Evaluation of Mobile Augmented Reality Hearing-Impaired Museum Visitors Engagement Instrument

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Abstract—Mobile Augmented Reality has come a long way since its inception as a multimedia system during the last few decades. From the concept of an Augmented Reality experience to actual smartphone applications, it has come a long way. Researchers have chosen to leverage the concept of engagement in the construction of Mobile Augmented Reality applications in order to boost museum visitors' engagement and provide a more effective learning environment. The majority of Mobile Augmented Reality applications, on the other hand, were designed with normal hearing visitors in mind, while hearing-impaired visitors are given less attention. Those with hearing difficulties have an unfavourable experience as a result of this, and are unsatisfied with their visit. The elements of Mobile Augmented Reality aimed at engaging hearing-impaired museum visitors are determined in this study. The next step was to construct a conceptual model, which was then validated through an expert review. In investigating any flaws of the instrument among hearing-impaired museum visitors, a pilot study was conducted to improve the items and determine their level of reliability. Participants in the study were hearing-impaired who visited one of Iraq's ancient museums. This study will focus on evaluating the prototype to see how effective it is at engaging hearing-impaired museum visitors in the near future.

Keywords—mobile augmented reality, hearing-impaired, museum visitors, engagement

1 Introduction

Augmented Reality (AR) combines computer-generated features with the real-world surroundings in creating a live environment, directly or indirectly [1]. It is established on mediated reality consisting of graphics, video, sound, and Global Positioning System. It has been used in a number of fields, including advertisement [2], education [3], engineering [4], edutainment [5], manufacturing [6], and medicine [7]. Technologies and support devices have been produced from the applications which can improve consumers 'perceptions of reality and make life better for them.

Mobile Augmented Reality (MAR) researchers are increasingly interested in improving museum visitors' engagement, learning, enjoyment, and personalised experiences. This has been demonstrated in earlier research on interactive museum MAR applications, such as [8]; [9]; [10]; [11]; [12] and [13]. According to the findings of the aforementioned studies, the museum MAR application can provide learnable guidance to visitors while they are visiting the museum. However, according to [14], [15], and [16], most MAR applications for museum failed to engage users properly. User engagement is vital in museum visit since it improves learning, enjoyment, and acceptance [16], [17], and [18]. As there are few research on the engagement of hearing-impaired (HI) during museum visits, particularly employing MAR, this study focuses on HI engagement during museum visits. In assisting HI visitors, engagement elements must be identified. Studies by [19] and [20] have identified the elements of engagement which are subsequently utilised in proposing the conceptual model of Mobile Augmented Reality for Hearing-Impaired Museum Visitors Engagement (MARHIME). The identified engagement elements will be used to develop AR-enabled application to help individuals with hearing problems. Similar to the MAR, these elements may improve the HI user experience during museum visits. In this study, the MARHIME instrument was evaluated by experts in various fields. The Cronbach's alphas for all of the elements were also utilised to interpret the instrument's reliability in the pilot study. The purpose for these steps is to evaluate the instrument of this study and identify the limitations of the research instrument.

2 Marhime conceptual model

As stated in a previous work [20], the MARHIME conceptual model is made up of six elements that were selected by experts. Engagement is represented by Aesthetics, Interaction, Usability, Motivation, Satisfaction, and Enjoyment in the model. Descriptions of the six elements are listed below.

2.1 Aesthetics

Aesthetics is the study of natural beauty, visual appeal, and appealing mobile settings. This means that the MAR's beauty must be noticeable in order for mobile users to be drawn to the application and the message representation provided by the MAR application. The element of Aesthetics was selected with three items which were adapted from the existing literatures [21]; [22] and [23].

2.2 Interaction

The state of being in command of an application is referred to as interaction whereby information, feedback, and interaction are provided in response to a specific action. This implies that a user and an application have a social relationship and are connected. The Interaction element was selected with three items which were adapted from the existing literatures [24] and [25].

2.3 Usability

Usability refers to the application's ease of use for the user and consistency of information. Ease of use is a tool for the evaluation of MAR applications and it helps user engagement with applications [26] and [24]. Usability was selected with three items which were adapted from the existing literatures [24] and [27].

2.4 Motivation

Motivation is the act of persuading a user to perform a specific action or activity. This means that motivation is a user's ability to execute a task. Motivation is the desire to be excited about an application in order to meet a goal. The element Motivation was selected with three items which were adapted from the existing literatures [28] and [29].

2.5 Satisfaction

The act of being satisfied and enthusiastic about an application is referred to as satisfaction. It also applies to pleasant experiences with an application that lead to the user fulfilling the application's expectations. The element Satisfaction was selected with three items which were adapted from the existing literatures [30]; [31] and [32].

2.6 Enjoyment

The sensation of pleasure, fun, and entertainment obtained through the use of an application is referred to as enjoyment. It also relates to users' perceptions of how much the interactive application's message has helped them. The element Enjoyment was selected with four items which were adapted from the existing literatures [33] and [34].

