DOI: https://doi.org/10.38027/iccaua2023en0186

Smart Access to the Past: Studying Digital Applications for Interaction with Cultural Heritage

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Abstract
The last decades witnessed an amalgamation between cultural heritage practises and digital technology, resulting in a new heritage experience. The presented research addresses the problem of lacking in specific guidelines or frameworks for generating efficient and memorable experiences for heritage sites using digital technologies (like VR and AR). Subsequently, it investigates the preservation of heritage and its impacts on different users. The study answers two main questions: How do new immersive technologies enhance the efficiency and attractiveness of experiencing cultural heritage sites? And how does new technological integration with heritage sites communicate the cultural significance of tangible and intangible heritage? In doing so, the study focuses on theoretical and empirical aspects of users' engagement in digital heritage applications by investigating the impact of a virtual tour of the cultural heritage site of Abu Simbel Temple in Aswan, Egypt. The results of the literature investigation and the empirical experiment resulted in the development of a conceptual model for generating an interactive digital experience for heritage sites to facilitate the analysis and evaluation of the presented digital projects.

Keywords: Cultural heritage; Digital heritage; Virtual reality; Virtual tours; Interactive experience.

1. Introduction

Different changes imposed by the rapid advances in smart technologies, human computer interaction, virtual reality, augmented reality, and mixed reality have been influencing different practices and concepts in cultural heritage management and preservation. This resulted in the adoption of new determinants in sustaining heritage sites, hence presenting new challenges to heritage experts, urban designers, and architects in integrating new media and virtual reality applications in contemporary heritage practices. Merging different smart applications, especially virtual reality and human-computer interaction practices in heritage presentation, will increase awareness and the process of enjoying heritage sites. Moreover, this will present their magnificent and charming features to the world, by adopting a new type of immersive experience (Aziz Amen, 2017; Aziz Amen & Nia, 2018; Amen & Kuzovic, 2018; Amen & Nia, 2021). The idea of the presented study was driven by the initiative of the Egyptian Ministry of Tourism to allow visitors from across the globe to remotely visit various heritage sites in Egypt during the COVID-19 outbreak confinement period in the form of virtual tours. It examines the role of virtual reality in creating different responsive experiences, which presents a new potential for creating a memorable experience for heritage sites.

Accordingly, the main objective of the presented research is to develop a framework for generating and evaluating a culturally rich virtual heritage environment. This could be used as a new method for heritage representation in contemporary society. Hence, to investigate the efficiency and preference for virtual reality applications in heritage presentation, the research used a mixed-method approach that combines data collection and analysis using qualitative and quantitative methodologies. Accordingly, the main objective of the presented research is to develop a framework for generating and evaluating a culturally rich and efficient virtual heritage environment. This could be used as a new method for heritage representation in contemporary society. Hence, to investigate the efficiency and preference for virtual reality applications in heritage presentation, the research used a mixed-method approach that combines data collection and analysis using qualitative and quantitative methodologies. The study answers two main questions: How do new immersive technologies enhance the efficiency and attractiveness of experiencing cultural heritage sites? And how does new technological integration with heritage sites communicate the cultural significance of tangible and intangible heritage? In this regard, the presented paper comprises an introduction, conclusions, and three main sections, namely: Part one is a theoretical background introducing mediated technologies and digital applications in heritage practices, especially virtual reality applications and virtual tours. It then synthesizes the main findings of the previous studies into an identification of integrated indicators for designing and evaluating virtual heritage tours. Part two describes the methods section, where a full illustration of the adopted experiment is presented and how the developed hypotheses were tested statistically. Part three presents the results of the experiment and verifies the proposed hypotheses for the study. Then the findings of both the theoretical background and empirical work highlight the formulation of the proposed framework. The three sections respectively highlight the efficiency of the newly

developed virtual reality tours for heritage sites in increasing awareness of different communities' cultures and heritage treasures. It shows the flexibility of visiting different amazing cultural spots while staying in one place. This endorses the digital charm for different practices in sustaining heritage sites. Figure 1 presents the structure of the study.

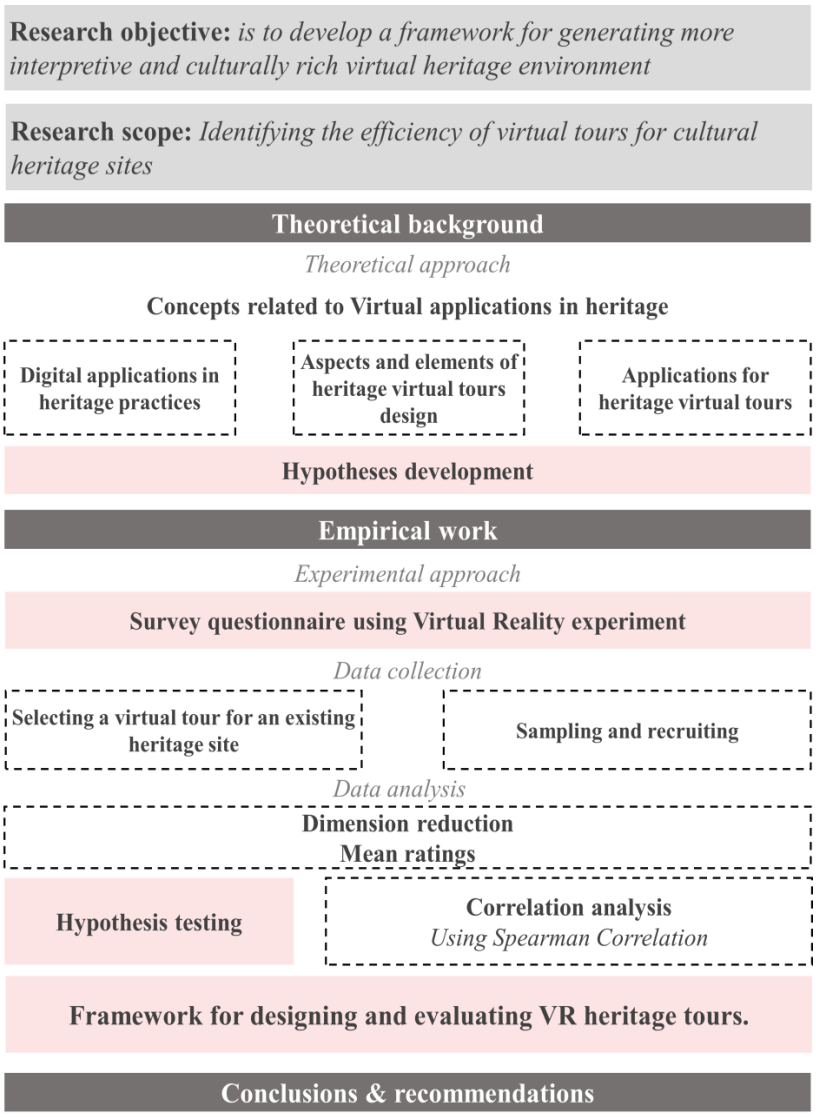

Figure 1. Structure of the Study (Developed by Author).

