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Tourists responses to mobile augmented reality travel guides: The role of emotions on adoption behavior

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ABSTRACT

This research presents a mobile augmented reality (MAR) travel guide, named CorfuAR, which supports personalized recommendations. We report the development process and devise a theoretical model that explores the adoption of MAR applications through their emotional impact. A field study on Corfu visitors ($n = 105$) shows that the functional properties of CorfuAR evoke feelings of pleasure and arousal, which, in turn, influence the behavioral intention of using it. This is the first study that empirically validates the relation between functional system properties, user emotions, and adoption behavior. The paper discusses also the theoretical and managerial implications of our study.

1. Introduction

Mobile and wireless technologies enable the provision of novel applications that support visitors while on the move. Such applications include mobile travel guides [1,2] and location-based infotainment services (e.g. GIS-based recommendations [1,3], annotation and bookmarking [4], and mobile social networking [5] to name but a few popular application types). In essence, these applications allow tourists to have seamless and ubiquitous access to travel-related information during their visiting experience, which is presented in a multimedia-rich way. At the same time, location sensing capabilities of mobile devices facilitate filtering of the travel information in order to be tailored to the travelers' needs and wants. The value of mobile travel solutions capitalizes on the properties of leisure and travel; they both concern intangible goods that are highly experiential and might be consumed on an ad hoc basis. Therefore, efficient organization and travelers-tailored presentation of travel-related information are of paramount importance for both tourists and tourism industry stakeholders.

Considering the above, it is not surprising that mobile travel-related applications have received scholars' attention from both an academic and practical perspectives. Topics of interest include approaches and methods to design and implement mobile travel systems and services [1,6–8], user adoption studies [2,9–11]; and business model formulation [12]. An

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underlying commonality among the different research themes refers to the design scope of such applications. Mobile guides involve users to be situated in the surrounding environment of a built place [13,14]. Nevertheless, the design of mobile guides assumes that the built place will fit the mobile device; people, places, and any point of interest (POI) are encoded in digital maps or context-aware notifications. Hence, the design focus of mobile guides lies on one principle; developing digital metaphors of the real-world that assist travelers in covering their information needs while on the move.

Mobile augmented reality (MAR) follows a different design paradigm. Instead of developing a virtual incarnation of the real world, MAR augments the real world with digital information. As such, the design canvas is expanded from the limited space of the mobile phone to also include the physical properties of the built world. MAR is a relatively new technology that offers new affordances for interaction. In essence, MAR promises to enhance user experience by superimposing digital objects or content over the surroundings of the real world [15]. Whilst early research focused on resolving the technical challenges of MAR [16–19] and demonstrating its application potential in several settings [20–23], few studies associate the value of MAR with the domains of travel and tourism [24–27].

This study attempts to shed light on the potential of MAR for supporting mobile tourism applications. We present CorfuAR, a mobile augmented reality tour guide, which supports personalized content provision and navigation features to tourists on the move. We describe the development efforts of our MAR travel guide and emphasize on building the users' profile for the personalized version based on static, pre-discovered activity preferences of users and tracking of their actual behavior. Moreover, we report evidence of an adoption study that assessed the users' intention to use CorfuAR not only in accordance with their perceived performance and usability, but also the emotional impact of the MAR prototype by employing Mehrabian and Russell's [28] PAD theory. The field study revealed the design choices of MAR travel guides that lead to increased user satisfaction and usage intention. All in all, we aspire to provide help to prospective designers and developers to engineer MAR tourism applications.

The paper is organized as follows. Section 2 discusses the functionality of mobile travel guides, the properties of mobile augmented reality applications and the potential for MAR in tourism. Section 3 outlines the functionality and architecture of CorfuAR. Section 4 emphasizes on the personalized version of the mobile augmented reality tourist guide. Section 5 details the methodology and results of the field study that we performed in order to assess the performance, usability and experiential impact of CorfuAR. Finally, we conclude the paper with a critical discussion on the academic and practical implications of our research pertaining to the development and evaluation of mobile augmented reality tourism applications.

2. Background

2.1. Mobile travel guides

Mobile travel guides have been the subject of scrutiny over the past years by academic scholars. Emphasis has been paid primarily to the identification of their architectural, technological and functional properties [1,29,30]. Consolidating their findings, mobile travel guides provide partially or fully four types of functionality: navigation services, content-based services, social and communication services, and commercial services.

The main concern of navigation services is routing users from their current location to a preferred point of interest (POI) by usually displaying a map of the surrounding area [31]. Content-based services refer to the provision of travel or POI related information. Specifically, these may include personalization features that filter and adapt the visualized content according to users' current context and profile [8,32]. Also, such services may incorporate search facilities to locate and receive information regarding places, topics, or exhibits of interest [33]; and bookmarking which allows users to add locations to an ad hoc generated itinerary in order to better plan, manage, and share their leisure experience [34].