3 Validity

The degree to which a score accurately reflects a concept is defined as validity [35]. To put it differently, validity refers to a study's use of an instrument that accurately assesses what it was designed to measure [36]. This paper discusses the content validity in the next section.

4 Content validity of an instrument

Content validity refers to the extent to which the items' content represents the suitable universe of all relevant items under investigation [37]. It can be verified by content experts, instrument development experts (who are familiar with statistics and instruments) [38], and professional experts [37]. According to [39], there should be at least two academic experts. The minimum number for content validity, according to [40], is five. The content validity of the current study was determined by five academic experts.

Meanwhile, at least one expert should be present for instrument construction, according to [39]. This was accomplished in this study, which included the appointment of an expert from Universiti Utara Malaysia's School of Quantitative Science. Professional experts consisted of HI where feedbacks from them were incorporated in the instrument's items.

5 Expert review for the instrument

The MARHIME instrument was reviewed by five experts from diverse institutions, and their fields of expertise included HI, MAR, AR, Museum, and Human-Computer Interaction (HCI). They are both male and female PhD holders with over five years of professional experience in their respective professions. A three-point scale comprising of D, M and R was used for the elements and items of the instrument [41]; [34]; [42] and [43]. The instruments were distributed using two methods: email and hand delivery, since the experts were selected from various continents. All instruments were collected from the experts using the same method in which they were delivered to them. All of the experts responded, and some even made recommendations. Table 1 shows the responses from the experts.

Table 1. Responses from expert review

Element	Items	Definitely not Relevant (D)	Relevant (R)	Maybe not Relevant (M)
Aesthetics	A1	0	5	0
	A2	0	5	0
	A3	0	5	0
Usability	U1	0	5	0
	U2	0	4	1
	U3	0	5	0
Interaction	I1	0	5	0
	I2	0	5	0
	I3	0	4	1
Motivation	M1	0	4	1
	M2	0	5	0
	M4	0	5	0
Satisfaction	S1	0	5	0
	S2	0	4	1
	S3	0	5	0
Enjoyment	E1	0	5	0
	E2	0	5	0
	E3	0	5	0
	E4	0	4	1

Dealing with HI people was tough [44]; [45]; [46], because of issues including low self-esteem, anxiety, and sadness, and they are often segregated from people who can hear normally [47]; [48]; [49]. They also have language and communication issues with normal people [50]; [44], therefore they pay little or no attention to issues [51]. As a result, HI people struggle to finish lengthy questionnaires [52]. According to [49], compared to normal people, HI are up to four times slower in terms of reading. As a consequence, in order to gather honest and realistic information and answers from them, surveys should include brief language and words that are simple and easy to read. The items listed in Table 2 are appropriate for the HI participants, based on these arguments. Table 2 shows the six MAR elements and all the 19 items. Since the 19-item scale was chosen by experts, the items' content validity as well as the scale's overall validity were both confirmed.

6 Data coding

The initial stage in preparing data for analysis is coding of all the items and elements [36] as shown in Table 2.

7 Pilot study for marhime prototype

It is a scaled-down version of a larger study intended to produce data for developing the scale and assessing its level of reliability [53]. A pilot study should be conducted to determine the suitability of those items because the current study has adapted items from many sources. Aside from ensuring item clarity, pilot study also demonstrates item layout and proper formulation depending on the difficulty or satisfaction of the participants when answering the questionnaire [55] and [56]. Cronbach's alpha was employed since it determines whether an item measures the same thing as the one for which it was intended [57]. A total of 16 HI visitors were chosen to participate in the pilot study. According to [58], a sample size of 12 to 25 participants is required to obtain information concerning the pilot study's flaws.

To assure the accuracy of their responses, the participants were chosen from among those with the highest degree of education. All of the participants were given questionnaires. As a result, some ambiguous wordings found during the pilot study were changed in the real evaluation to improve HI comprehension. This study proceeded to evaluate the MARHIME prototype among 16 HI museum visitors pertaining to their engagement. A pilot study was conducted before the HI museum visitors' evaluation in order to achieve good findings from the responses of the participants. Data analysis was conducted to see if the MARHIME prototype succeeded in engaging the HI visitors. Future work includes the MARHIME prototype evaluation among HI Iraqi museum visitors. The HI participants in the pilot study session are depicted in Figure 1.