2. Theoretical Background

Previous studies highlighted the prominence of emerging digital technologies and digital media in generating interactive environments along the World Wide Web to increase awareness of cultural heritage sites (Song & Selim, 2022; Styliani et al., 2009). What is really interesting about digital media technologies applications in heritage practices is not only the representation of tangible and intangible heritage but also the ability to collect and process data on heritage assets, like laser scanners, VR scanners, geophysical surveys, and geographic information systems (GIS). Likewise, its allowances to engage different users through mobile devices, gaming, and virtual or augmented reality are all over the globe (Economou, 2015; Liritzis, 2015). Accordingly, the management and understanding of heritage have been impacted by digital technology, but it is a two-way relationship since extensive difficulties with heritage interpretation have an impact on how digital tools are used. The ethics of archaeologists, architects, urban designers and other specialists as heritage experts, as well as the representation of multiple interest groups, are just few examples of the problems of the larger picture that affect how digital applications are applied. Hence, it is important to consider the possibilities of digital media technologies and the different ways in which they have affected cultural heritage approaches (Barrado-Timón & Hidalgo-Giralt, 2019; Economou, 2015; Rossi & Rabie, 2021).

One of the most impressive emerging digital techniques in heritage practices is virtual reality (VR). It can take its users to different locations, representing interactive virtual content in interesting forms (Portman et al., 2015). A substantial number of studies have used immersive reality technology for a variety of application themes, making virtual heritage (VH) one of the few fields to do so early on. The term 'virtual heritage' appeared to describe the works dealing with VR and cultural heritage (Roussou & Drettakis, 2003). Virtual reality has remained the standard of immersive reality technology for virtual reconstruction and virtual museums (Hammady, R, Ma, M, and Strathearn, 2020; Mafkereseb Kassahun Bekele, 2021). Previous literature has shown how immersive reality technology may enhance museums and locations of cultural heritage by providing visitors with fun, interactive, and immersive experiences (Man & Gao, 2022; Trunfio et al., 2022).

2.1. Virtual Reality Tours for Heritage Sites

These tours can be accessed through a computer or mobile device and provide users with an immersive experience of a location without physically being at the actual site. Virtual tours are becoming increasingly popular in the tourism industry, showing different attractions and popular destinations (Godovykh et al., 2022; Mahgoub, 2022). With advancements in technology, virtual tours are becoming more interactive and realistic, offering users a truly immersive experience. As virtual reality continues to evolve, it's likely that virtual tours will become even more sophisticated and widely used in various activities. Recently, it showed an effective role in preventing the complete suspension of touristic activities during crises by offering different prospects to practice tourism (Pestek & Sarvan, 2021). However, it is important to consider the ethical implications of such technologies, such as the potential for addiction and their impact on social interaction. As virtual reality continues to evolve, it will be interesting to see how it shapes our society and changes the way people interact with different types of technology (Rainoldi et al., 2018).

Apparently, different studies were established to identify the various factors relevant to the implementation of smart technology and digital applications in heritage presentation. VR heritage tours specifically were widely investigated in terms of their benefits, design, usability, and users' interaction (El-said, 2022; Rahaman & Kiang, 2017). However, the proposed model related to VR applications and VR tours for heritage sites dealt mainly with its benefits in terms of documentation and representation, as well as its benefits in heritage preservation (El-said, 2022). Accordingly, the study highlights the gap in investigating the efficacy of VR tours in increasing awareness and the tendency to visit physical sites to enjoy the realistic experience. Table 1 shows the research gap by covering the different aspects required for this research and comparing it to the key sources in the field.

According to the previous literature, the interaction and experience of users within digital and virtual heritage applications were highlighted by numerous studies. Different components and aspects of generating an interactive experience were of major concern (Al Subhi et al., 2016; Marcus & Baradit, 2015). However, the presented study will focus on the efficacy of the virtual tour for heritage sites and how it impacts the desire of different users to visit the physical site in reality.

Table 1. Highlighting the research gap (Developed by Author).

Source	Main features					
	Factors	**Indicators**	**Applications**	**Users interaction**	**Efficiency**	**Awareness/ experience**
(Marcus & Baradit, 2015)	•		•			•
(Al Subhi et al., 2016)		•		•	•	•
(Rahaman et al., 2016)	•		•	•		
(Hajirasouli et al., 2021)	•		•	•		•
(El-said, 2022)	•		•	•		•
The presented study	•	•	•	•	•	•

2.2. Application of Virtual Reality Tours for Heritage Sites

Virtual reality technology can help preserving, sustaining and representing heritage sites by creating many digital records that can be used for conservation, exploration and education purposes. Three major aspects for understanding, designing and evaluating VR tours were identified in previous literature, which are: context, users and technology. Context is a crucial aspect in creating VR tours, it involves understanding the historical and cultural significance of the site. It also involves the reflection of the site significance on the users and how they perceive it. Context should be presented in a way that offers a perfect visual quality and details to become more engaging and informative (Çizel & Ajanovic, 2018; Machidon et al., 2018). Users are another important aspect for generating VR tours, since it should be tailored to meet their expectations, satisfaction and interests. The way users navigate and control the tour is essential to be included in designing and evaluating the presented tours since it adds to its value

and influences the experience of its users. Technology is also an essential aspect and plays a significant role for in designing effective VR tours. Using interactive features that offer a realistic simulation for the experience makes the tour more informative and engaging (Tan & Rahaman, 2009). In addition to the mentioned aspects; accessibility and inclusivity are essential attributes for designing VR tours that shall be taken into consideration. This can involve providing different alternatives for those with disabilities to cater diverse audience. Table 2 shows the indicators underneath each aspect derived from reviewing different methods and approaches regarding adopting virtual reality technologies in cultural heritage practices

As concluded from previous literature, VR has revolutionized the way people experience heritage sites, and there are numerous patterns of applications for VR tours. Recreation of certain cultural, sacred experiences or events is one of these patterns, where users are allowed to experience a certain atmosphere of historical events. Exploration is another pattern where users can explore specific sites with different levels of detail. VR can take users deep into underwater heritage sites or underground tunnels or up high on top of towers (Argyriou et al., 2020; Bruno et al., 2020). Interactive or manipulative exhibits and education are another pattern of application where users can learn about the historical artefacts and interact with them. This helps users learn about the significance of different assets in a more engaging way. This pattern is more efficient for younger audiences, like students, who might not be interested in traditional museums and exhibits. Contribution is another pattern of application for VR tours, where users are able to contribute their own content to the tour itself in a virtual manner. Overall, these applications provide a range of opportunities for users to engage with cultural heritage sites (Argyriou et al., 2020).