Social and communication services support liaison between the travelers and the accommodation providers, exhibition owners and other stakeholders involved in service provision [12,35]. Moreover, they enable sharing of tourists' experiences through a variety of websites (Facebook, Twitter, TripAdvisor, Blogger, and many other popular online social networks); and in different ways, ranging from posting their stories, their comments, to even their pictures and movie clips [5,36]. It should be noted that recently, social media have emerged as a substantial part of the online tourism domain [37]. Finally, commercial services support mobile purchases and reservations of tourism-related products [38,39].

These functional properties of mobile travel guides follow a common user experience metaphor. Instead of reinforcing the relationship of the travelers with the physical surroundings, these guides develop a simulated environment where individuals are required to be immersed in for requesting and receiving digital content and information. On the contrary, mobile augmented reality aims at shifting the attention of individuals back to the real world, not its digital incarnation. The following subsections discuss the characteristics of MAR technology that justify the growing interest in MAR-enhanced travel and tourist services and applications.

2.2. Mobile augmented reality (MAR)

The concept of MAR was developed around the mid-1990s, applying Augmented Reality (AR) in mobile settings. Rather than trying to create an entirely simulated environment, MAR starts with reality itself and then augments it by overlaying digital information on top of the real world. The novelty of MAR relies on its usability aspect; it enhances the traditional user experience while interacting with a mobile device [40].

Using a display, such as a mobile phone or a tablet, users may see a live view of the world surrounding them, augmented with digital annotations, graphics and other information superimposed upon it. The user points the device in the direction of an item of interest and the system augments the output with additional information about the environment. The extra information varies from names of buildings visible on a city skyline, or information related to the points of interest; to real-time notifications regarding location or time dependent events (e.g. menu discounts in restaurants).

As such, the properties of MAR-enhanced systems rely on augmented reality principles: they combine real and virtual objects in a real environment; they run interactively, and in real time; and they register real and virtual objects with each other [41]. Likewise, MAR minimizes task-switching by promoting continuous use and reducing distractions [42]. As such, it is not surprising that industrial scholars have decided to capitalize on MAR experiential features and devise new mobile-based, enhanced interaction means. For example, Google Glass (i.e. a wearable AR head-mounted display (HMD)) augments users' visual perception of their world by adding layers of virtual information on top of it. The same principles apply to audio information that complements users' audio perception of the world. In the same spirit, it is widely believed that AR technologies are maturing and become well established; this fact favors the broad implementation of AR applications within the next ten years [43]. Respectively, the recent advances in mobile computing hardware and software, but specifically the proliferation of smart mobile phones, seem to pave the way for mass, faster adoption of mobile augmented reality applications [44–46]. Recent introduction of publicly available MAR development platforms (e.g. Layar, Wikitude and Junaio) confirm the growing interest in MAR systems and services, as well as support the implementation of such applications.

In agreement with industry, academia foresees an enormous potential for MAR technology; researchers have acknowledged that the combination of mobile and AR features presents unique opportunities for the deployment of novel applications in diverse contexts. In fact, MAR has been employed to support students learning [20,47,48], university campus touring [49], library services [50], architectural design [51], smart home environments [52]; and phobias treatment [53] to name but a few application domains.

2.3. MAR applications: the potential for MAR in tourism

The emergence of MAR has given the opportunity to tourism organizations and destinations to provide a large amount of relevant tourist information in a different form than simply checking online sources or travel guides, thus enhancing the overall tourism experience [44,54–56]. In a nutshell, from a business standpoint, MAR can influence the marketing of travel destinations and reach more customers by enhancing their travel experiences.

Specifically, MAR systems are ideal tools for guiding tourists through unfamiliar environments and providing useful information about them. Navigation and way finding were one of the first application areas for MAR and still remains the most widely used feature in prototypes and commercial tourism-related applications [30]. But we should emphasize that augmented displays have the potential to reduce the mental effort required for navigation, as well as provide to travelers with an opportunity to discover unknown surroundings through visual, audio and 3D location-based information [55]. MAR can show virtual paths and directional arrows to facilitate navigation (e.g. Nearest Tube application), deliver augmented and interactive information regarding dining, museums, entertainment et al. (examples of such applications include mTrip, Tuscany+, and MobiAR), as well as provide real-time immediate translation of written text on signs, menus et al. (e.g. Word Lens) [57].

Moreover, AR systems can help tourists to re-live historic life and events by reviving ancient temples and historic buildings as 3D objects, which are placed on the actual monument. The first cultural heritage site that benefited from an augmented virtual reconstruction of an ancient temple was Olympia in Greece, where researchers developed the ArcheoGuide AR system [58].

Further, in terms of motivating and engaging tourists, thus enhancing the overall tourism experience, AR applications have the strengths of developing enjoyable holiday trips through the integration of AR gaming (e.g. TimeWarp [59]). These applications provide opportunities for tourists to become familiar with unknown areas in an enjoyable and educational manner.