Table 2. Elements and items for the marhime instrument

Element	Item	Code
Aesthetics	Aesthetics item 1	A1
	Aesthetics item 2	A2
	Aesthetics item 3	A3
Usability	Usability item 1	U1
	Usability item 2	U2
	Usability item 3	U3
Interaction	Interaction item 1	I1
	Interaction item 2	I2
	Interaction item 3	I3
Motivation	Motivation item 1	M1
	Motivation item 2	M2
	Motivation item 3	M4
Satisfaction	Satisfaction item 1	S1
	Satisfaction item 2	S2
	Satisfaction item 3	S3
Enjoyment	Enjoyment item 1	E1
	Enjoyment item 2	E2
	Enjoyment item 3	E3
	Enjoyment item 4	E4

Fig. 1. Hi participants during pilot study

8 Results

The pilot study saves time during the actual evaluation. In addition, the participants' responses were beneficial in improving some of the items because there were

weaknesses in formulating some of them due to the use of inappropriate words that might lead to misunderstanding [53]. Many researchers, including [59] and [60], advocated Cronbach's alpha testing for the pilot study to ensure the reliability of the elements. This tool was used to see if the items measured the same thing that was intended [57]. The level of reliability, according to [54], spans from 0 to 1, with a minimum acceptability of 0.60 to 0.70. In addition, item analysis approach was used to show the most connected items to the construct using the Corrected Item-Total Correlation test, with any items with a value of less than 0.30 being eliminated [61].

A sample size of 12 to 25 participants, according to [54], is adequate to yield all of the relevant information on the flaws in the pilot study. 16 questionnaires were distributed to HI visitors to verify the accuracy of their responses. As a result, certain ambiguous words were modified to improve the understanding in the actual evaluation. As shown in Table 3 and Figure 2, the Corrected Item-Total Correlation was higher than 0.30 for all of the items, ranging from 0.438 to 0.916. If Item Deleted, Cronbach's Alpha ranges from 0.952 to 0.961, indicating that the items are highly reliable. Furthermore, all constructs have achieved acceptable reliability, as Cronbach's alpha ranges from 0.750 to 0.942, which is greater than 0.70 as suggested by [62].

9 Conclusions

The items for each element in this study were adapted from previous studies. They were validated by academic experts in the areas of HI, AR, MAR, HCI, and Museums. Items were selected by the experts based on suitability to the particular element. One of them even rectified several grammatical issues, and others offered suggestions for improving the items. In addition, before deploying the instrument on the HI users during the real evaluation, this study conducted a pilot study to confirm that the items were appropriate and to pre-test the instrument. The MARHIME conceptual model comprises of six MAR elements in engaging the HI museum visitors. All six elements and items were accepted by experts and also reliable through a pilot study. In the near future, this study will involve HI during a museum visit where an evaluation of the MARHIME prototype's engagement capabilities will be undertaken whereby they will be given access to interact with the prototype.

Table 3. Pilot study measurements' and items' reliability

Elements	Item	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Aesthetics	Aesthetics item 1	0.771	0.956	0.757
	Aesthetics item 2	0.814	0.954	
	Aesthetics item 3	0.695	0.956	
Usability	Usability item 1	0.783	0.954	0.884
	Usability item 2	0.677	0.956	
	Usability item 3	0.778	0.954	

(Continued)

Table 3. Pilot study measurements' and items' reliability *(Continued)*

Elements	Item	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha
Interaction	Motivation item 1	0.869	0.955	0.750
	Motivation item 2	0.553	0.957	
	Motivation item 3	0.752	0.955	
Satisfaction	Satisfaction item 1	0.902	0.952	0.942
	Satisfaction item 2	0.900	0.952	
	Satisfaction item 3	0.829	0.953	
Enjoyment	Enjoyment item 1	0.642	0.961	0.802
	Enjoyment item 2	0.853	0.953	
	Enjoyment item 3	0.738	0.955	
	Enjoyment item 4	0.750	0.955	

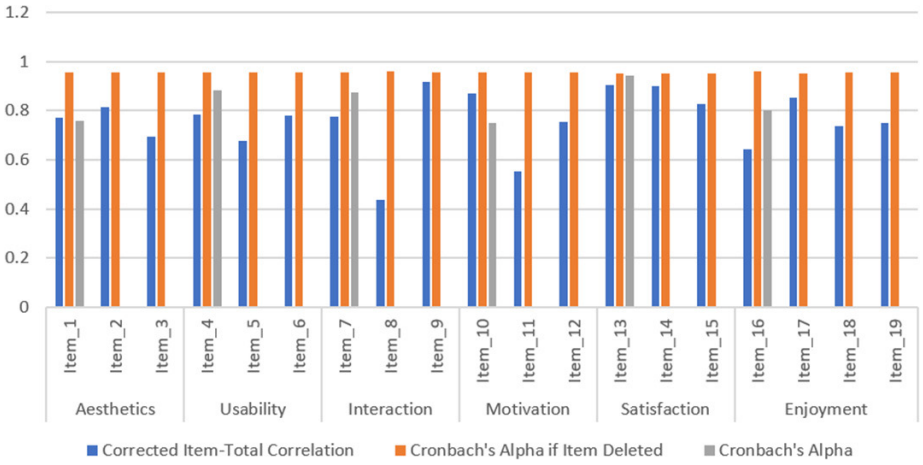

Fig. 2. Frequency measurement reliability of items

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