According to the research main questions and objective, three main patterns of applications for VR tours were adopted in the presented study, namely; **exploration**, **manipulation** and **contribution**.

Table 2. Aspects and elements for virtual heritage tour design (Developed by Author).

Aspects	Indicators/ variables	Source	Design	Evaluation
Context (Information experience)	Site Information (contents, location …etc.)	(Hajirasouli et al., 2021; S.-U. Kim et al., 2017; Pervolarakis et al., 2023; Rahaman & Kiang, 2017)	•	
	History/Background		•	
	Significance and Value		•	
	Reflection		•	
	Observation		•	
	Contextual setting (external environment)		•	
	Awareness/learning (about the site)			•
	Tendency to visit the site			•
	Visual quality			•
User (Interactive experience)	Control/freedom	(Hajirasouli et al., 2021; S.-U. Kim et al., 2017; Marcus & Baradit, 2015; Roussou & Katifori, 2018)		•
	Navigation instructions			•
	Navigation aids (wayfinding)		•	
	Guide		•	
	Comfort		•	
	Immersion		•	
	Manipulation		•	
	Expectations			•
	Satisfaction			•
	Comfort			•
Technology (Multimedia experience)	Images & visual output	(Çizel & Ajanovic, 2018; Godovykh et al., 2022; S.-U. Kim et al., 2017; Marcus & Baradit, 2015; Pervolarakis et al., 2023; Rahaman et al., 2016; Tan & Rahaman, 2009)	•	
	Colors		•	
	Effects		•	
	Sound		•	
	Quality		•	
	Structured information (text ..etc.)		•	
	Virtual scenes		•	
	Walking simulation		•	
	Ease of use			•
	Full engagement			•
	Navigation			•
	Understanding			•
	Clarity			•
	Efficiency			•

2.3. Research Hypotheses

Considering the objective of the presented study, in addition to the research question and after reviewing the previous literature review that investigated the impact of VR tours on the experiences of different users, five hypotheses were proposed:

> ***H01:*** *The efficiency of the virtual tour has a positive effect on increasing the tendency of users to visit the heritage site in reality.*
> ***H02:*** *The clarity, visual quality, and users' ability to control the virtual tour are positively correlated with its efficiency.*
> ***H03:*** *The efficiency of the virtual tour influences positively the users' expectations of the experience as well as their satisfaction.*
> ***H04:*** *The ease of navigation and usability of the virtual tour influence its efficiency.*
> ***H05:*** *The understanding of the virtual tour in terms of site information positively affects its efficiency.*

The proposed hypotheses study the relationship between the efficiency of the virtual tour and how much it encourages users to visit the heritage site in reality. It also investigates the relationship between eight variables (clarity, visual quality, controllability, usability, navigation, and users' expectations) and the effectiveness of the virtual tour experience. By examining these eight key variables, the study can gain valuable insights into how to improve virtual tour experiences. Understanding how these factors affect the efficiency of virtual tours can generate more engaging and effective experiences that will encourage users to visit heritage sites in reality. Ultimately, this research could have significant implications for tourism and help promote greater appreciation and understanding of cultural heritage.

3. Material and Methods

The presented study followed an experimental approach using a designed virtual tour to identify what indicators influence its efficiency and its impact on encouraging visiting heritage sites. The virtual tour was selected from the initiative of the Egyptian Ministry of Tourism, which started during the lockdown period of COVID-19 to allow people to visit the tourist sites online using their computers, smart phones, or any accessible VR tools they have at home (Egyptian Streets, 2020). The established tours were posted on their official website and social media accounts; it was collaboration between the ministry itself and partners from international scientific archaeological institutes. Hence, the research followed an experimental approach using a designed virtual tour to identify its impact on encouraging visiting heritage sites. Accordingly, the virtual tour of Abu Simbel Temple (Aswan, Egypt) was selected as one of the most popular heritage sites in Egypt (https://egymonuments.gov.eg/news/virtual-tour-for-abu-simbel-temple/).

3.1. Experiment Design and Data Collection

The entire experiment, along with all the assessments, was designed and conducted in the VR lab at the architecture department, Faculty of Engineering, Cairo University. Using the VR Oculus Quest 2 headset, participants were asked voluntarily to experience a virtual tour of Abu Simbel for around 5–11 minutes. Then they are asked to answer a series of questions about their virtual experience. The study was advertised as a "VR visit to Abu Simbel" among the students and employees at the Architecture Department at Cairo University. Participants were introduced to the objective of the study and the idea of a virtual presentation of heritage sites. Moreover, they were introduced to the Oculus headset and how they were supposed to use it during the experiment before they started their tour. At the beginning of the experiment, participants were asked to preview a short video of the temple in VR mode before experiencing it in fully immersive VR mode. This was considered preparation for the VR experience, especially if it was their first-time using VR headsets. Figure 2 shows screen shots for the VR tour of Abu Simbel temple and Figure 3, Figure 4, and Figure 5 show photos for the experiment conducted in the VR laboratory.

3.2. Measurements

The study adopted a part of a previously established experiment performed by (El-said, 2022), with the main difference in the procedures. The previous study investigated the tours online; whereas the current work investigated only one tour using a VR head mounted display. With regards to the previously stated hypotheses, the research investigated sets of variables to measure usability, the extent of enjoying the tour, the satisfaction of users, and the motivation to visit the actual site. Previously established scales were included in this study from previous literature to measure the extracted variables, mainly the ease of use, which was adopted from (Huang et al., 2013; Venkatesh et al., 2003) and the tendency to visit the actual heritage site, which was adopted from (Huang et al., 2013).

Since the study used an existing VR tour, the indicators for evaluating the tours were the ones selected to be measured (see Table 2). Accordingly, only 13 indicators were measured during the experiment. Since the study used an existing VR tour, the indicators for evaluating the tours were the ones selected to be measured (see Table 2). Accordingly, only 13 indicators were measured during the experiment. Participants were asked to rate the indicators to evaluate and understand their full experience and also rate its efficiency.

Consequently, after experiencing the VR tour participants were required to answer a survey questionnaire that consisted of five main sections, which can be found at (https://forms.gle/9cACJcfYrs3XsjPs7). The first section is background information like gender, age and educational background. Second, third and fourth sections comprise questions for the indicators of the three aspects; **context**, **users**, and **technology**. On 5 points Likert scale participants were asked to rate the indicators underneath each aspect, where 0 represents the least rating and 5 represents the strongest rating. Correspondingly, the fifth section comprised multiple choice questions, asking about what they liked more about the experience and what they disliked adopted from (Ren & Chen, 2021). Moreover, participants were asked about the elements of the tour itself and added what elements caught their attention most during the virtual experience. At the end of the survey, they were asked to freely add their comments if they had any.