MAR applications may also assist destination-marketing organizations to gain competitive advantage through the use of advanced information technologies [60]. A significant characteristic of MAR, which differentiates it from other context-aware systems and mostly contributes to enhancing the tourist experience, is its innovative technological character, which engages and impresses the user. This element of MAR functionality provides applications that follow MAR design principles with advanced marketing-related capabilities, which – when applied correctly – can lead to strong destination branding and reaching more tourists. An example of a destination that aims to enhance the overall tourist experience using AR is Dublin, with the Dublin AR project [60]. The use of AR in Dublin originated from the idea to support Dublin's brand development of "innovative city" in Europe. During this project, they developed a mobile AR application for the tourism industry, which will be applied via tourist trails in various parts of the destination by considering various tourism stakeholders.

Even though literature contains several frameworks and principles surrounding the design of MAR (e.g. [57,61]), such works highlight the need of examining MAR development from a user-centered point of view, i.e. developing sample MAR applications, evaluating their use, acceptance and experiential qualities and, finally, fleshing good design practices for further

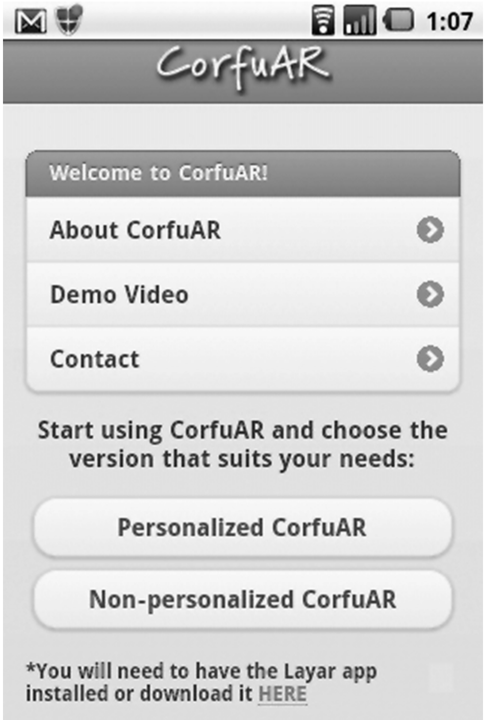

Fig. 1. The homepage of CorfuAR mobile augmented reality application.

use and improvement. Naturally, the development process should be described in full detail for research repeatability purposes. This study presents the development of an MAR tourist guide for the principal city of Corfu island in Greece. The ultimate purpose is to report evidence and provide the first insights regarding the design of MAR applications for tourism and the visitors' intention to adopt such MAR services, through a field study. As a research sub-question, the work goes one step beyond usability by exploring the experiential impact and the stimulation of emotions from the use of the developed MAR travel guide.

3. CorfuAR: a mobile augmented reality travel guide supporting personalized recommendations

3.1. System overview

CorfuAR is a high fidelity prototype of an MAR tour guide for the principal city of Corfu island in Greece, which is also named Corfu. The guide is available for Android devices in two versions: a personalized and a non-personalized one. Generally, the system provides the basic functionality of a mobile travel guide, namely displaying information about points of interest (POI), routing to selected locations; as well as social media features (i.e. recommendation of POIs to other peers of the same cluster). Moreover, the personalized version recommends specific points of interest to the system users based on a combination of pre-discovered and real-time, dynamically updated preferences. User preferences and segmentation have been extrapolated based on a technique recommended by the World Tourism Organization.

3.2. Functionality

Initially, the application welcomes the user and presents the available options (Fig. 1). Users may select the non-personalized version of CorfuAR, in which entire content is available without any means of filtering or aggregation. Alternatively, users may prefer the personalized CorfuAR, in which content is automatically filtered based on user profile and contextual data. It should be noted that this option is offered only for the first time when the user interacts with the system. In all future usage interactions, the guide proceeds with the initial user preference; users may change their selection through a respective option in the welcome menu.

CorfuAR supports nine categories of POIs (Fig. 2). The personalized version of the application contains the entire content of the non-personalized version (approximately 90 POIs); however it visualizes the filtered, recommended POIs in a different way, through colors, in order to easily notify the user about recommended content in his/her surroundings. Thus, no content is excluded in the personalized version; on the contrary, the relevant information is highlighted.

Fig. 2. The 9 categories of points of interest (POI) supported by CorfuAR.

Fig. 3. CorfuAR travel guide in action.

The size of each POI's icon is dynamically changing according to the distance of users from that POI. The larger the icon, the closer the user is to the POI (Fig. 3). All POIs are displayed as gray 2D icons, apart from the personalized ones that are displayed as colored 2D icons. We use three different colors (red, green and blue) corresponding to three users' groups with common preferences produced by the users' segmentation process described in Section 4.

