 2015; Haugstvedt & Krogstie, 2012; H. Lee, Chung, & Jung, 2015). MuseumEye supposes to transfer knowledge and to enrich the contextual information of the exhibit. It also attempts to change the mental image of the ancient Egyptian's civilisation. Usefulness was exploited in many museum studies as a construct to be assessed (Haugstvedt & Krogstie, 2012; C. E. Hughes et al., 2005; Wojciechowski & Cellary, 2013).

Intention to use (ITU) is measured to assess the sustainability of the system in the museum post-experiment. Several museum studies employed this construct (H. Lee et al., 2015; Wojciechowski & Cellary, 2013; Yilmaz, 2016).

H1: Usefulness (USF) has a significant direct relationship with intention to use (ITU) MuseumEye.

People engaged in activities of pleasure and enjoyment (Teo & Lim, 1997). Davis, Bagozzi, and Warshaw (1992) defined enjoyment as *"the extent to which the activity of using the technology is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated"*. In this study, MuseumEye brings amusement and pleasure to visitors during the dissemination of information through storytelling and narratives.

Visitors prefer to be active users, not passive listeners, so they prefer to perform interactions as much as possible. Based on the design of MuseumEye guide, the system uses hand gesture control to enhance and personalise the museum tour experience. Hence, the evaluation of this aspect is crucial to the evaluation as if the system is not engaging, it will be neglected by visitors in the future. Enjoyment was measured in many previous museums studies (C. E. Hughes et al., 2005) (Schmalstieg & Wagner, 2007; Sylaiou et al., 2010).

5.2 Enjoyment

Empirically, the perceived Enjoyment (ENJ) has a significant effect on the intention to use (ITU) as the joyfulness that users can feel after using the MR applications can motivate them to continue using the system in the future. Similar studies can prove this relation (Haugstvedt & Krogstie, 2012; H. Lee et al., 2015; Leue & Jung, 2014; Sylaiou et al., 2010; Wojciechowski & Cellary, 2013). Also, the perceived usefulness (USF) as an extrinsic motivation construct also has a significant effect on the perceived Enjoyment (ENJ) as an extrinsic motivation construct presented in a related study (Koenig-Lewis, Marquet, Palmer, & Zhao, 2015).

H2: Enjoyment (ENJ) has a significant direct relationship with intention to use (ITU) MuseumEye.

H3: Enjoyment (ENJ) significantly mediates the relationship between usefulness (USF) and intention to use (ITU) MuseumEye.

5.3 Interactivity

Interactivity (INT) is defined as *"the user capability of modifying the environment and receiving feedback to his/her actions"* (Carrozzino & Bergamasco, 2010, p. 435). Due to the particular hand gesture that is required to accomplish the interaction in HoloLens, this aspect measures the ability to do the interaction to the designed UI as it is considered a new experience for users to face.

Once users interact with MuseumEye, they can perceive two different types of interactions; HCI and interpersonal interaction. HCI considers the MR system in the museum environment, and Interpersonal interaction is a result of the interaction between the visitor and his/her peers. Thus, interaction influences the intention to use (ITU) defined by (Liu, Chen, Sun, Wible, & Kuo, 2010).

H4: Interactivity (INT) has a significant direct relationship with intention to use (ITU) MuseumEye.

5.4 Multimedia & UI

Multimedia and UI are aspects of the content design and comprise video and audio documentaries and informative images (Karoulis et al., 2006). In addition to measuring the aesthetical quality of the UI and content, it was helpful to assist the user in performing actions. Good UI and multimedia content can influence visitors to engage and grasp information towards perceived ease of use (EOU), and influence INT. Similar studies proved the relationship between MUI and ITU (Hong, Hwang, Hsu, Wong, & Chen, 2011). Other studies showed (MUI) has a positive influence on the ease of use (EOU) of IS (Liu et al., 2010).

H5: Multimedia (MUI) has a significant direct relationship with intention to use (ITU).

H6: Multimedia (MUI) has a significant direct relationship with ease of use (EOU).

5.5 Ease of Use

Ease of Use (EOU) as defined by Davis *"the degree to which a person believes that using a particular system would be free of effort"* (Davis, 1989, p. 320). It investigates the usability of the system and how much the user feel comfortable, especially the obligation to wear a device during the tour. It further considers the user's ability to reach the function that triggers what the user expects to reach. According to (Davis, 1985, 1989), EOU is one of the essential factors to predict user acceptance by measuring the effect of behaviour usage. EOU has a positive and significant influence in the intention to use (ITU) construct in related contexts (Chung et al., 2015; Haugstvedt & Krogstie, 2012; H. Lee et al., 2015).

H7: Ease of Use (EOU) has a significant direct relationship with intention to use (ITU).

5.6 Role of guide

Role of Guide (ROG) is a construct created by this research and introduced as a new form of MR guidance in museums. It applies the essential guidance roles, such as exploring new venues, disseminating information, pathfinder. The aim of the quantitative study is to investigate whether the role of the guide is achieved through MuseumEye and whether its influence on the behaviour of future INT.

This aspect measures whether MuseumEye can perform the role of the human guide and compensate for the absence of a human tour guide. It also measures the effectiveness of disseminating the information required and help the visitor to explore and discover the exhibited items.

H8: Role of guide (ROG) has a significant direct relationship with intention to use (ITU).

The hypothesis investigates the perceived usefulness (USF) of using MuseumEye on the satisfaction of the guidance service and the effect on the intention to use (ITU). This study examines whether the role of guide (ROG) as a mediator influences the usefulness (USF) and the intention to use (ITU) as it is previously hypothesised.

H9: Role of guide (ROG) significantly mediates the relationship between usefulness

(USF) and intention to use (ITU).

