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AUGMENTED REALITY LIMITATIONS IN THE TOURISM SECTOR

Limitaciones de la realidad aumentada en el sector turístico

Limitações da realidade aumentada no setor de turismo

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ABSTRACT

Technology development and augmented reality (AR) applications emergence have transformed the experiential process in tourism. AR offers enormous potential and advantages to the tourism sector, especially after COVID-19. However, this study aims to find and gain further knowledge of AR's limitations. This research analysed the AR platform *Imageen Tarraco* (Tarragona, Spain) based on a users' survey, in-depth interviews and a focus group (FG). The analysis showed the lack of knowledge and the technical problems as the application's most challenging limitations and their causes. It also allowed categorizing the overall challenges by type of public and delving into the factors that promote their use or non-use. The study provides useful recommendations to AR platform creators and the destination management organizations (DMOS) that implement them.

Keywords: Augmented reality; limitations; tourism; technology readiness; experience.

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RESUMEN

El desarrollo de la tecnología y la irrupción de las aplicaciones de Realidad Aumentada (RA) han transformado el proceso experiencial en el turismo. Se ha demostrado el gran potencial y las ventajas que esta ofrece al sector, especialmente tras la COVID-19. El objetivo de este estudio es averiguar y profundizar en el conocimiento de las posibles limitaciones que aún presentan las aplicaciones de RA. Esta investigación analizó una plataforma de RA, Imageen Tarraco (Tarragona, España) a partir de una encuesta a usuarios, entrevistas a profundidad y un grupo focal. El análisis mostró el desconocimiento y los problemas técnicos como las grandes limitaciones de la aplicación. Categorizó las limitaciones por tipo de público, profundizó en los factores que favorecen o no su uso y las principales causas de estas limitaciones. El estudio proporciona recomendaciones útiles tanto para los creadores de plataformas de RA como para las organizaciones de gestión de destino (OGD) que las implementan.

Palabras clave: realidad aumentada; limitaciones; turismo; preparación tecnológica; experiencia.

RESUMO

O desenvolvimento da tecnologia e o surgimento de aplicativos de Realidade Aumentada (RA) transformaram o processo experiencial no campo do turismo. Ficou demonstrado o grande potencial e vantagens que a RA oferece ao setor do turismo, sobretudo após o Covid-19. No entanto, o objetivo deste estudo é descobrir e aprofundar o conhecimento de quais são as possíveis limitações ainda apresentadas pelas aplicações de RA. A metodologia utilizada incluiu a realização de entrevistas em profundidade e um grupo focal. A análise mostra a falta de conhecimento e os problemas técnicos, como as grandes limitações do aplicativo, sendo recomendado categorizar as limitações por tipo de público, aprofundar os fatores que favorecem a sua utilização, ou não, e as principais causas dessas limitações. O estudo fornece recomendações úteis, tanto para os criadores de plataformas de RA quanto para as *Destination Management Organizations* (DMOS) que as implementam.

Palavras-chave: realidade aumentada; limitações; turismo; prontidão tecnológica; experiência.

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Introduction

New technologies have changed how destination management organizations (DMOs) promote tourism experiences and the way tourists live them at the destinations (Huang et al., 2016; Marasco et al., 2018). Technological development has expanded the experiential process (van Nuenen & Scarles, 2021) and increased the co-creation of value by users (Neuhofer et al., 2014) through their interaction with technology. In this context, augmented reality (AR) applications are increasingly used as experiential and marketing tools in tourism (Cranmer et al., 2020). Moreover, after the mobility restrictions and social distancing due to COVID-19, AR increased in the tourism sector because it provides tourists safety and satisfactory experiences (Mohanty et al., 2020).

AR is a visualization technique that superimposes virtual multimedia objects on real physical spaces (Kounavis et al., 2012), while virtual reality (VR) offers a new virtual world in which users can immerse themselves (Guerra et al., 2015). Some authors consider AR applications a form of VR, and they analyse them together (Guttentag, 2010), while others regard them as different platforms (Burdea & Coiffet, 2003). Hence, many studies have also analysed the potential of VR and AR together (Jung & tom Dieck, 2017; Jung et al., 2015), highlighting the co-creation of value and the experiences promotions among users. In any case, this study focused on AR.