Naturally, marker-based and geo-based AR is prone to the ''occlusion problem''; the real world (e.g. the user's hand) or the AR contents itself (e.g. an AR object) may visually cover the AR content that is being displayed, thus the user can lose valuable information [54,57]. The CorfuAR application is no exception; indeed, the possibility of a close large POI icon that covers a smaller one of a distant POI exists. However, we took any measure technologically possible to provide to the user extra options that solve the occlusion problem. The user can see all the POIs in list view or on a map (using Google Maps). Alternatively, the user can set a distance filter, excluding POIs that are very far away and may cause extra ''noise''. The default value for the distance filter is 500 m.

The main window of the application supports three distinct types of functionality (Fig. 3). First, users may request and receive information about a displayed POI by selecting it on the screen of their mobile device (e.g. cultural information, visiting hours, ticket prices and so on—'Info' in Fig. 3). Second, users may recommend a POI to other peers in their cluster by pressing the ''Recommend'' button. This social media feature is available only through the personalized version of CorfuAR. Finally, users may ask for navigation directions to a specific location/POI by pressing the ''Take me there'' button. Directions are displayed on a Google Maps terrain.

The supplementary information regarding each POI was provided by the Cultural Heritage website of the Municipality of Corfu (www.corfutour.gr). All content was exported to an additional database server hosted within the Department of Informatics at the Ionian University (referred as CorfuAR database) for redundancy purposes, in cases that the direct link with the host server was lost. Information was adjusted to fit the mobile device presentation capabilities. As for the geo-location information of each POI, it was obtained using the Google Maps platform.

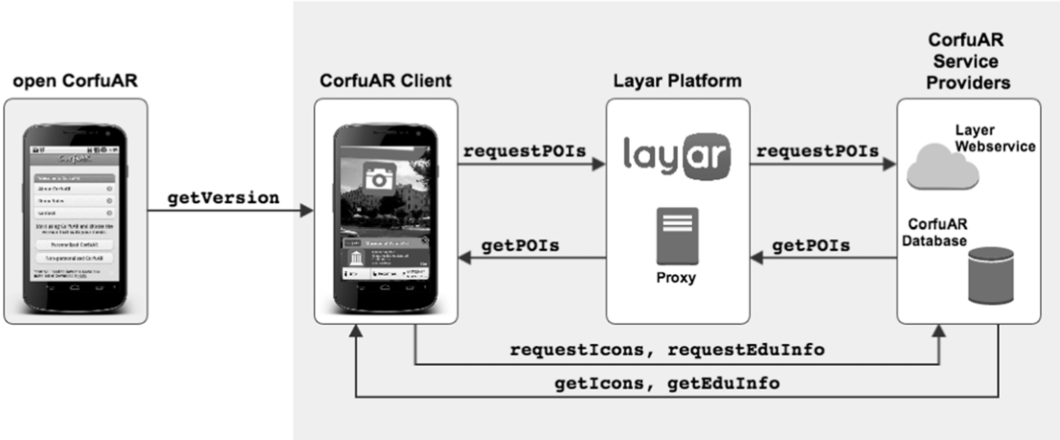

Fig. 4. The architecture of CorfuAR.

3.3. Architecture

The CorfuAR application was implemented using the Layar platform and is available for Android devices. Layar is an AR browser, which adds "layers" of AR content on top of the real worldview. CorfuAR is developed as a "layer" of Layar, utilizing the functionality and the high quality features of this platform.

According to the system architecture (Fig. 4), when the users open the CorfuAR application, they have to choose between the two versions: personalized and non-personalized (getVersion in Fig. 4). Then, in case the users have selected the personalized version, they fill the clustering questionnaire for the personalized version, which is implemented in PHP scripting language and is hosted in the CorfuAR server. Following the initial categorization of application users into one cluster, CorfuAR opens one of the 4 respective versions (basic, blue, red, or green) and initiates communication with the Layar Platform. The CorfuAR Client sends a getPOIs request to the Layar Platform, which, in turn, forwards the request to the CorfuAR Service Provider (requestPOIs in Fig. 4). Then, the CorfuAR Service Provider sends the augmented reality content back to the Layar Platform (getPOIs in Fig. 4). Finally, the Layar Platform validates the getPOIs response and passes it to the CorfuAR Client (getPOIs in Fig. 4), which visualizes the content to the mobile device.

A very important element of CorfuAR's architecture is the CorfuAR database, which consists of 4 tables corresponding to the versions of CorfuAR. Each CorfuAR database table contains – amongst the Layar-related ID information – all the POIs' GPS coordination (longitude, latitude, altitude), the 2D icons of each cluster and a direct link to the information content providers. The cultural information of each POI is also stored in the CorfuAR database (respecting the terms and conditions of the source for copying and distributing the material), to ensure the availability of the information even if the original source/webpage is down (requestEduInfo and getEduInfo in Fig. 4).