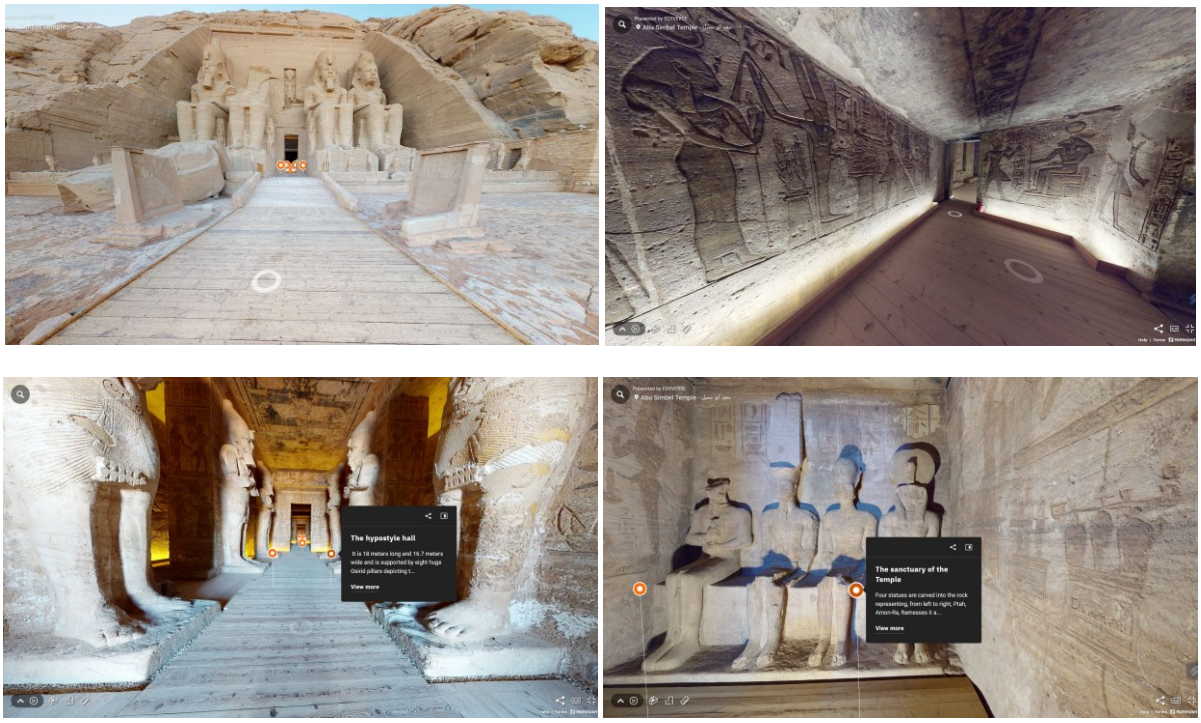

Figure 2. Screenshots for VR environment of Abu Simbel temple (https://egymonuments.gov.eg/news/virtual-tour-for-abu-simbel-temple/).

3.3. Sampling and Participants

A total of 105 students and employees participated I n the experiment, with 105 responses; however, 7 responses were removed as a result of being outliers. Accordingly, a sample of 98 participants was included for the final data analysis. For this level of investigation, the sample size was considered adequate to support the conclusions of the presented study (Bryman, 2008; Creswell, n.d.). Regarding the demographic data summary of the sample, it consisted of 48 males (49%) and 50 females (51%), aged from 18 to 45 years old; 75 of the participants were aged from 18 to 25 (76.5%); 18 were aged between 26 and 35 (18.4%); and 5 were aged from 36 to 45 (5.1%), as shown in Figure 6 and Figure 7. Using Google Forms, participants were kindly requested to sign an online consent form for their participation in the study, then they were asked about their age and level of education, their dominant controller (whether they are left-handed or right-handed), and their familiarity with VR applications. As illustrated in Figure 8 and Figure 9, participants weren't familiar with VR applications (80.6%), while only 19 participants had used VR applications before (19.4%). Also, only 17 participants have visited Abu Simble Temple before (17.5%), while 81 participants haven't (82.5%).

Figure 3. Study participants exploring Abu Simbel temple via VR (Taken by Author).

Figure 4. Participants were given instructions before conducting the experiment (Taken by Author).

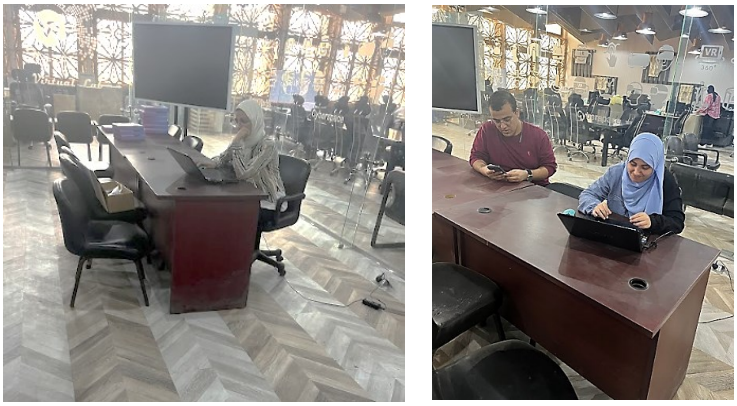

Figure 5. Participants answering the survey questionnaire (Taken by Author).

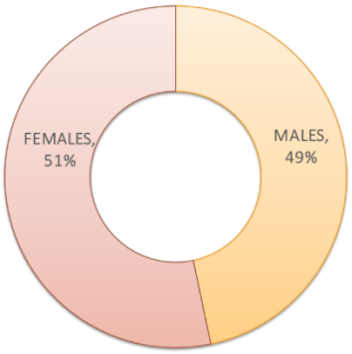

Figure 6. Gender distribution (Developed by Author).

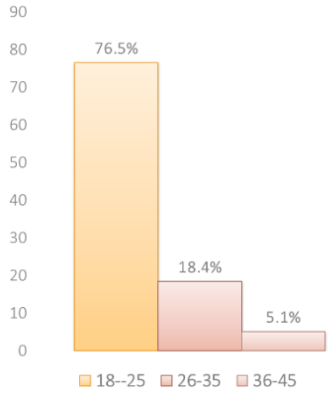

Figure 7. Age distribution (Developed by Author).