AR applications allow viewing images superimposed on historical heritage. They re-create cultural heritage and promote history, heritage, culture and tourism (Guerra et al., 2015; Tsai, 2020). In addition, the development of smartphones and technologies such as AR allows users to interact with heritage sites and tourist attractions, and it enhances the visitors' experience (Jiang et al., 2022; Jingen Liang & Elliot, 2021).

Several studies (Jung et al., 2015; Marasco et al., 2018) have shown that AR applications are particularly interesting for tourism, as they enable tourists' interaction with destinations. They also allow the creation of personalized and satisfying experiences (Tsai, 2020), which in turn increase their attraction and the decisions to visit the destination (Huang et al., 2012).

Furthermore, AR applications add value to the heritage and the destinations (Tscheu & Buhalis, 2016); they influence the destinations' image creation and are essential tools for tourism marketing management (Hyun & O'Keefe, 2012; Marasco et al., 2018; Rauschnabel et al., 2022; Tussyadiah et al., 2018). Hence, their addition to communication strategies (Huang et al., 2016). This has meant that tourist destinations, seeking to be more attractive to tourists and to set themselves apart from competitors, increasingly introduce these technologies to further promote the tourist experience (Buhalis & Amaranggana, 2015). Jiang et al. (2022) have demonstrated that virtual AR heritage enhances memorable tourism experiences.

Given the AR applications' potential and advantages, destinations are increasingly implementing them. However, they have not enjoyed the expected rapid and widespread (Chung et al., 2015) due, firstly, to their execution financial cost to the destinations and, secondly, because they are still not broadly used by many users or tourists. Moreover, despite the rapid technological developments, AR applications continue to have many limitations (Cranmer et al., 2016), and more studies are needed to identify and solve them. Investigations on the limitations of AR are virtually non-existent, but previous related research (Ayeh et al., 2013; Chung et al., 2015; tom Dieck & Jung, 2018) has analysed the users' technological acceptance of AR applications. They have shown the factors that influence the AR applications' use but have not considered which of them influence their non-use. Also, there are other factors that

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influence the non-use of the applications unrelated to the users' decision to accept these platforms. Therefore, this study aims to deepen the knowledge and understanding of all AR platforms existing limitations that restrict their widespread use to increase their functionality.

Literature Review

Potential and Limitations of AR and VR Applications

Several studies focused on VR applications have demonstrated their potential as tools for tourism marketing by DMOS (Guttentag, 2010; Huang et al., 2013; Huang et al., 2016; Huang et al., 2012). Likewise, most investigations considering solely AR have documented its potential for promoting heritage, history, culture and tourism (Cranmer et al., 2018; Guerra et al., 2015; tom Dieck & Jung, 2017) and enhancing the tourists' experience (Huang et al., 2016; Jung & tom Dieck, 2017; Jung et al., 2015; tom Dieck et al., 2016). AR applications are especially interesting for tourism destinations because they allow DMOS to interact with tourists and create more satisfying experiences (Chung et al., 2015; Han et al., 2018; Jung et al., 2015; Tscheu & Buhalis, 2016), involving increased attraction for tourists and more decisions to visit the destination (Huang et al., 2012). Thus, AR applications add value to heritage and destinations (Tscheu & Buhalis, 2016), they influence their image construction, and they are essential for tourism marketing (Hyun & O'Keefe, 2012; Marasco et al., 2018; Tussyadiah et al., 2018) and the DMO's strategic communication (Huang et al., 2016) management. Cranmer et al. (2020) have shown the broadness of AR's actual value for the tourism industry provides value in five dimensions: marketing, finances, tourist, epistemic and organization.