Finally, the personalization feature of CorfuAR is implemented following a two rounds algorithm. During the first round, the application identifies in which cluster users belong to, based on their responses in the clustering questionnaire. Users may save their preferences for all future usage sessions, but they can also modify them should they desire to switch from one personalization layer to another. Respectively, the second round of the algorithm takes into account the number of 'Recommendations' of each POI and the total number of visits that each POI received from other users of the same cluster. The first 15 POIs with the highest count (popularity) are automatically displayed as colored 2D icons (blue, red or green according to the cluster) since they are the recommended ones, whereas all the other POIs ($90 - 15 = 75$) are displayed keeping the "basic" gray icon (requestIcons and getIcons in Fig. 4). This algorithm that enables personalization in CorfuAR is further analyzed in Section 4.

4. The personalized version of CorfuAR: discovery and evolution of users' preferences

Personalizing the information provision might prove to be an important element in the design of mobile augmented reality applications in order to minimize risks of information overload [16]. In this research, we embellished the CorfuAR system with personalization capabilities by developing a filtering tool that automatically selects and presents to the users the content that matches their preferences. Naturally, the discovery of the users' preferences and the subsequent users clustering are prerequisite to the application of this filtering tool. The filtering tool presents the application content that we have pre-allocated to each cluster (users' profile).

Table 1
Activities assigned to the three users' clusters (profiles).

Users' cluster (profile)	Activity
Blue	Business (seminars, conferences, business meetings) Culture (monuments, sights, arts, history, museums, architecture) Religion (churches, monastic sites, temples, holy shrines)
Red	Shopping (clothing stores, souvenirs, hobbies, gifts) Nightlife (bars, clubs, events, meeting people) Gastronomy (food, restaurants, tavernas)
Green	Nature study (nature reserves, bird watching, wild life) Tripping (walking, exploration, tripping, hiking) Water sports (boating, surfing, waterskiing, sailing)

Actually, we employed the tourists' segmentation practice of the World Tourism Organization in order to cluster the users and, thus, to provide the personalized content. In the mid-90s, the Irish National Tourism Organization applied a tourist management plan based on categorization of tourists according to their activities when in Ireland. The same technique of classifying the visitors was officially adopted by the World Tourism Organization under the name "activity segmentation". This technique is implemented based on an activities-related questionnaire, where tourists choose the activities appealing to them during their stay [62].

Activity segmentation captures the activities range of tourists while they visit a destination. The tourism industry can take advantage of this method to discover and define new discrete market segments corresponding to activities groups, as well as document the activities and examine the visitors' level of satisfaction. Each activity is documented through qualitative and quantitative research, so as to separate opportunistic activities from activities than define market segments. Hence, the long-term benefit is the design and provision of products and services that really cover the tourists' needs or the evaluation and improvement of the existing ones.

We applied the "activity segmentation" technique to cluster the CorfuAR users because activities, which can define discrete market segments, are those that are supported by facilities, locations, and services in various places. Even though activities are not the main reason for visiting a place, they can be an important part of the overall tourist experience [63]. Therefore, the categorization and tracking of tourist activities could be seen as an essential and investigative guide, in order to preserve, and improve the experiential performance of destinations. The more the tourism industry knows about the behavior of an average tourist, the more capable it is to provide a satisfactory plan to him [64].

Specifically for CorfuAR, we used nine activity categories to segment the Corfu tourists into three clusters, namely three user's profiles. Three categories of activities were assigned to each cluster (see Table 1). Users are instructed to fill the questionnaire with those activities during their first interaction with the application (see Fig. 5). The results of the questionnaire-based segmentation process assign each user to one of the three clusters. We adopted this number of clusters based on extant segmentation studies in tourism journals (e.g. [65–67]), which indicate that tourists may be classified in three broad clusters based on their activities: thematic-based (i.e. business, religious etc.), entertainment-based (i.e., shopping, night-life), and action-driven tourism (i.e. sports, tripping etc.). In CorfuAR, the blue cluster represents thematic-driven tourists; the red and the green cluster represent entertainment-driven tourists and action-driven tourists, respectively.

Ultimately, the personalized version of CorfuAR displays the personalized POIs to the user as red, blue or green icons according to the user's predefined profile. Nevertheless, we put an effort to accomplish real-time update of the pre-discovered users' preferences and assignment to one of the three clusters. In effect, we utilize a two-fold approach to explore and interpret the users' behavior during their visit to Corfu. First, we apply a Google Analytics tracking code to every webpage with POI-related content. Thus, we have the opportunity to find out those POIs that caught the users' attention and they wanted to take additional information about them. Likewise, by tracking the GPS data on a user's mobile device, we were able to infer when a user physically visited a POI that was included in his recommended list of POIs and, also, increase the relevance of the POI with the cluster each user belonged to. Based on this real-time captured information about the users' preferences, the users' questionnaire-based assignment to one of the three clusters was either corroborated or updated. Hence, the application supports real-time switching of tourists between different clusters. In effect, if tourists systematically express interest about POIs that do not belong to their cluster (either by requesting information about them or by physically visiting them) the application will eventually switch them to the cluster that better grasps their travel needs.