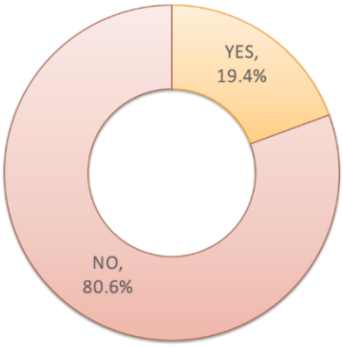

Figure 8. Answer to "Are you familiar with VR applications?" (Developed by Author).

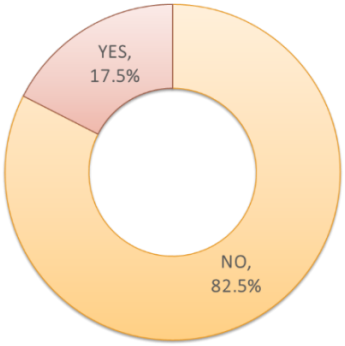

Figure 9. Answer to "Have you visited Abu Simbel temple before?" (Developed by Author).

3.4. Data Analysis

The collected data was analysed using the Statistical Package for Social Sciences (IBM-SPSS V.22) to test the proposed hypothesis and analyse the results related to the users' experience with the virtual tour. However, before starting the actual analysis, the data was screened and checked for normality, and all values of skewness and kurtosis were below ±2, which shows that all data followed a normal distribution (H.-Y. Kim, 2013).

Furthermore, reliability analysis was performed to check the consistency of the rating measurement for the designed survey. Cronbach Alpha coefficient was used to conduct the test, and it turned out to be 0.727 for all the measured items in the survey, which is larger than 0.7. Accordingly, all the ratings were considered reliable with good consistency, so it is safe to run statistical tests to draw conclusions (Pallant, 2020).

4. Results

This section presents findings and analysis of the data collected during the conducted experiment.

4.1. Principal Component Analysis

In order to investigate if the measured dimensions need to be reduced and to understand the average fitting for the data, a principal component analysis was performed on the measured variables. First Kaiser-Meyer-Olkin measure of sampling adequacy scored 0.7 1 which was greater than 0.6, this meant that the data were suitable for factor analysis. The communalities ranged between o.552 and 0.930 so they were considered moderate and strong. Varimax rotation was performed with one as eigenvalue; hence, factor loadings showed that awareness and engagement variables should be excluded from the calculations due to their weak loadings.

4.2. Mean Ratings and Frequencies

Rating means for each one of the selected eleven variables were calculated. Table 3 and Figure 10 show the mean ratings for the eleven variables along with standard deviations and Cronbach's alpha to show the reliability of the measurements. Mean rating scores ranged from 3.5 to 4.9, ease of use (T01) scored the highest mean rating while comfort (U04) scored the lowest mean rating (M=4.88 and M=3.54).

Table 3. Means, SDs, Factor loadings, Normal distribution, and Cronbach's alpha α (Developed by Author using SPSS).

Variables		Mean	SD	Normal distribution		Loading	α	N
				Skew	Kurtosis			
Tendency to visit the site	**C01**	4.52	0.88	-1.12	0.47	0.733	0.70	98
Awareness		*(dropped)*						
Visual quality	**C02**	4.31	0.63	-0.35	-0.65	0. 783	0.70	98
Control	**U01**	4.16	0.77	-0.43	-0.75	0.698	0.72	98
Expectations	**U02**	4.43	0.69	-0.80	-0.53	0.740	0.72	98
Satisfaction	**U03**	4.54	0.69	-1.39	1.32	0.749	0.72	98
Comfort	**U04**	3.54	0.69	-1.39	1.32	0.747	0.72	98
Ease of use	**T01**	4.88	0.24	-0.30	-0.45	0.812	0.67	98
Engagement		*(dropped)*						
Navigation	**T02**	4.27	0.71	-0.44	-0.93	0.734	0.67	98
Understanding	**T03**	4.42	0.57	-0.34	-0.77	0.822	0.67	98
Clarity	**T04**	4.48	0.58	-0.57	-0.63	0.772	0.67	98
Efficiency	**T05**	4.53	0.63	-1.04	-0.30	0.759	0.72	98

Participants were asked about what they liked most about visiting Abu Simble Temple virtually, and 70.4% of the answers showed that the realistic feeling of existence in the temple itself was the best of the presented

experience. They also claimed that the sense of immersion and sense of scale, along with the clarity of details and realistic colours and materials, were the most significant elements that caught their attention during this short tour (see Table 4). The temple's architecture was truly impressive, with elaborate carvings and details. Users were particularly impressed by the level of detail, which made them feel as if they were truly transported to another place. Moreover, as participants explored the temple, they were struck by the realistic sense of scale. Overall, the experience was unforgettable, leaving a lasting impression on all the participants. In compliance with this state, 45.9% stated that the sense of immersion is the most preferable element in the overall experience. Also, 40.8% highlighted the scenography as the most preferable element.

On the other side, participants disliked the initial feeling of dizziness they experienced at the beginning of using the headset 37.8% selected "the feeling of dizziness" as the most disliked part of the experience. Also, 27.5% complained about the movement or navigation method between different points in the temple.

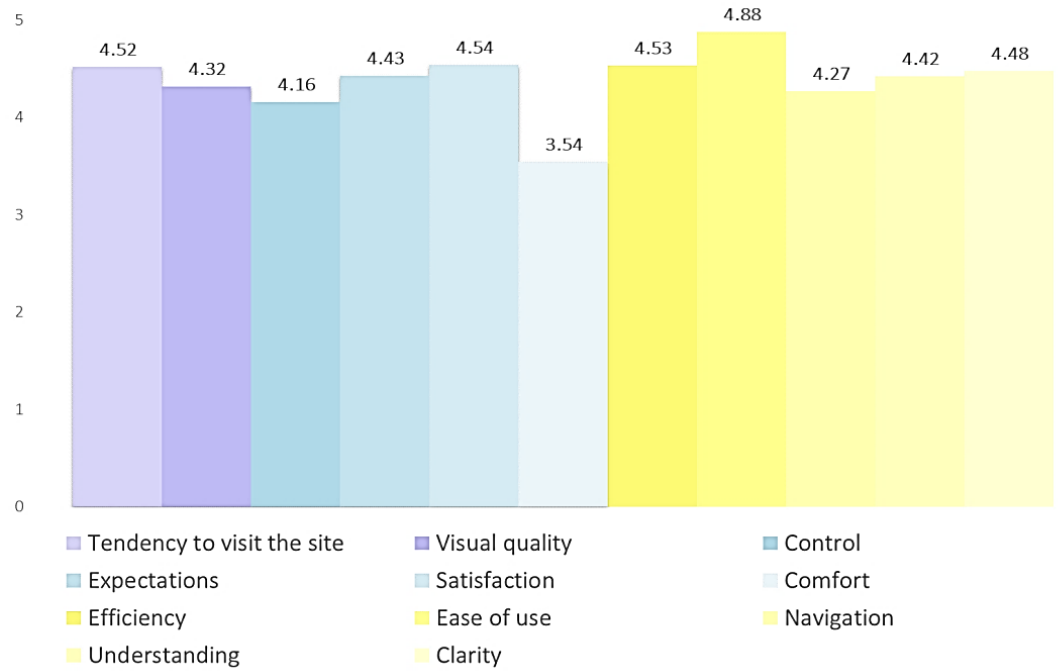

Figure 10. Mean ratings for the 11 variables (Developed by Author).