Although the potential of these applications has been more than proven, their implementation and use have not increased as quickly as expected, and they still show some limitations (Chung et al., 2015). Therefore, some critical studies have begun to emerge. Mascho and Singh (2014) noted the VR limitations in *Second Life*; they highlighted the lack of knowledge of the platform and usability problems arising from users' technological skills. Studies on the limitations of AR are also scarce. Dueholm and Smed (2014) studied the heritage site DMOS' resistance to adopting AR applications due to the possible effects on the authenticity perception of heritage sites or tourist attractions. Others have studied users' acceptance of these technologies (tom Dieck & Jung, 2018) and their accessibility and usability (Leue et al., 2015; tom Dieck et al., 2016; tom Dieck et al., 2018). Yung and Khoo-Lattimore (2019), in a literature review of VR and AR in tourism studies, identified gaps in the use of AR applications.

The Role of Technology Acceptance Models (TAM) and Technology Readiness (TR)

There is a whole area of studies that focuses on the users' acceptance of AR based on TAM (Ayeh et al., 2013; Chung et al., 2015; tom Dieck & Jung, 2018; Jingen Liang & Elliot, 2021) demonstrating the factors that encourage their use. These factors' absence could imply limitations in their use and, therefore, must be addressed. These studies are based on Davis (1986) creation of the TAM and prior research on technology acceptance (Wu et al., 2011). They consider that identifying the potential use of new technologies must examine the user's acceptance, primarily their usefulness and perceived usability (Lin et al., 2007). In the tourism field, Leue et al. (2014) and tom Dieck and Jung (2018) have adapted the TAM to the acceptance of AR, adding external variables that allowed them to better analyse the peculiarities of these applications. Kalantari and Rauschnabel (2018) also applied the TAM to analyse

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users' acceptance behaviour of AR smart glasses with Microsoft HoloLens. They found that perceived usability is determinant for users' AR applications acceptance.

Most authors agree on considering users' TR (Chung et al., 2015; Lin & Chang, 2011; Lin & Hsieh, 2007; Oh et al., 2014) as a determining factor for technology acceptance. Some call it personal innovativeness (Jung et al., 2015; tom Dieck & Jung, 2018; Wu & Lai, 2021; Yussof et al., 2011; Zarmipou et al., 2012).

TR is the propensity of tourists to use new technologies (Parasuraman, 2000), while technology acceptance is the decision to use them. Lin et al. (2007) integrated TR with TAM and created the Technology Readiness Acceptance Model (TRAM) to better explain the tourists' usage intention, later used in other studies (Lin & Chang, 2011; Oh et al., 2014).

Many other factors have also been identified as relevant and have been analysed regarding AR acceptance. Huang et al. (2013), based on the TAM and the Hedonic Theory, identified these technologies' perceived and actual usability. Prayag et al. (2013) diagnosed the importance of emotional experiences, while others determined the enjoyment (Haugstvedt & Krogstie, 2012; Leue et al., 2014), the perceived benefits (Olsson et al., 2012), the quality of information (Jung et al., 2015; Olsson et al., 2012) and the perceived authenticity (Tsai, 2020). Leue et al. (2014) took the existing literature to propose a theoretical model of AR acceptance considering five factors: enjoyment, users' perceived benefits when using the applications, personal innovativeness or predisposition to use these new technologies, rich and high-quality information, and cost of use.

A similar study by Jung et al. (2015) highlighted personal innovativeness as a determining factor for accepting the use of AR applications, demonstrating that it affects user satisfaction. It has been shown that satisfaction improves the recommendation of its use (Ayeh et al., 2013). These authors highlighted other factors such as content, system and personalized service quality. Content quality increases the social value of the application, user satisfaction and subsequent recommendations (Lee et al., 2014). System quality is measured by functionality and usability, which also has a direct effect on users' satisfaction and intended use (Jung et al., 2015). Finally, personalized service quality refers to the ability to provide personalized information.

Chung et al. (2015) highlighted other essential factors that lead tourists to use AR applications: TR, the visual aspect of the applications and whether they find valuable information, and the situational factor, that is, the external conditions that facilitate their use. Lee et al. (2015) even showed that cultural differences are a factor that influences AR acceptance.