5. Evaluation

After its first upload on Google Play online store on May 2012, CorfuAR has been uniquely downloaded and installed 729 times. The research team has not undergone any marketing/promotion activities to reinforce the usage of CorfuAR, because the application comprises an academic effort and its respective downloading and use is free of charge. To assess the performance, usability and experiential impact of CorfuAR prototype, we performed a field study. In particular, visitors of

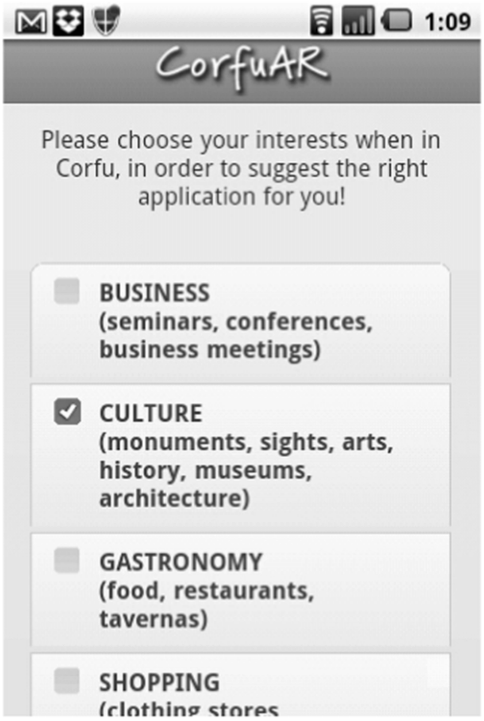

Fig. 5. Sample of the activity-related questionnaire for discovering the user's profile.

Table 2
Sample demographics.

Dimension	Value	Total (N)	Percentage
Gender	Male	52	49.6%
	Female	53	50.4%
Age	19–25	28	26.7%
	26–35	42	40%
	36–50	28	26.7%
	50+	7	6.6%
Education	School graduate	15	14.2%
	University graduate	45	42.9%
	Post-graduate	45	42.9%

Corfu city were invited to download, install, and use the application during their stay. As a final request, the participants of the field study were asked to fill in an evaluation questionnaire.

5.1. Users sampling

We used convenience sampling methodology to invite prospective users of CorfuAR travel guide. Our sample pool consisted of individuals who would visit Corfu city for leisure or business activities, were owners of Android devices and had experience in using mobile applications. In order to achieve the heterogeneity of the sample, instead of just enlisting only academia-related participants, we turned into the general population by enlisting individuals in the proximity in order to avoid bias and ensure the credibility of the results. Invitations to Corfu visitors were extended randomly and for a period of two weeks. The research team approached random groups of friends and/or family members, verified that they were owners of Android devices, and explained to them the objectives of the study. In case those visitors were interested in participating to the study, they were prompted to download the application to their mobile phone.

The study was executed twice, in August 2013 and June 2014. These months exhibit high activity in the local tourism sector; therefore we consider them as appropriate to measure the effectiveness of the developed application. In total, 105 tourists accepted our invitation to participate in our field study (33 during August 2013 and 72 during June 2014). Table 2 includes the sample demographics. The sample comprised of almost equally distributed men and women. Furthermore, the majority of the participants were educated (holders of a university degree) and over 26 years old. All participants had over six years experience of using mobile applications.

5.2. Methodology

Initially, the research team explained the objectives of the study to randomly approached groups of tourists. Should the approached individuals expressed interest to participate in the study, they were directed to the Google Play store to download the CorfuAR application to their mobile phones. Subsequently, they were asked to use the system as a guiding tool during their visit to Corfu. The participants used their own Android devices, in order for us to capture the effect of the hardware heterogeneity (hardware performance and how that affects the overall experience), as well as to exclude any "wow effect" that introducing a new device to the participants could cause and, potentially, skew the experiential results. Along this line, participants were free to use between the personalized and non-personalized versions of the application. Before ending their visit to Corfu, participants were asked to fill in an evaluation questionnaire. Each questionnaire was associated with the corresponding version of the application, based on the users' preferences in the home menu.

The study had a two-fold objective. First, we opted to evaluate the perceived adoption behavior of individuals towards CorfuAR. To this end, we employed established factors from extant technology adoption theories and environmental psychology to measure the performance, usability, emotional stimulus, and usage behavior of the application. Specifically, driven by the experiential qualities of mobile augmented reality [40], we explored the underlying process whereby the technological attributes of CorfuAR influence the usage behavior of the application through the formulation of different types of emotions. Second, we sought for differences between individuals using the personalized version of the application and ones using the non-personalized version on the selected user adoption and emotional factors.