This hypothesis investigates whether the interactivity (INT) the user performs can enhance the satisfaction of being guided (ROG) by MuseumEye system and then it can positively motivate visitors to continue using it (ITU) in the future. As in H4, it was hypothesised the influence of interactivity (INT) on the intention to use (ITU).

H10: Role of guide (ROG) significantly mediates the relationship between interactivity (INT) and intention to use (ITU).

As previously hypothesised in H5, multimedia and UI (MUI) has an influence on the intention to use (ITU), this hypothesis investigates whether the good multimedia and UI can boost the satisfaction of being guided and achieved the desired role of guide (ROG) then correspondingly can influence the intention to use (ITU).

H11: Role of guide (ROG) significantly mediates the relationship between multimedia and UI (MUI) and the intention to use (ITU).

This hypothesis investigates whether the ease of using the system (EOU) can motivate the user to be guided (ROG) by MuseumEye then it can motivate the user to continue using the system in the future (ITU). This assumption was built based on the hypothesis of H7, which considers the ease of use (EOU) influences the intention to use (ITU).

H12: Role of guide (ROG) significantly mediates the relationship between ease of use (EOU) and intention to use (ITU).

6. Empirical methodology

6.1 Data collection

A mixed-method data gather approach was implemented in this study using quantitative questions combined with Likert scales permitted the cross-analysis of open-ended inquiries with numerical ratings.

The first stage of the evaluation covers the practical implementation: The experiment started by giving participants a short tutorial on how to perform air tapping and make the rest of hand gestures. Then, the subjects were asked to start their tour by the autoloaded storytelling scenes; and have the option to choose the interactive points that trigger the antique navigation scenes as depicted in Fig. 8. b) The second stage evaluates the MuseumEye application and the aspects depicted in the framework. In this stage, 200 questionnaires were distributed to the museum visitors who participated in the experiment. There are two types of museum visitors who participated in this experiment. The first who accepted the invitation of the experiment through a promotional video of the MuseumEye system was published on social media. The second who volunteered to participate when they saw other visitors experience new manners of touring.

Fig. 8. Photo shots from experiencing MuseumEye at the Egyptian Museum in Cairo

The evaluation process expected different abilities to become accustomed to it, even after a discrete tutorial period. It is vital to embrace the user experience of the system, as it reflects the user's level of interest and engagement with the immersive experience. It also obstructs the flow of information that can be gained during the tour. Due to it being a new technology, it was expected that most of the users have not used the device before and that they would be unfamiliar with the hand interactions. The MR tour was supervised from the beginning to end to provide additional support and aid in technical difficulties. Each participant took between 30 to 40 minutes to finish the MR tour in the museum room of Tutankhamun.

The sample size of this study is based on previous museum studies by (Bellotti et al., 2002; Lanir, Kuflik, Dim, Wecker, & Stock, 2013; Liarokapis, Sylaiou, & Mountain, 2008) intended to reach 200 participants as an adequate sample size. However, after discarding incomplete questionnaires, there were 171 valid participants. As a consequence, the final sample size was equal to a study conducted by Rubino, Xhembulla, Martina, Bottino, and Malnati (2013). This sample size fits the analysis methods of exploratory factor analysis (EFA) and confirmatory data analysis (CFA). The sample size for the quantitative method was 122 participants.

For demographical analysis, the age of test subjects in relation to MR technology was a significant factor. In consideration, (Dean, 2002) pursued measuring the exposure of Information and Communication Technologies (ICTs) to children compared with adults. The study concluded that younger audiences expect the computer system to be part of museum installations and prefer interactivity in education systems (Best, 2012). Hence, younger subjects may have different perspectives, levels of usability and skills than adults. Another assumption might take into consideration older audiences, often called 'silver surfers', who use computer software as a hobby and might be willing to use the museum systems (Owen et al., 2005). Accordingly, test subjects were categorised into the following age groups: 18 to 25, 26-40, and 41-60.

Gender statistical analysis was conducted, with a view to exploring links between the use and adoption of MR technology across different genders. According to (Owen et al., 2005), it is commonly known that males adopt technologies faster than females. Thus, the evaluation of gender aims to explore if this phenomenon occurs in the present study.

6.2 Measures

The questionnaire includes 35 questions with corresponding 5-point Likert scales to ratel one = strongly disagree, to 5 = strongly agree as employed in (C. E. Hughes et al., 2005). The questionnaire took, on average, 8-10 minutes to be complete. The questionnaires employ (QUIS) Questionnaire for User Interface Satisfaction which asses the user satisfaction of the system according to the interface and the usability aspects (Chin, Diehl, & Norman, 1988). The qualitative inquiries are an open space for visitors to write positive and negative testimonies concerning their experience of MuseumEye. Finally, as the study was deployed in the Cario Museum, questionnaire inquiries were translated into the Arabic language for ease of understanding.

The quantitative data was analysed using AMOS to compute the EFA and CFA, and the qualitative data were analysed thematically using Nvivo after translating the language from Arabic to English then transcript it intros the software. The questionnaires were piloted through academic students and staff to ensure the clarity and understandability of the questions was acceptable. Their feedback was taken into consideration, particularly in the submission of the ethical approval form by the ministry of antiquities in Egypt and the museum management staff.

6. Results

6.1 Demographic Results

The sample size - 171 participants - has fairly equal representation in terms of gender: 57.3% male and 42.7% female. Also, the participants were divided into three age groups, the age groups from 18 to 25 and 24-40 were represented the sample with percentages 47.4% and 42.1%, respectively. These results represent a high level of interest for experiencing new technologies in museums from the younger groups in contrast with the older participants since the latter group resulted in 10.5% of the sample size.