Tom Dieck and Jung (2018) expanded the model created by Leue et al. (2014), which is currently one of the most comprehensive models. It includes seven factors: quality information, quality system, cost of use (whether you have free Wi-Fi or it must be paid for), recommendations, personal innovation, risk, and facilitating conditions. More recently, Oyman et al. (2022) showed that consumer novelty seeking, perceived enjoyment, perceived usefulness, perceived informativeness and perceived usability had a positive and direct effect on the behavioural intentions to use AR. Furthermore, Wu and Lai (2021) showed that personal innovativeness, performance expectancy, effort expectancy, social influence and celebrity involvement influence AR acceptance.

Other studies have analysed which AR application aspects provide users with the most value, experiences and satisfaction. Tscheu and Buhalis (2016), for example, highlighted: easy-to-use, personalization, storytelling and user engagement; they suggested considering both the benefits and the costs incurred by users to analyse AR applications use. The costs may include security risks, time lost in management or embarrassing appearance, among others. Therefore, AR applications must seek to maximize benefits and reduce costs if they are to be used (Yovcheva et al.,

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2012). Leue et al. (2015) highlighted social presence, enjoyment and user engagement as indispensable elements for promoting tourist's experiences. Tussyadiah et al. (2018) emphasized the feeling of presence by creating more satisfying experiences, and Chung et al. (2018) the perceived advantage of the applications and their aesthetics.

Despite the studies presented, there is a need to ascertain which factors or their absence lead to the decision to non-use of AR platforms. In addition, it is also necessary to analyse other limitations of the use of AR applications, such as lack of awareness of its existence, technical errors or mobile devices that prevent their use AR need support, development, promotion, clear communication, transparency, maintenance, funding and launching (Cranmer et al., 2021). Therefore, this study aims to analyse all the possible limitations AR applications still have, categorize them and delve into the reasons for their existence to find practical solutions that improve their implementation and use at destinations.

Methodology

Case Study: Imageen Tarraco

This is an AR platform that, since 2015, has been offering AR content at four monuments pertaining to the heritage of the Roman city of Tarragona: the amphitheatre, the circus, the Temple of Augustus and the Forum. Once the application is downloaded, it works by placing the mobile device on the QR code points. The platform offers images of the four monuments from Roman times, even with the public in them doing their activities. For example, the amphitheatre shows a chariot race with the audience in the stands cheering.

Tarragona is a city of about 140000 inhabitants, located in the North-East of Spain; it is a destination on the Gold Coast, renowned for its Roman heritage and archaeological legacy, which in its declaration as a World Heritage Site by UNESCO in 2000.

Study Structure and Analysis Methodologies

This study's central part is qualitative, with a survey to support the data. It is based on a focus group (FG) of locals and visitors of different genders and age groups selected without knowing if they knew of the application or not and on fifteen in-depth interviews with individuals of different ages and origins selected from the questionnaire according to their knowledge and their use of the Imageen platform. Qualitative methodologies provide several reasons and thoughts behind the limitations of the application.

The FG was conducted in November of 2019 with nine Tarragona locals and nine other individuals of different genders and from different age groups selected without knowing if they knew about the application. It helped to develop the script for the in-depth interview.

A total of fifteen in-depth interviews were conducted with the members of the sample. Five individuals were selected from the initial study sample who did not know about the application (group E1), five who knew and had used it (group E2) and five who knew it but had never used it (group E3); all of them were representative of the different sociodemographic segments.

The script for the in-depth interviews had the same variables as the survey. However, the questions were open-ended for respondents to go deeper into the reasons behind their responses and the AR application limitations.

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The interviews were conducted in October and November of 2019. They were recorded, transcribed and analysed based on an analysis template.

The quantitative section consisted of a survey of 150 individuals (75 locals and 75 tourists or visitors) to find out whether they knew of the *Imageen Tarraco* application and if they had viewed it. The quantitative component only contextualizes the issue and allows observing the frequencies of the variables and their relationship with respondents' TR.

The interviews were conducted at the DMO's offices, in hotels and in different touristic attractions of Tarragona. It consisted of three sections. The first one referred to sociodemographic data and to the respondent's knowledge about the application. If they knew about it, the second section was administered. It inquired how they had found out about the application and if they had used it. If they had used it, interviewers proceeded with the third section, which asked about the study's variables: the tourist experience and sense of presence generated, the information about the heritage, the society and the history of the destination, and the assessment of the application as a tool for brand communication (Huertas & Gonzalo, 2020).