Table 4. VR tour experience's details and elements (Developed by Author).

	N	%
What did you like most of the experience? (*more than one answer can be selected****)***		
The passage	31	31.6%
The exploration	50	51%
The asset	7	7.1%
The graphics	50	51%
The realism	69	70.4%
Other	1	1.02%
All of the above	1	1.02%
What did you dislike most of the experience? (*more than one answer can be selected****)***		
The falling	17	17.3%
The dizziness	37	37.8%
The movement	27	27.5%
The graphics	7	7.1%
The duration was too short	4	4.08%
The duration was too long	14	14.3%
Other	17	17.3%

Table 4 . (*cont'd)*		
What did you find as the most preferable element of the experience? (*more than one answer can be selected****)***		
The scenography	40	40.8%
The type of interaction	36	36.7%
The atmosphere	41	41.8%
The sense of immersion	45	45.9%
The style of setting	32	32.7%

State if there are any specific elements that caught your attention in the tour. (*open ended question****)***
The statues scale and details
The reality of art details on the temple walls
The surrounding context
The clarity of details and colors****
The tour delivered a sense of sacredness of Ancient Egyptian architecture
The paths' navigation
The lighting effects
The scale and sense of immersion****
The gateway/entrance
*****significantly repeated answers*

4.3. Hypotheses testing: Correlation analysis

Correlation analysis was performed to test the stated hypotheses and examine the relationship between the different variables of the study. Spearman ranking correlation test was used in this study to investigate the relationships between the dependent variable and its predictors. Table 5 shows spearman rank order correlation coefficient (r_s) for all the variables. All variables showed significant correlations with efficiency (T05) at (p = 0.05) and (p = 0.01), except for navigation (T02), which showed a weak, insignificant correlation with the efficiency of the VR tour. Users' expectations (U02), satisfaction (U03), and comfort (U04) have a moderate correlation with its efficiency (T05) ($0.5 < r_s < 0.3$). Also, the efficiency showed a medium significant correlation with the tendency to visit the site (C01) ($r_s = 0.03$). The rest of the correlations are shown to be weak ($0.3 < r_s < 0.1$). Moreover, some interesting correlations were found like the correlation between users' satisfaction and (U03) users' comfort (U04) ($r_s = 1.00$) which is a very strong correlation. Also the correlation between the ease of use (T02) of the tour and how it meets users' expectations (U02) ($r_s = 0.612$) which is considered as a very strong correlation as well, both were significant at p= 0.05.

Table 5. Spearman Correlation for the variables showing the bivariate association for the hypotheses (Developed by Author using SPSS).

	C01	C02	U01	U02	U03	U04	T01	T02	T03	T04	T05
C01	1										
C02	0.125	1									
U01	0.163	0.062	1								
U02	0.107	0.119	0.329**	1							
U03	0.052	0.091	0.143	0.370**	1						
U04	0.052	0.091	0.143	0.370**	**1.00****	1					
T01	0.1	0.115	0.166	**0.612****	0.203*	0.230*	1				
T02	-0.105	0.079	0.204	0.1	0.035	0.035	0.282**	1			
T03	0.276	0.303**	0.171	0.067	0.22	0.022	0.044	0.220*	1		
T04	0.268**	0.433**	0.44	0.217*	0.117	0.117	0.03	-0.062	-0.7	1	
T05	**0.309** H1**	**0.219* H2**	**0.284** H2**	**0.367** H3**	**0.403** H3**	**0.403* * H4**	**0.275** H4**	**0.127 H4**	**0.261** H5**	**0.289** H2**	1

** significance at 0.01 level (2-tailed)*
*** significance at 0.05 level (2-tailed)*

Results show that all the tested hypotheses shall be accepted except for H04, which tests the influence of three predictors (comfort, ease of use, and navigation) on efficiency; only navigation showed an insignificant correlation with efficiency. Therefore, it will be rejected as a predictor. Otherwise, H01, H02, H03, and H05 shall be accepted due to the significance found in the correlation analysis as shown in Table 6. In summary, moderate positive correlations were found for tendency to visit the site (C01), expectation (U02), satisfaction (U03), and comfort (U04); weak correlations were revealed for visual quality (C02), control (U01), clarity (T04), ease of use (T01), and

understanding (T03). Figure 11 demonstrates a structured model showing how all the indicators work together and impacts the efficiency of experiencing VR tours and how it all impacts the tendency of different users to visit the site in reality.

Table 6. Hypotheses testing and decision (Developed by Author).

#	Predictor(s)	Dependent variable	r_s	p value	Decision
H01	Efficiency (T05)	Tendency to visit the site (C01)	0.309**	0.002	Support
H02	Visual quality (C02)	Efficiency (T05)	0.284**	0.005	Support
	Control (U01)		0.219**	0.003	Support
	Clarity (T04)		0.289**	0.004	Support
H03	Expectation (U02)	Efficiency (T05)	0.367**	0.000	Support
	Satisfaction (U03)		0.403**	0.000	Support
H04	Comfort (U04)	Efficiency (T05)	0.403**	0.000	Support
	Ease of use (T01)		0.275**	0.006	Support
	Navigation (T02)		0.127	0.214	Reject
H05	Understanding (T03)	Efficiency (T05)	0.261**	0.009	Support