In terms of the awareness of immersive technology, the participants were asked questions about their prior knowledge of AR, VR or MR technologies and whether they had experienced AR before. Indeed, 120 of participants (70.2%) were aware of AR, VR or technology. Moreover, 73 participants (42.7%) had heard of AR apps, such as Layar, Wikitude or Pokémon Go. 56 participants (32.7%) had experience with wearing AR/VR/MR headsets/smart glasses. This was followed by an open question asking the participant to confirm what device they had worn before. Interestingly, these participants had experience with Oculus Rift, HTC Vive, Samsung VR Gear, Google Cardboard, VR Box or Microsoft HoloLens. Then, 44 (25.7%) participants had experienced AR applications before, and 9 (5.3%) had experienced AR in museums. All of the 9 participants had experienced AR in "The Wall of Knowledge" (Cultnat, 2016) exhibition at the same museum.

6.2 Descriptive Analysis

There were 27 system evaluation questions, which were formed and distributed to be adequate and sufficient for each construct, which in turn ranged between 3 to 5 questions per construct. Table 2 depicts the composition of the descriptive analysis including the minimum, maximum, standard deviation, and the overall mean values of the seven aspects. The lowest minimum value of the aspects was the 'Interactivity' as 1.00, and the highest is 3.00 for two aspects, 'Usefulness' and 'Ease of Use'. Interestingly, all maximum values are 5.00. Regarding the mean values, the highest mean value is 4.55 for the "Intention to use" aspect and the lowest mean values is 4.13 for the 'Interactivity'. Moreover, two mean values are identical as they are 4.33. Also, another two values are almost identical as they are 4.38 and 4.39 for the aspects' ease of use' and 'Role of being a guide' respectively. Generally, most of the mean values represent strong positive responses towards using the system in the targeted museum.

Table 2
Descriptive Analysis of all evaluation constructs for participants

Constructs in Technology Acceptance Model	No. of questions	Minimum	Maximum	Mean	Std. Deviation
Enjoyment (ENJ)	5	2.20	5.00	4.37	.52
Usefulness (USF)	4	3.00	5.00	4.37	.51
Multimedia and UI (MUI)	4	1.00	5.00	4.33	.62
Ease of Use (EOU)	4	3.00	5.00	4.39	.50
Interactivity (INT)	3	1.00	5.00	4.13	.74
Role of being a guide (ROG)	4	2.00	5.00	4.38	.61
Intention to Use (ITU)	3	2.50	5.00	4.55	.57

6.3 Correlation and Regression Analysis

Despite the fact that the majority of the survey questions extracted from previous studies, two round of factor analysis conducted in this study. It starts with exploratory factor analysis (EFA) in order to explore the structure of the relationship between the other variables and the emerged variable (Costello & Osborne, 2005). As 'Role of a guide' is developed from the literature, and it is needed to be explored within the other variables. EFA followed by the confirmatory factor analysis (CFA). The need of testing CFA after EFA is simple because EFA explores those factors that best regenerate the variables under the maximum likelihood conditions, while CFA explores particular hypothesis concerning the nature of the factors (Gorsuch, 1983). CFA was conducted by AMOS software in order to assess the unidimensionality. All the items were above 0.5, which is the acceptable cut off point (Comrey & Lee, 2013). Table 3 presents the questions of the survey with EFA, CFA, AVE and Cronbach's *Alpha.*

Cronbach's *Alpha* (α) was used to measure the reliability of the survey, whereas the average variance extracted (AVE) used to test the convergent validity. Table 4 showed the correlation and discriminate validity, where the analysis indicated that the factors could test what the other variables cannot (Hair, Anderson, Babin, & Black, 2010). The correlation, on the other hand, with diagonal value considers <0.01, all of these indicators were statistically acceptable (Wooldridge, 2015).

Table 3
Construct reliability and convergent validity coefficient

	EFA	CFA	AVE	α
Enjoyment			.50	.83
The storytelling of King Tutankhamun is interesting.	.77	.77		
Revealing the secret information around antiques is interesting.	.71	.65		
I enjoyed exploring the exhibits with the help of MuseumEye	.69	.71		
I found this application enjoying in museum tours.	.69	.70		
The content is engaging enough to focus on it till the end.	.65	.69		
Usefulness			.51	.80
The language is clear and understandable.	.67	.72		
Images signposted during the narration are beneficial.	.75	.74		
The information about the collection is satisfactory as expected	.66	.65		
I could clearly see the benefit of exploring virtual antiques.	.69	.73		
Multimedia and UI			.57	.83
I like the 3D characters (king, queen, maids ...etc.).	.77	.78		
The historical music is engaging and supports the immersion.	.75	.72		
The 3D scanned antiques are representing the authentic pieces.	.71	.72		
I like the user interface design (buttons, graphics, icons ... etc).	.80	.78		
Ease of Use			.50	.81
It was comfortable to use the 'MuseumEye' application.	.74	.76		
I did not experience nausea or headache using MuseumEye.	.65	.60		
I could look around the room comfortably.	.68	.66		
I could do air tap on the virtual objects appropriately.	.73	.78		
Interactivity			.62	.85
I could interact with the user interface as I expected.	.80	.75		
I could move between scenes easily.	.81	.85		
I could reveal all hints (information) from yellow circles easily.	.74	.77		
Role of guide			.63	.87

MuseumEye enhances the understanding of historical knowledge.	.72	.76		
Visitors will be more independent in tours by using MuseumEye	.84	.83		
This application more like a tour guide than a tool for guidance.	.79	.82		
I found MuseumEye is efficient in museums' navigation.	.74	.75		
Intention to use			.50	.84
I want to see more stories and more development in MuseumEye.	.68	.72		
I prefer to use MuseumEye as a guiding tool in this museum.	.75	.73		
To what extent you recommend MuseumEye for your friends to use?	.69	.67		