Analysis Variables

Since the interest was to analyse the limitations of AR applications use (i.e., finding out why they are not used), the main analysis variables were 1. The lack of awareness of the existence of the application by potential users and among those who know it, 2. Voluntary non-use of the application, and 3. Involuntary non-use. To explain variable 1, respondents were asked if they knew about the application and how they had found it. To explain variable 2, they had to give the reasons that led them to decide to use or not use the application; for variable 3, they had to report any technical problems or impediments they had that did not allow them to view it despite wanting to.

Table 1 contains the study variables and the items considered in the quantitative and qualitative analyses, created from a collection of variables and items from previous AR and VR studies. Items collected involved the non-use of the application—such as not knowing about it—its use, and TR in regards to both of them. It should be noted that previous studies have mainly analysed the factors promoting the use of AR applications; hence, it was decided to collect them all, both positive and negative, to gain a global vision to determine which of them have been decisive in the non-use of the AR analysed.

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Table 1. Variables Analysed

No-knowledge of the application	Knowledge - voluntary non-use of the application	Knowledge - involuntary non-use of the application
(Mascho & Singh, 2014)	TR / Personal innovativeness (Mascho & Singh, 2014; Jung et al., 2015; tom Dieck & Jung, 2018; Yussof et al., 2011; Zarmipou et al., 2012; Chung et al., 2015; Lin et al., 2014; Leue et al., 2014; Wu & Lai, 2021; Oyman et al., 2022) Authenticity (Dueholm & Smed, 2014) Enjoyment (Haugstvedt & Krogstie, 2012; Leue et al., 2014; 2015; Oyman et al., 2022) Usability (Huang et al., 2013; tom Dieck & Jung, 2018; Tscheu & Buhalis, 2016; Kalantari & Rauschnabel, 2018; Oyman et al., 2022) Emotional experience (Prayag et al., 2013) Quality of information (Leue et al., 2014; Chung et al., 2015; tom Dieck & Jung, 2018; Oyman et al., 2022) Visual appeal / Aesthetics (Chung et al., 2015: 2018; Tscheu & Buhalis, 2016) System quality (tom Dieck & Jung, 2018) Situational factor (Chung et al., 2015) Cultural factor (Lee et al., 2015) Personnalisation (Tscheu & Buhalis, 2016) Storytelling (Tscheu & Buhalis, 2016) Engagement (Tscheu & Buhalis, 2016; Leue et al., 2015) Sense of presence (Leue et al., 2015; Tussyadiah et al., 2017) Recommendations / social influence / celebrity involvement (tom Dieck & Jung, 2018; Wu & Lai, 2021) Perceived advantages (Chung et al., 2018) Risks/Costs —time, money, etc.— (Leue et al., 2014; tom Dieck & Jung, 2018)	TR / Personal innovativeness (Mascho & Singh, 2014; Jung et al., 2015; tom Dieck & Jung, 2018; Yussof et al., 2011; Zarmipou et al., 2012; Chung et al., 2015; Lin et al., 2014; Leue et al., 2014)

Source: The authors

As many studies highlight the importance and influence of TR (Chung et al., 2015; Mascho & Singh, 2014; Oyman et al., 2022; tom Dieck & Jung, 2018) in the use of AR applications, this has been crossed with the analysis variables to demonstrate their influence and find out whether it may constitute a limitation. It should also be noted that most authors analyse TR without distinguishing whether its absence affects users' ability to use AR applications or their decision not to use them. This study examines the different effects of this factor on the decisions and behaviour of users because not knowing about and not being able to use the application are not the same as

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choosing not to use it. We must point out that most prior studies are quantitative and provide frequencies of use, but they do not go into depth on the reasons and arguments provided by users to justify how they interact with the application.

Results

1. Unawareness of the existence of the AR application

The first variable is potential users' unawareness of the existence of the application and what it offers (Table 2).