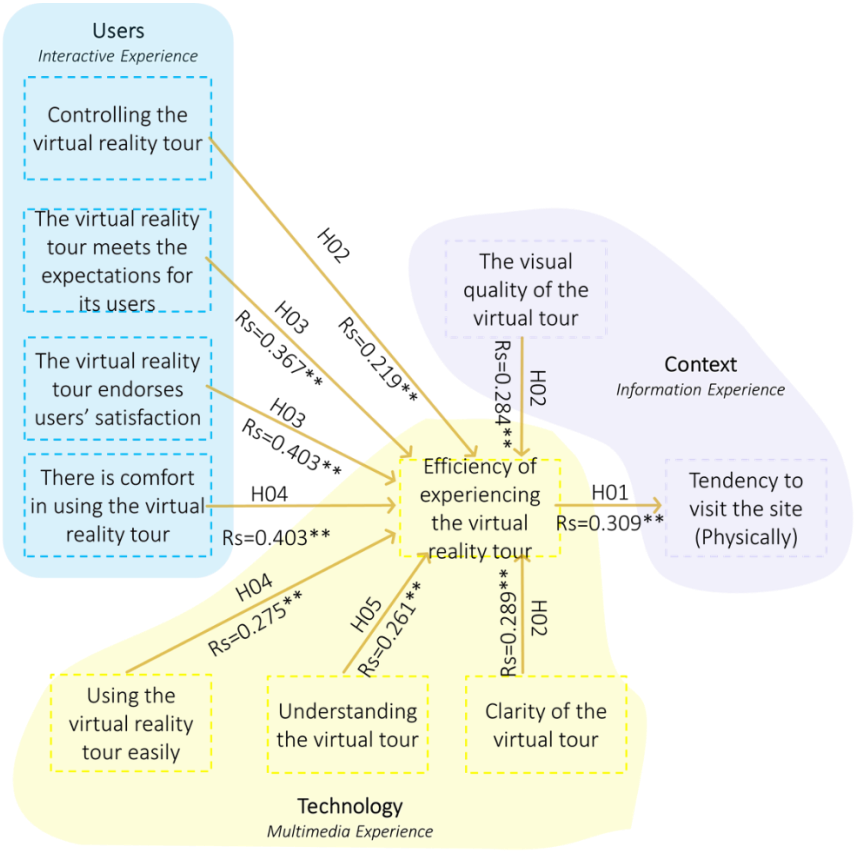

Figure 11. Indicators and aspects working together in terms of increasing efficiency and impact on visiting the site (Developed by Author).

5. Discussion

The study explored the efficiency of virtual tours for heritage sites. The results are encouraging with regards to a sample of 98 participants, which is considered adequate for the experimental study. Results of the experiment confirmed that the efficiency of virtual tours for cultural heritage sites depends on eight important indicators, namely: visual quality of the tour graphics, users' control, meeting users' expectations, users' satisfaction, users' comfort, and users' understanding of the whole setting. Moreover, it appears that the efficiency of virtual tours for cultural heritage sites doesn't depend on users' navigation through the tour. Conversely, the efficiency of the virtual tour impacts the desire of users to visit the actual site in reality in a positive way. It is also noticed that the tendency to visit the site is not affected by the previous experience of users who visited the site in reality before

visiting it virtually. On the contrary, they wanted to visit the site again since they noticed details that they hadn't paid attention to on their previous physical visit.

The results revealed that the indicators related to the users' aspect are strongly related to the efficiency of the VR tour itself. Though the technology of designing the VR tour is important, its success in encouraging people to visit the heritage asset is mainly related to how it delivers its value and significance. Consequently, it is crucial to consider the users' perspective when designing a VR tour. This includes understanding their needs and preferences, as well as their level of familiarity with the heritage asset. Additionally, factors such as ease of use, interactivity, and immersion are also important to consider. By taking these factors into account, VR tours can be designed that not only show the heritage asset in an engaging way but also encourage visitors to experience it in person. Ultimately, the success of a VR tour is measured by its ability to inspire and educate visitors about the heritage asset.

Based on the critical literature review and empirical work a framework for designing and evaluating VR heritage tours could be proposed, as presented in Figure 12. The framework is designed based on the fact that each aspect encompasses a set of indicators that could be used in the design and evaluation processes. The basic concept of the proposed framework is based on highlighting the relation between the three main aspects of VR tours, which are context, users, and technology, along with the three levels of applications, namely: exploration, manipulation, and contribution. The proposed framework for VR tours presents a comprehensive approach to designing and evaluating VR experiences. Immersive experiences that cater to different user needs and preferences can be generated. By incorporating relevant indicators into the design and evaluation process, such as user engagement, usability, and effectiveness, designers can ensure that their VR tours are both enjoyable and informative.

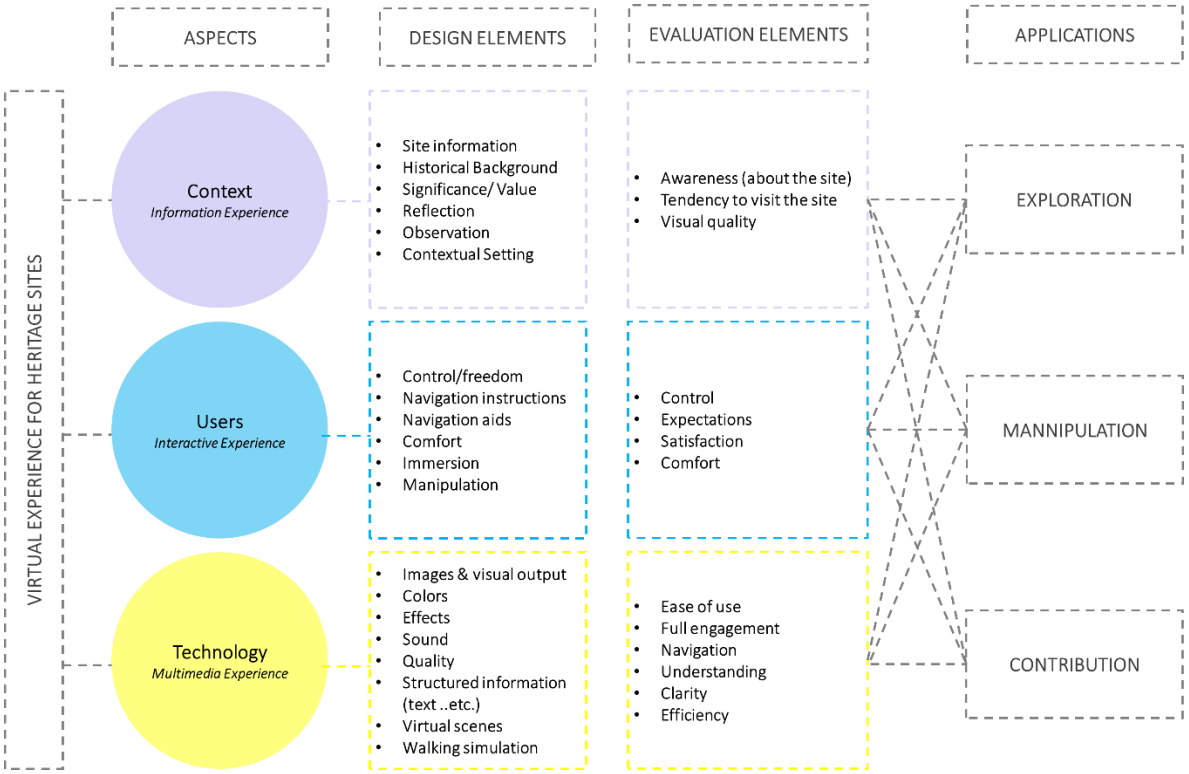

Figure 12. framework for designing and evaluating VR heritage tours (Developed by Author).