Table 4
Correlation and Discriminant validity

	ENJ	USF	MUI	INT	EOU	ROG	ITU	Discriminant validity
ENJ	**.71**							**.71**
USF	.49**	**.71**						**.71**
MUI	.47**	.46**	**.75**					**.75**
INT	.45**	.51**	.48**	**.71**				**.71**
EOU	.32**	.29**	.45**	.36**	**.79**			**.79**
ROG	.46**	.43**	.50**	.53**	.29**	**.79**		**.79**
ITU	.35**	.32**	.42**	.37**	.29**	.66**	**.71**	**.71**

** Correlation is significant at the 0.01 level (2-tailed).

6.4 Testing Hypothesis

The PROCESS is an analysis tool developed by A. Hayes (2013). PROCESS enables the test of the direct and indirect impact as well as it allows the test more than one mediators without sample size restrictions which are a key issue in other tools such as 'Structure Equation Modelling' (A. Hayes, 2013; A. F. Hayes, 2012). PROCESS results do not much differ from the structure equation model results; however, PROCESS calculate each equation sedately instead of concurrently (A. F. Hayes, Montoya, & Rockwood, 2017). The path considered significant when its Confidence Interval (CI) does not contain zero (A. Hayes, 2013).

The mediation test runs through bootstrap (5000), which is the recommended number for bootstrap (Preacher & Hayes, 2008). The bootstrap has been chosen to test the mediation impact as it deals with type I error (reject the true null hypotheses) and can provide correct results despite the sample size (Claudy, Peterson, & Pagell, 2016; Preacher & Hayes, 2008).

The Hypotheses was tested using PROCESS with both direct and indirect relationships measured, as depicted in Table 5 (A. F. Hayes, 2017). The indirect effect between the constructs (Usefulness, Interactivity, Multimedia & UI, and Ease of use) with the intention of use represented in two models where each model contains one mediator namely: Role of guide for model 1 and enjoyment for model 2. The results demonstrated that role of guide significantly mediated the relationship between usefulness and the intention to use (β = .19, CI95%= .08, .33; R^2=.27), supported H9. Model 2 showed that enjoyment does not mediate the relationship between usefulness and intention to use (β = .03, CI95%= .06, .12; R^2=.25), rejected H3. Model 1 further, represented the significant mediation of the role of guide between interactivity, multimedia, ease of use from one side and the intention of use form the other side (β = .27, CI95%= .18, .40; R^2=.44), (β = .28, CI95%= .16, .48; R^2=.45), (β = .21, CI95%= .09, .39; R^2=.45) respectively, supporting H10, H11, and H12.

Table 5
Hypotheses tests

Indirect Effect			
		Model 1 ➔ROG➔ ITU	Model 2 ➔ENJ➔ ITU
USF	β	.19**	.03
	R^2	.27	.25
	MSE	.28	.21
INT	β	.27**	
	R^2	.44	
	MSE	.19	
MUI	β	.28**	
	R^2	.45	
	MSE	.19	
EOU	β	.21**	
	R^2	.45	
	MSE	.18	

Direct Effect			
		β	t
H1	USF➔ ITU	.03	.34
H2	ENJ ➔ITU	.06	.75
H4	INT ➔ITU	.02	.29
H8	ROG➔ ITU	.61*	9.5
H5	MUI➔ ITU	.35*	4.5
H7	EOU➔ ITU	.10	1.07
H6	MUI➔ EOU	.44*	8.56

** CI 95% does not contain zero. *Significant P <.01 MSE=Mean Square Error

The direct impact indicated that only the multimedia variable has a significant impact on intention to use (β = .35, t=4.5, p<.01), supported H5. Usefulness (β = .03, t=.34, p>.05), enjoyment (β = .06, t=.75, p>.05), interactivity (β = .02, t=.29, p>.05), and ease of use (β = .10, t=1.07, p>.05), do not have a direct impact on intention to use. Rejected H1, H2, H4, and H7. Finally, the results showed a significant direct impact of the role of guide on the intention to use (β = .61, t=9.5, p<.01), supported H8. As well as, there is a significant direct impact of multimedia and UI on ease of use (β = .44, t=8.56, p<.01), supporting H6. Fig. 9 depicts the research framework with regression coefficient values between the constructs.