Table 2. Reflections on Limitations Concerning Unawareness of the Application

Reflections on unawareness of the application	Limitations of the Channels of knowledge
Everyone thinks that knowledge of the application is very low, both among locals and tourists (FG and all interviewees)	Those who are unaware of the application do not know how it is communicated as they have not seen it on any medium (FG, E1.1, E1.2, E1.3, E1.4, E1.5, E2.1, E2.2)
Locals believe it is important the AR is known because it adds value to the city of Tarragona (E2.1, E3.2)	People generally have not seen the posters, except for those who live opposite them or the tourists who are already informed and know what they are looking for (FG)
They can act as ambassadors and show it to visitors (E1.1, I1.2)	The posters attract little attention and do not identify the AR (FG and all interviewees)
For tourists, AR is an added value to the heritage of the destination (E2.5)	Internet communication is scarce and ineffective (FG, E3.1, E2.2, E1.2, E3.1, E1.4)
Some consider it a tourist attraction in itself (E3.4)	

Source: The authors

Survey data reinforces those results. Table 3 shows a rather high global unawareness percentage of the AR application (51.33 %). It is surprising as it is a significant commitment to the city's heritage tourism, which implies financial resources and promotional efforts.

Table 3. Respondents' knowledge of *Imageen*

	Tourists	Locals	Total
Know	54.67 %	42.67 %	**48.67 %**
Do not know	45.33 %	57.33 %	**51.33 %**

Source: The authors

The data show significant differences between tourists and locals. Interestingly, the tourists know the AR application better (reaching 54.67 %) than the locals, of whom 57.33 % are unaware of it. This evidences a lack of effective communication among the local public and poor signalling and information about the application at the four points where it can be viewed. But the data on the unawareness of its existence are also high for tourists

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since almost half of the visitors are unaware of the application, which suggests a limitation in publicizing the AR application among tourists.

The AR application communication channels observation showed that the main one is the tourist office (30.14 %), followed by street posters (27.40 %) and the Internet (20.55 %). This indicates good communication management by the tourist office but less communicative efficiency of outdoor advertising and online communication. The low incidence of the Internet as a channel for dissemination and knowledge of the application by visitors is surprising.

Among participants unaware of the AR application, who accounted for the majority of FG and the interviewees from this group, all showed surprise at not knowing it, interest in using it and thought critically about the communication made of the application.

> *"People from Tarragona don't know about it (...) But it is important for them to know, to be able to show it to family and friends who come to visit" (E1.2.)*
> *"I've been here for days, and if you hadn't mentioned the application, I'd have left without knowing about it" (E1.3.)*

The interviewees who knew about it also thought that very few people from Tarragona and tourists knew about the application; its communication is scarce and poor.

> *"The posters are hardly visible. I [know] because I live next door. And if you see them, you don't know what it is" (E2.3.)*

Among the reasons given for the lack of awareness inefficient, online communication was one of them. Middle-aged participants believe that it should be increased through social networks; the youngest, through Instagram. Older people would promote further communication through the traditional local media such as TV or the free press. Some point out that the application's link should be on the City Council's tourism website and all digital spaces, as well as in travel forums, recommendation sites and other tourism-related digital spaces.

> *"If you want to reach young people, it must be on Insta" (E2.3.)*
> *"At the end of the guided visits it should be shown as a complement" (FG.)*
> *"The best advertising would be to see people using it and see their faces and their expressions" (E3.1.)*
> *"The Tourist Board should put the QR code of the application on all materials it produces promoting tourism" (E2.4.)*

If we compare the knowledge-ignorance of the AR application according to the users' expressed technological preparation, those with low TR are not so aware of it; the opposite is for higher TR users. Thus, TR not only shows higher percentages in the use of AR applications, as previous studies have shown (Chung et al., 2015; Mascho and Singh, 2014; tom Dieck and Jung, 2018) but also greater awareness of the application. The reason for this could be that frequent smartphone and new technologies users have longer Internet browsing times and have more access to technological information and applications.