5.3. Instrument development

The evaluation questionnaire enclosed measurement dimensions that have been validated in past information systems studies. To assess the adoption behavior of CorfuAR prototype users, we employed factors from the second iteration of the Unified Theory of Acceptance and Use of Technology, which is commonly referred to as UTAUT2 [68]. This framework has been originally used to explain the adoption of mobile applications. Moreover, UTAUT2 has been utilized as a guiding charter to explore the adoption of other application types, which are similar to CorfuAR, such as virtual worlds [69] and multimedia heritage archive services [70].

Respectively, we measured emotions stimulation from the use of CorfuAR by employing Mehrabian and Russell's [28] PAD theory, which has been primarily used to explain consumer behavior in marketing studies [71,72]. According to this theory, all emotional responses to physical and social stimuli can be captured on three affective states: pleasure, arousal, and dominance (PAD). Individual positions against these emotional states may, in turn, express human affective reactions and, consequently, influence behavior formulation. Recently, information systems scholars have articulated PAD as a supportive basis to explain information technology adoption, usually in conjunction with another established technology adoption theory [73]. In this spirit, we postulate that pinpointing the emotional impact of the MAR application will be critical for understanding the degree of users satisfaction, morale, or performance; and generally their adoption behavior. Finally, since MAR travel applications are technological innovations for tourism, we measured the effect of participants' perceived innovativeness on the adoption of CorfuAR. Our consolidated framework, combining both theories, is illustrated in Fig. 6.

To bridge UTAUT2 and PAD, we employed the Stimulus–Organism–Response model (S–O–R) model, which was originally developed by Mehrabian and Russell [28] and dictates that stimuli (e.g., performance of an information system) evoke individuals' emotional states, which in turn determine behavioral responses. The framework has been validated in the context of high-technology products [74], as in the case of MAR applications, therefore it constitutes a suitable core for our analysis.

Table 3 summarizes the measurement factors included in our evaluation instrument. Each factor was captured by multiple items. We used a Likert scale anchored from 1 (completely disagree) to 7 (completely agree) to collect individual item scores. The detailed items of the questionnaire can be found in the Appendix.

5.4. Results

5.4.1. The effect of personalization on adoption behavior and emotional responses

Table 4 illustrates the consolidated results per evaluation factor. First, we report the average scores for the full sample of respondents ($N = 105$). Then, we distinguish scores between the samples that used the personalized version of the application ($N = 69$) and the non-personalized version ($N = 36$) respectively, because we are interested in the differences between them.

To probe for statistical differences between both groups, we performed an independent samples t-test, the results of which are also included in Table 4. Out of the 69 individuals that used the personalized version of the application, 24 were

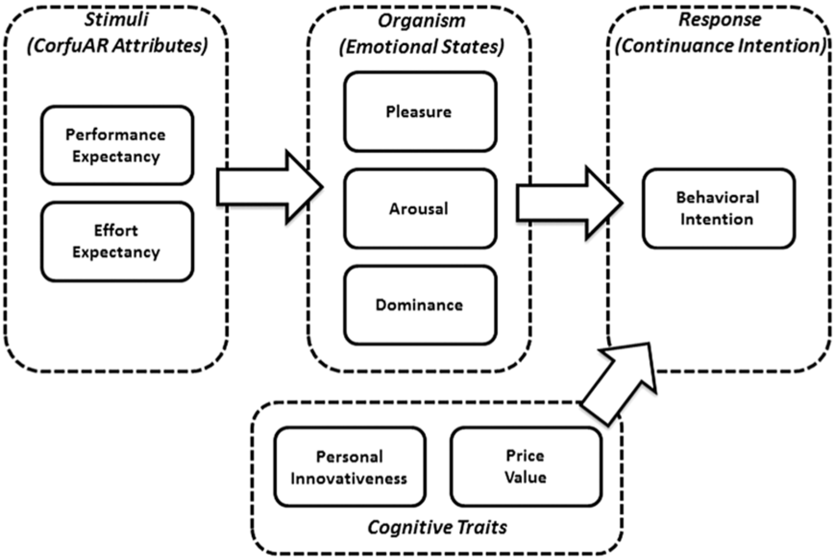

Fig. 6. Research framework.

Table 3
Instrument dimensions and definitions.

Dimension	Measurement factor	Definition	# of items	Reference
CorfuAR attributes	Performance expectancy	The degree to which using the application will benefit users in their travel-related activities.	3	Venkatesh et al. [68]
	Effort expectancy	The degree of usability associated with using the application.	4	
Continuance intention	Behavioral intention	The perceived intention to continue using the application after the initial usage.	3	
Emotional states	Pleasure	The degree to which the application evokes a pleasant (or unpleasant) emotion to users.	6	Mehrabian and Russell [28]
	Arousal	The intensity degree of the pleasant or unpleasant emotion.	6	
	Dominance	The controlling and dominant nature of the emotion.	6	
Cognitive traits	Personal innovativeness	Individuals' propensity to experiment with new information technologies.	3	Agarwal and Prasad [75]
	Price value	Cognitive tradeoff between the perceived benefits of the application and the cost of using it (e.g. network usage).	2	Venkatesh et al. [68]

Table 4
Descriptive statistics of evaluation dimensions and comparison between personalized and non-personalized versions.