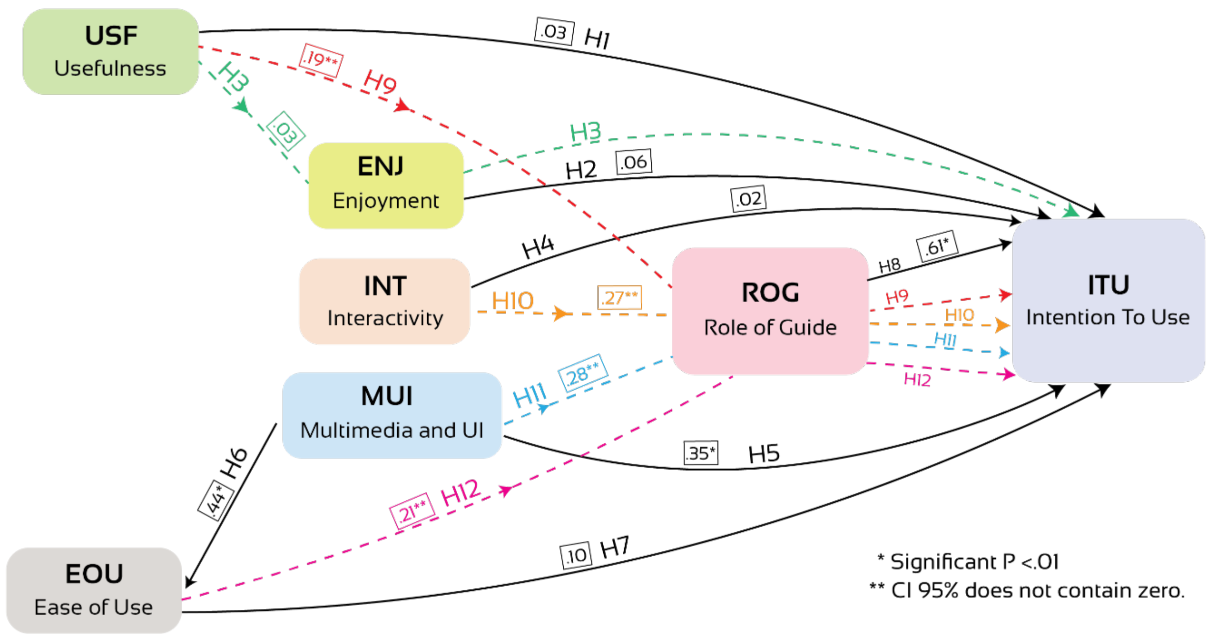

Fig. 9. Conceptual Framework

6.5 Responses to Open-ended Questions

The participants were enthusiastic and positive in their responses to the open-ended questions, and 122 out of 171 participants responded in their questionnaires. The tables below analyse the qualitative responses quantitatively by frequency. Table 6 shows the aspects that the participants considered the most significant factors of the design and application of MuseumEye. Table 7 depicts the open questions that investigate the aspects which were not preferable and needed to be improved. Note that frequencies in Tables 6 and 7 refer to concepts rather than exact phrases.

Table 6
Participants' responses on open questions that explore the best aspects

What are the best aspects of MuseumEye?	Frequency
<u>Enjoyment</u>: *"The application was interesting, entertaining and engaging."*	15
<u>Immersion</u>: *"Isolation from surrounding people and the museum room and entering a pharaonic environment and the music helped me to make the experiment more immersive."*	16
<u>Multimedia and UI</u>: *"I like the graphics, images, music and the presentation manner."*	20
<u>Role of being a guide</u>: *"It can take the role of the museum guide or the labels' role, and it gives me information on the issue I want to know about."*	6
<u>Scenario and storytelling:</u> *"I want to see more storytelling and other contexts developed into MuseumEye."*	8
<u>Usefulness</u>: *"It contains beneficial information and very simple explanations."*	17
<u>Ease of use:</u> *"The system and very easy. It was very simple, and I managed to navigate the system."*	14

Interaction: *"The navigation of the statues makes me feel that I was engaged more."*	18
Content is not distracting: *"The presentation of the king did not distract me out of the content of the museum."*	4
Independence: *"The visitor gets privacy", "More independence."*	7
Overall Satisfaction phrases: *"I like the idea and its implementation."*	12
The willingness of future use: *"I wish to see it permanently in the museum."*	4
Total	102

Table 7
Participants' responses to the aspects that need to be improved

What are other aspects, which are not so good about MuseumEye?	Frequency
FOV: *"Field of view was very narrow."*	5
Other language support: *"I wish to see the Arabic version."*	3
HoloLens weight: *"Little bit heavy."*	3
More Stories and more content*: "I wish I can see a menu that can list all the museum collections which have 100 antiques."*	4
Usability: *"Swiping and clicking is somehow cumbersome and need more instructions."*	5
Graphics and 3D models: *"The statue of Tutankhamun was not identical to the authentic one."*	6
Need more time to use: "The period of using it was so short."	3
Total	31

Based on the total results of the tables, contribution to the best aspects was higher than questions relating to improvements, given it was 102 responses against 31. The aspect the participants most had views on was 'Multimedia and UI', with 20 comments, followed by the 'Interaction' aspect with 18 comments. 'Usefulness' was mentioned 17 times, and 'Enjoyment' aspect mentioned 15 times. Then, 'Ease of use' was mentioned 14 times, and finally, 'Role of being a Guide' was mentioned six times.

Regarding Table 6, which investigated potential improvements and limitations of the MuseumEye application, six participants commented on how King Tutankhamun looked authentic compared with statues. Another group that comprised of 5 participants complained about the narrow field of view. Additionally, a further group of five participants complained about difficulties with the interactions and the lack of instructions. Finally, the open question provided crucial information used to evaluate the efficiency of the MuseumEye as an information system.

7. Discussion

According to the results of the participants' profiles, the differences in the age groups showed different levels of AR/VR awareness. According to Dean (2002), exposure to information systems in younger age groups is greater than adults. This was apparent in the results, which showed a higher awareness of the age group 18-. The older age group 26-40 had a greater awareness than the 41-60 age group. These findings indicate that the level of computer skills and the willingness of using IT is greater in younger individuals. However, 10% of the sample were above the age of 40 and showed an adequate level of awareness and experience of AR/VR.

As stated in the results, male participants showed a higher level of awareness and experience of AR/VR than the female participants, which coincides with what Owen et al. (2005) study. Generally, the sampled participants showed a sufficient level of familiarity with the technology, which encouraged participants to embrace MR technology during the experiment. The quantitative results indicated that the role of the MR guide mediated the relations between guests and extended the intention to use. Moreover, not all the relations between the constructs and the intention to use were strong. Fig. 10. represents the structured model after the weak correlations between constructs were removed.