2. Knowledge and voluntary and involuntary non-use of the AR application

Merely knowing about the application is not sufficient for end users to use the application. If we look at the second and third variables, the voluntary or involuntary use or non-use of the application, of the 48.67 % of all respondents

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who know about it, only 26 % use it, and 22.67 % do not. If we look at the degree of use according to users' place of origin, there is a slight difference between visitors and locals; the former use it more. It should be noted that according to the FG, locals do not dispose of the same leisure time as the tourists. Therefore, it is surprising that almost half of those who knew about it have not used it either. Quantitatively, the reasons for the non-use of the application are lack of time (61,76 %), technical problems (20.59 %) and no reason (17.65 %). Table 4 shows the reasons behind them.

Table 4. Reasons for Voluntary Non-Use of the Application

Factors influencing voluntary non-use	Reasons
Lack of interest	
Lack of authenticity	(Youth) It does not attract their attention enough.
	(Tourists) Consider the application artificial and prefer to see the places in their current, real state (E5.1)
Lack of enjoyment	The application should be more entertaining and fun.
Lack of gaming	(Youth) A game incites playing with and using the application.
Lack of interactivity	(Youth) An interactive application makes users spend more time in it.
Lack of usability	(Oldest) The application should be easy to download and use.
Lack of quality information	It should offer more historical, architectural and heritage-related information in a personalized way.
	The personal stories of people who lived in that era are interesting.
Lack of storytelling	They did not have enough space on the phone, insufficient data or no Wi-Fi.
Technical issues	

Source: The authors

The results of the FG and the interviews showed that many of the responses justified by the lack of time in the quantitative study hid the lack of attractiveness, lack of interest and inability to capture attention. The youngest interviewees show less interest in using it, despite knowing about it more.

> *"Sure, there are people from Tarragona who know the application, like me, and don't bother to view it. There's no interest in knowing something you already see every day. However, when you're on holiday and you visit a place, you are more interested in what you see" (E2.1.)*
> *"I've never seen the platform because I haven't had time. Because of laziness, because I haven't given it thought, because I wasn't curious enough..." (E2.3)*

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However, all middle-aged and older interviewees displayed an interest in using the application.

"I would view it. I think it's very interesting. It's not the same as looking at just stones" (I1.4.)

Moreover, some of the tourists who knew about it and voluntarily have not used it stated that their reason for this is the lack of authenticity they perceived as they consider it somewhat artificial and prefer to see the real site.

"I prefer to see what's left of the monuments as they are now, even if they are just stones, to a reproduction" (E3.5.)

Both the FG and the interviewees of various origins and ages that had viewed the application emphasized that for the platform to be used by more people and repeatedly, it would need to be more entertaining and fun.

"The application should involve a tour of the 4 monuments, and you have to go from one to the other. As if it were a tour through history" (FG.)

The youngest, moreover, requested the introduction of gaming and interactivity so that the application would be more attractive and interesting.

"It would be nice if you could make the chariots race and win or lose races using the phone as a remote. Something simple but that incites you to do it" (E3.1.)

For the older respondents, usability is the reason behind their non-use.

"People of my age, if it is a bit tricky, they don't view it. If the applications are easy, like the one for the bus, it's fine." (E1.1.)

In general, participants also highlighted the importance of the information quality and extension and the need for it to be customized and changed or extended over time for people to use it again. They even emphasized the importance of storytelling to make the application more attractive.

"For children, there needs to be more information but in the form of family stories and about people who lived at that time. Storytelling gets you interested" (FG.)

"I think it is important that it should provide new information to the existing heritage that can be visited. Superimposing both spectacular images and providing historical information about what it was like, what they used to do there..." (E1.5.)

The older the respondents and interviewees were, the more technical problems they manifested. Younger and middle-aged people did not stress technical issues. However, they voluntarily did not use the application because they lacked space on their phone to download it, and others did not dispose of a data connection to do so. It should be noted that technical problems not only affect those who wanted to view the application but could not. It was also a reason for deciding not to use it.

"I searched on the website and when I saw there was no direct link to the application that made me not use it" (E2.2.)