According to the outcomes of the study a set of recommendations for developing and generating efficient VR tours could be identified:

- Generating immersive experiences that transfer users to different heritage sites and make them feel as if they physically exist there.
- Incorporating interactive elements into their VR tours that could be challenging for different users to actively engage with the content. This could enhance the user experience and improves knowledge retention.
- Making VR tours accessible to extensive and wide range of users. By offering displays in different languages and adding flexible accessibility features for users with disabilities, and compatibility with different software(s) and devices.

- Implementing interactive elements that allow users to engage with the environment and learn about historical events, traditions and intangible heritage in a more engaging way.
- Updating the tours frequently to be compatible with the latest technical features.
- Incorporating social features such as multiplayer modes or user-generated content could enhance the sense of community and make the experience more enjoyable for users.
- Making sure to engage users in the design process by collecting their feedback to identify their preferences.
- Optimizing graphics and VR performance to ensure a smooth and immersive experience for users.

The research summary in Figure 13 provides a concise overview of the key findings and contributions of the presented work. The summary also highlights how the proposed research questions were addressed and answered through the study. Different indicators are shown to have a significant impact on heritage tours efficiency and attractiveness, which answers the first research question (RQ1). Furthermore, the results showed that the use of VR technology can greatly enhance the overall experience of heritage tours through its immersive and engaging nature. This communicates the cultural significance of heritage assets through clarity of details and good visual quality, which answers the second research question (RQ2).

Additionally, the use of VR technology can make heritage tours more attractive to younger generations, who are more accustomed to using technology in their daily lives. This can help increase interest in cultural heritage and preserve it for future generations. Overall, the study provides valuable insights into the factors that influence VR heritage tours efficiency and offers practical recommendations for improving their effectiveness and sustainability.

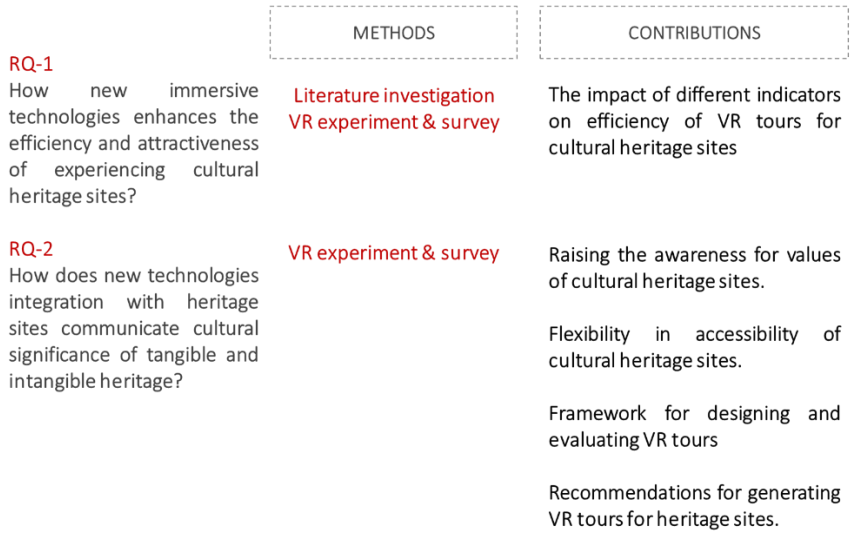

Figure 13. Research contribution (Developed by Author).

6. Conclusions

Virtual reality implementation in cultural heritage practises is an evolving field that has greatly established possibilities for sustaining heritage sites and engaging visitors in a more immersive experience. With the use of virtual reality technology, cultural heritage sites can be preserved and presented in a more interactive and engaging way. The presented study investigated the efficiency of virtual reality tours in enhancing the tendency to visit cultural heritage sites. It highlighted the fact that virtual reality technology provides a more immersive and engaging experience, allowing visitors to explore and interact with the site in an exciting way. The immersive nature of VR technology allows visitors to feel as though they are truly experiencing the site, which can lead to a deeper appreciation and understanding of its significance. This suggests that virtual reality can be an effective tool for promoting tourism and encouraging cultural heritage exploration. Moreover, virtual reality tours may be particularly beneficial for individuals who are unable to physically visit the site due to geographical or physical limitations.

The presented work identified the relationship between the three main constituents of virtual tour design for heritage sites, namely; context, users, and technology. Underneath each of the three constituents, the research highlighted the indicators that have a significant impact on virtual tours of heritage sites. The efficiency of the virtual tour experience appeared to have a significant influence on the tendency of different users to visit the

presented heritage site. Comfort and Satisfaction of users while experiencing virtual tours are perfectly correlated, which makes users' comfort an important aspect to be taken into consideration during VR experience design. A well-designed virtual tour can provide a sense of immersion and excitement that motivates experiencing the site in real-life. However, it is important to note that virtual tours should not be seen as a replacement for physical visits, but rather as a complementary tool for enhancing visitors' overall experience.

The presented study contributes to the literature on cultural heritage representation in virtual reality by proposing a comprehensive framework for designing and evaluating VR tours. By considering factors such as immersion, interactivity, storytelling, and audio effects, engaging and memorable experiences that transport users to different times and places can be generated. Prioritising usability and effectiveness ensure that users are able to navigate the virtual environment easily and learn about different heritage assets. Additionally, the implications of the presented framework can extend beyond cultural heritage representation to heritage education, entertainment, and tourism. As VR technology continues to evolve and become more accessible, it is important to have a clear understanding of how to create effective VR experiences that meet user needs, satisfactions, and expectations.

The research study has some limitations that can be handled in future work in this line of research. First, the results of the study are based on one virtual tour of a specific heritage site (Ancient Egyptian monument) with a special experience. Second, the sample size needed to represent different age groups in a balanced manner. Third, only one indicator (efficiency) was tested to measure its impact on the tendency to visit the actual heritage site. More indicators need to be investigated in order to design a comprehensive VR experience.

Moving forward; the study suggests directions for future research to test the full proposed model on a virtual tour heritage using both levels design and evaluation. Also, testing the impact of different indicators on the tendency of visiting the actual heritage site is another suggestion. Finally, investigating more advanced virtual tours for heritage sites, like the ones with audio effects, motion input, and storytelling.

Acknowledgements

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interests

The author declares no conflict of interest.

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