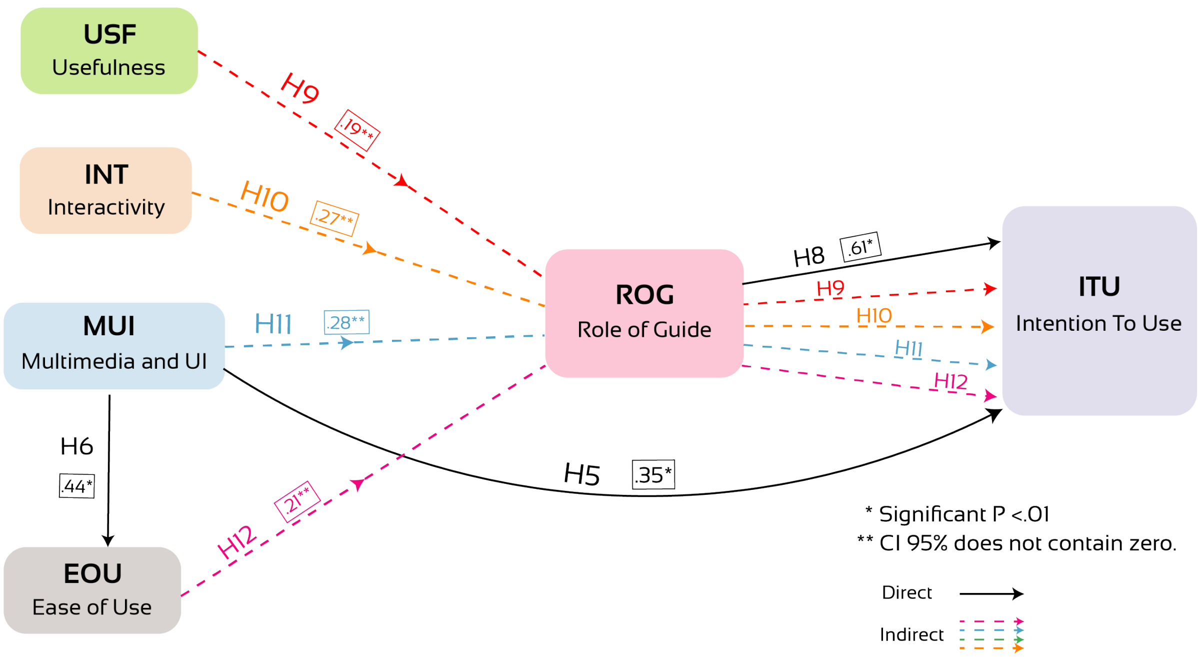

Fig. 10. The Structured Model

The perceived usefulness of MuseumEye does not influence on the intention to use and does not collate with previous studies (Chung et al., 2015; Haugstvedt & Krogstie, 2012; H. Lee et al., 2015). However, the perceived usefulness influenced the intention to use when the guide role mediate the relationship (β= .19, R^2=0.27, CI95% = .08, .33). However, it did not encourage the intention to use when the perceived enjoyment mediates the relationship.

This result highlights the significance of the guide role of MuseumEye. This outcome corresponds with the outcomes of similar studies that used mobile guide such as (Haugstvedt & Krogstie, 2012) resulted (R^2=0.38, p<0.001), (H. Lee et al., 2015) resulted (β= .23, p<0.05) and (Balog & Pribeanu, 2010) resulted (β =0.24, t value=2. 27, p<0.05).

Thus, the MusuemEye provided a virtual guide proximal to a human guide who accompanies a visitor wherever he/she goes. Moreover, disseminating the information like a human guide boosts the usefulness of the application, which impacts on the visitors' intention of future usage (Joachims, Freitag, & Mitchell, 1997). Due to the uniqueness of this study, it was not easy to find a similar study that measured indirect relationships that can embed mediators between the measured constructs. Moreover, mediating the role of guide in the framework is what this study contributes to evaluate the MR guide systems. Regarding the qualitative results on the perceived usefulness, 17 participants stated that there was *"beneficial information and very easy explanations"* in the open-ended questions.

This study did not show a significant influence on the intention to use MuseumEye in the future. This result contradicts the results of other studies (Haugstvedt & Krogstie, 2012; H. Lee et al., 2015) and the reason is the perceived enjoyment might not be sufficient enough to be an intrinsic motivation for the usage. The qualitative analysis showed 15 participants who stated: *"the application was interesting, entertaining and engaging"*. This theme indicates that this construct was achieved successfully in the MR guide, and it can satisfy part of the personal context defined by Falk and Dierking (2016).

The perceived interaction with MuseumEye showed less correlation with the intention to use the system in the future; however, it collates significantly when the role of guide mediates the two constructs, as indicated in the results ($\beta = .27$, CI95%= .18, .40; $R^2=.44$) of Liu et al. (2010) who measured the student's interactions with the online learning websites and its correlation with the intention to use, and it resulted ($\beta= .12$, $p< 0.5$). The qualitative results for this construct were positive, as 18 participants commented that *"the navigation of the statues makes me feel that I was engaged more".* This can satisfy part of the social-cultural context that construct the museum experience according to Falk and Dierking (2016), as visitors can interact with other visitors either who are immersed in the MR experience or not.

The multimedia and UI did not have a positive influence on the intention to use MuseumEye directly but did when the role of guide abilities mediate the relationship. The study showed higher correlations to the intention to use MuseumEye more than other studies, as it resulted ($\beta= .28$, $R^2=0.45$, CI95% = .16, .48). For instance, a study such as (Hong et al., 2011) who examined the interface design of the online learning websites on the intention to use it and it resulted ($\beta= .10$, $p< 0.05$). This can indicate that when users engage with multimedia content and the UI, that affect positively on future usage.