"When I discovered the application, I had a phone whose memory did not allow for many apps. I didn't download anything that wasn't essential" (E2.4.)

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Conclusions

This study shows that the first limitation regarding AR applications use is the lack of knowledge of them due to poor communication among tourists and locals. This limitation is beyond the users' control for deciding to use these technologies. Given the AR application advantages (Jung et al., 2015; Marasco et al., 2018) and their potential as tourism marketing tools (Hyun & O'Keefe, 2012; Marasco et al., 2018; Rauschnabel et al., 2022; Tussyadiah et al., 2018), heritage sites or DMOs that implement them must perform efficient strategic communication to make it known to the public in general. This confirms the findings from Cranmer et al. (2021) that communication is critical for reducing resistance to AR use and realising its benefits.

A second limitation that prevents their use but is not attributable to users is technical problems. This factor must be distinguished from TR, the users' abilities to use technology (Hyun & O'Keefe, 2012; Marasco et al., 2018; Tussyadiah et al., 2018). Technical problems have affected users who wanted to use the application but could not, mostly the elderly who did not know how to download the application or did not have a mobile with the capacity to do so. This factor has also affected young people who decided not to use the application because they did not have enough space on their mobile or enough data or Wi-Fi capacity. It is, therefore, necessary for the creators of these applications and the DMOs that implement them to make sure that they can be downloaded and ensure free Wi-Fi on site, among other aspects.

This study has demonstrated that TR significantly influences AR applications' use (Marasco et al., 2018; Oyman et al., 2022; Tussyadiah et al., 2018; Wu & Lai, 2021), but it also showed that its lack is one of the main limitations faced by AR users. Also, it should be noted that previous studies have addressed TR as a factor globally affecting technology acceptance. In this study, we distinguished its impact on the three analysis variables. In addition to affecting the voluntary acceptance of technology and the individuals' ability to solve technical problems, it also affects the knowledge / lack of knowledge of the application. This adds a new value to this factor which increases its potential to influence.

Another contribution of this study is the combination of the quantitative and qualitative approaches to provide deeper information about the real reasons behind the user's decisions. This was demonstrated in the question about people's decision not to use the application, to which most responded it was to lack of time or technical problems. However, the qualitative study showed that lack of time really involved an absence of interest, based on the perceived unattractiveness due to the scarce gaming, enjoyment and interactivity they perceived of the application.

The most interesting constraints are the ones that lead users who know about AR applications to choose not to use them. The qualitative study has shown that there are certain factors that most influence their non-use. Young people identified them as lack of enjoyment, gaming and interactivity. Enjoyment (Haugstvedt & Krogstie, 2012; Leue et al., 2015; Leue et al., 2014; Oyman et al., 2022) was already highlighted in previous studies, and interactivity coincides with engagement (Leue et al., 2015; Tscheu & Buhalis, 2016), but the demand for gaming in these applications is something novel that emerged in both the FG and the in-depth interviews. In contrast, older participants considered the lack of usability as a major limitation. This has traditionally been the factor associated with TAM (Huang et al., 2013; tom Dieck & Jung, 2018; Tscheu & Buhalis, 2016). In fact, the qualitative study showed those are the reasons for users to fail or be unable to access the application.

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Two other determining factors that render the application less attractive and may lead to it not being viewed are the lack of quality information and storytelling. In the FG and the in-depth interviews, it emerged that quality historical, architectural and cultural information was necessary for people to wish to use the application. Jung et al. (2015), Olsson et al. (2012) and Oyman et al. (2022) already stressed the importance of this factor. In the present study, potential users requested that this information be adapted to the different targets (tourists, locals, school children, etc.). Storytelling is also considered crucial for the applications' attractiveness and use, as previous authors have already noted (Tscheu & Buhalis, 2016). Although this factor is not included within the TAM as a determinant factor for technology acceptance, our qualitative study highlighted it as being.

Therefore, the results of this study are interesting for AR application creators and for the DMOS who should implement applications that include games for the younger public and interactive resources and look after issues concerning quality information and storytelling. They should also consider usability, provide free Wi-Fi and address all the technological aspects for users to download and use the application.

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