Also, multimedia and UI had a strong influence on the perceived ease of use ($\beta= .44$, $t = 8.56$, $p< 0.01$). This correlates with other studies such as (Liu et al., 2010), ($\beta= .47$, $p< 0.001$) and (Cho, Cheng, & Lai, 2009), ($\beta= .55$, $p< 0.001$). In addition, good multimedia and UI design reduce the fear of using computers or systems and motivate users to use it (Shneiderman & Plaisant, 2010). The qualitative analysis showed that participants enjoyed interacting with hand gestures and the images, videos, visual effects and the 3D sounds. About 20 participants stated: *"I like the graphics, images, music and the presentation manner"*. The designed multimedia and Microsoft HoloLens itself helped the visitors to feel the immersion of the virtual environment, as mentioned previously.

The perceived ease of using MuseumEye did not influence the intention to use; however, it did when the guide roles mediate the two constructs. This means the ease of using the system alongside the guide abilities can encourage the user to use the system in the future. Per the results of this study ($\beta = .21$, CI95%= .09, .39; R^2=.45) which correlate with (Haugstvedt & Krogstie, 2012) which measured the influence of the perceived ease of using the AR mobile guide on the willingness to use it, ($\beta = .15$, $t = 2.060$, $p < 0.05$).

Moreover, Liu et al. (2010) explored the ease of using the online learning systems on the intention to use ($\beta = .12$, $p < 0.05$). Also, Luarn and Lin (2005) who measured the perceived ease of use on mobile banking on the willingness to use it ($\beta = .33$, $t = 6.61$, $p < 0.01$). The rationale is the tutorial of using MuseumEye prior to the participants' tour enhanced perceiving the usability and the ease of use. However, that was not enough for motivating users to use the system in the future till the users were able to instruct the virtual guide to give information in a particular time and location (Jan, Roque, Leuski, Morie, & Traum, 2009). The open questions revealed that 16 visitors commented on how they were immersed in a pharaonic environment in this ancient time with the king and his guards. However, five visitors complained about Microsoft HoloLens' narrow field of view and claimed that it blocked their sight and made visuals fall in a narrow rectangle.

The role of the guide is the most vital aspect of this study, as this research introduces a replacement guide for existing human-guided tours using the 'MuseumEye' application.

Interestingly, the guidance capabilities of the MuseumEye system had the most substantial influence on the intention to use the system in museums ($\beta = .61$, $t=9.5$, $p<.01$). This result proves the significance of the role of guide on the intention to use among all other measured constructs. These statistics conclude that the MuseumEye system solves the current human guiding problem which exists in the targeted museum. The qualitative results showed that the participants enjoyed the way the system can help the user gather information, along with its ability to engage younger visitors in overcoming the complexity of delivering a great deal of historical information in this context. Despite these positive comments, there were some other arguments and critical comments that touched on the social interactions during the tour and the social isolation that could occur.

However, the system can enable shared experiences between two or more users of the system, and in this case, social interaction might be encouraged. After demonstrating the role of guide in MuseumEye as proof of MR guide concept, the following table – Table 8 - conducts a comparison between MuseumEye and the human guides according to the roles of guides defined by various scholars (Almagor, 1985; Cohen, 1985; Holloway, 1981) and recent studies (Goodwin, 2007; Zhang & Chow, 2004). Indeed, it is impossible to compare human cognitive skills with AI or technological functions. However, this comparison is a way to push MR guides to rise as a potential substitute and a successful guided method in museums.

Table 8
A critical comparison between human guides and the MuseumEye guide

Role of Guide	Human Guide	MuseumEye Guide
'Pathfinder' (Cohen, 1985)	Pathfinding could be achieved effectively, and the guide can lead to interesting items in every hall and room sequentially. Also, he/she can create a pre-designed thematic tour starting from the entrance to the exit.	It could be applicable; however, the system was designed to give the visitor a choice to take the preferable scenario from the visitor's perspective. Also, MuseumEye can have the ability to give suggestions for the next recommended item to be visited. However, this functionality will be available on further developments.
'Mentor' (Cohen, 1985) (Best, 2012)	A human guide can more effectively be a personal tutor and a spiritual advisor in a more humanistic sense than other guide tools. Also, he/she can have a sense of humour and engage visitors in discussions to enlighten them about specific facts via face-to-face communications. Although this role is effective for human guide, guides could go away from the main topics or speak about restricted topics such as religion or politics, as explained in the exploratory study.	MuseumEye could be a mentor, but there are limitations in the ability of artificial intelligence to conduct face-to-face communication. Although it has this ability in some respects, it cannot do it effectively like a human. The MuseumEye system can represent the virtual guide as a human who can communicate to the visitors in one way of communication. It can enlighten visitors about facts, but it cannot go off-topic, as the content is created professionally by museum experts
'Actor' (Holloway, 1981)	This role is achieved effectively if the human guide has rich experience in performing this act before; otherwise, he/she could have 'stage fright', which can affect negatively on the museum experience of visitors. The advantage of this role is in human interactions, which can make the human guide perform even better based on their level of confidence.	MuseumEye cannot suffer from 'stage fright' as it is a robotic performance and is pre-prepared and recorded by experts in studios. So, the virtual guide can be an actor, but it suffers (at this stage) from human communications.
'Information-giver' (Holloway, 1981)	The human guide can perform this role effectively based on studying, practising and memorising the thematic tour he/she designed for his/her group. However, it is still limited due to human memory, and it is expected that the 'information greedy' visitors will ask questions that the guide cannot answer. It is a subjective ability, and it can vary	MuseumEye is an effective information-giver, as it can unlock levels of information based on the visitor's requests. It also can suit the three types of visitors that Sparacino (2002) suggested. The information is not limited to human memory like the human guide - the information is prepared and created by museum experts. Also, the quality of disseminating the information does

Role of Guide	Human Guide	MuseumEye Guide
	from a guide to guide based on his/her skills.	not vary, which makes the system provide information at a constant level of quality.
‘Leader’ (Cohen, 1985)	This is a more social or humanist role, and human guides can perform it effectively depending on the personal skills of the guide. So, he/she is not only a pathfinder but also can be a leader in museum discussions, control the topic, control the time and inspire guests. However, this is not preferable for some types of visitors who desire to walk independently without being followed by someone.	Due to deficiencies in artificial intelligence at the time of creating the system, this social role is not quite applicable. However, it gives the visitor full control over timing, the flow of information and the location visited. It suits independent visitors who do not prefer to be led by someone.
‘Teacher’ (Holloway, 1981) (Fine & Speer, 1985)	This is a more social or humanist role, and the human guides can perform it effectively depending on the personal skills of the guide. It can work effectively with visitors of different age groups since the human guide can teach and provide information to kids differently to older ages	This role could be achieved, but not as effective as the human guide since it relies on human interactions. However, the content and the narrations could be created based on the age group of the visitor, so the way of teaching could vary based on the visitors’ age, culture, and background. Although this function is not in the application at the moment, it could be included in further developments.
‘Interpreter/Translator’ (Almagor, 1985) (Holloway, 1981)	This role could be achieved effectively by the human guide as human guides can have the skills to speak multiple languages.	This role could be achieved effectively by MuseumEye. The system can interpret the information in many languages. This function is not present at the moment, but it could be applicable in further developments.
‘Caretaker’ (Fine & Speer, 1985)	This role is more applicable in outdoor museums, where hazards might be present. However, the human guide can take care of the group he/she walks with and can ensure their safety until their tour ends.	Normally, MuseumEye is designed to work indoors, such as in museums and exhibitions. If there hazards present, MuseumEye can advise visitors and inform them of health and safety instructions. This feature can be considered in further developments.
‘Ambassador’ (Holloway, 1981)	The native human guide can act as an ambassador for his country and represent his/her culture to international visitors and further spread cultural information.	MuseumEye can act as an ambassador. Moreover, the virtual guide can be designed to act as one of the ancient people who lived in this period, i.e. King Tutankhamun.
‘Organiser’ (K. Hughes, 1991)	The human guide can design his/her tour and organise it based on the time given by his/her visitors. This role does not fit the individual visitor who desires not to be led by a guide.	MuseumEye gives the user or the visitor the control to organise their time and the program of the tour. This role can fit the independent visitor and who walks individually.

Role of Guide	Human Guide	MuseumEye Guide
'Culture-broker' (Holloway, 1981)	This role could be achieved effectively, as the human guide can introduce the culture physically or psychologically to international tourists.	MuseumEye can achieve this role effectively, as it can introduce the culture physically or psychologically to international tourists.
'Catalyst' (Holloway, 1981)	Human guides can perform this role efficiently, as it requires a higher level of human interaction.	This role is not applicable even if MuseumEye was running on the shared experience mode, as it requires a higher level of human interaction.
'Salesperson' (Fine & Speer, 1985)	Human guides can inform visitors to buy souvenirs from museum shops if they are interested.	MuseumEye can do this role and inform visitors to buy souvenirs. Absolutely, not in a humanistic way but it can do it interestingly.

8. Conclusion

To conclude, this research introduced a framework for assessing a novel spatial MR guide for enhancing the traditional museum experience by replacing the human tour guide with a virtual model. The primary contribution of this paper is the critical examination of the role of the guide in MR technologies for museums. This study proved that designing the guide system according to the main roles of guides that are stated in the most cited museum studies can stimulate the visitors' intention to use the system in the future. The framework introduced in this study is the first conceptual framework that can measure the role of the tour guide in MR systems among relevant significant factors, and the willingness of future use by museum users is to be expected.

The limitations of this study: Firstly, due to the museum's restriction on conducting experiments with foreign visitors, the participants of our study are Egyptian visitors only. This aspect limited the diversity of participants in terms of their backgrounds and cultural perspectives. Secondly, it is vital to make participants embrace the user experience of the system before the experiment, as it reflects the user's level of interest and engagement with the immersive experience. It also obstructs the flow of information that can be gained during the tour.

Future Research: Further research can put more focus on utilising the new editions of holographic devices to mature the role of the guide with more capabilities. By the time of this research, the second version of Microsoft HoloLens was released, and the opportunity of incorporation of the artificial intelligence (AI) (Pollefeys, 2017) (Goode, 2019) can have greater potential to maximise the museum virtual guides abilities.

The findings of this study have greater implications in other areas of tourism and open prospects of MR in the cultural heritage sector, and it takes the traditional museum experience to a new level of engagement and interactive experience. The MR technique, currently deployed in museums, could be an important vehicle for driving the tourism industry towards achieving success, and thus this might directly reflect on Egypt's economy. Through adopting the technology, the awareness of the wearable technology and the ability to interact with holograms will be familiar in the context of museums and cultural heritage. It is especially relevant when trying to reach the younger Egyptian generations, through using new technology that creates rich, fun and engaging experiences for visitors, rather than touring in a traditional method. This method enriches the historical knowledge of both native and non-native visitors.

Acknowledgement

This study was constructed from a PhD thesis by the 1st author. We would like to thank the Egyptian museum in Cairo curators for their help and support. Also, we want to thank The Egyptian government for facilitating the experiment and getting all approvals requested.

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