Evaluation factor	Total AVG (Std) ($N = 105$)	Personalized version AVG (Std) ($N = 69$)	Non-personalized version AVG (Std) ($N = 36$)	t-test results (personalized–non-personalized)
Performance expectancy	5.69 (0.94)	5.68 (1.01)	5.71 (0.832)	−0.187 ($p = 0.852$)
Effort expectancy	5.69 (1.02)	5.62 (1.09)	5.82 (0.889)	−0.950 ($p = 0.344$)
Price value	6.43 (0.84)	6.39 (0.903)	6.52 (0.705)	−0.789 ($p = 0.432$)
Behavioral intention	4.88 (1.23)	4.81 (1.25)	5.01 (1.21)	−0.812 ($p = 0.418$)
Pleasure	5.28 (1.03)	5.18 (1.13)	5.48 (0.799)	−1.435 ($p = 0.154$)
Arousal	4.42 (0.82)	4.44 (0.86)	4.40 (0.751)	0.189 ($p = 0.850$)
Dominance	4.75 (1.01)	4.77 (1.01)	4.71 (0.895)	0.300 ($p = 0.765$)
Personal innovativeness	5.50 (1.21)	5.60 (1.20)	5.31 (1.21)	1.141 ($p = 0.257$)

allocated under the blue cluster, 25 were allocated under the red cluster and the remaining 20 were allocated under the green cluster. To preserve user privacy, we did not associate each individual questionnaire with its corresponding cluster. Therefore, we cannot report the demographics information of each cluster.

Overall, participants favored the performance and usability of CorfuAR. Subjects appreciated the usefulness of the application in terms of giving information about displayed points of interest and providing navigation guidelines (mean score 5.69, SD 0.94). Likewise, they valued the ease of use that mobile augmented reality introduces in the interaction elements of mobile guides (mean score: 5.69, SD 1.02).

Furthermore, the study participants esteemed the application's value compared to its acquisition cost. We treat these findings with caution, because we acknowledge that CorfuAR was offered free of charge; users were only subject to indirect costs that, primarily, included 3G network usage. Regarding usage behavior, the respondents expressed their overall willingness to use the system again during their next visit to Corfu (mean score: 4.88, SD: 1.23).

From an emotional standpoint, the evaluation results suggest that participants were overall satisfied with CorfuAR. Indeed, positive emotions predominated among the perceived feelings of individuals who used the MAR application. Pleasure received the highest score among the three emotional states (mean score 5.28, SD: 1.03) followed by dominance (mean score 4.75, SD: 1.01) and arousal (mean score 4.42, SD: 0.82). Such responses usually indicate that participants exhibit feelings of happiness and satisfaction pertaining to the stimuli under investigation [76], which in this research reflects the attitude of users towards CorfuAR.

Interestingly, the results indicate that there are no statistical differences between the two groups. Hence, the tourists who used the personalized version of CorfuAR perceived the same degrees of functional, emotional, and usability qualities with the sub-group that used the non-personalized version of CorfuAR. Consequently, we conclude that the personalization feature did not affect the adoption behavior and emotional response of the study participants.

Since there are no statistical differences between the two samples, we merged their responses in order to proceed to our core research objective, namely to analyze how the technology properties of the application influence the usage behavior of individuals through the formulation of different types of emotions.

5.4.2. The role of emotions on formulating usage behavior

We employed partial least squares (PLS) analysis using SmartPLS to obtain path weights for relationships and coefficients of determination for the dependent variables that measure tourists' emotions and usage behavior towards CorfuAR. Significance of associations was determined by running a bootstrapping procedure with 500 samples. Using two-tailed significance values, significance intervals are set as $p < 0.05$ $(t \geq 1.968)$, $p < 0.01$ $(t \geq 2.592)$, and $p < 0.001 (t \geq 3.323)$. Before empirically examining the model associations, we performed a set of reliability and validity tests to assess whether the instrument items load adequately to their respective factors. The results of this analysis are included in Table 5. All values are above the acceptable thresholds (composite reliability >0.7; AVE >0.5; Cronbach's Alpha >0.7).

Table 6 reflects all the correlations among constructs with diagonal elements containing the square root of the average variance extracted (AVE). The correlation for every pair of constructs did not exceed the square root of AVE, meaning that all constructs measure different objects and differ from each other, indicating high discriminant validity. We also assessed multicollinearity through the Variance Inflation Factor (VIF). For all constructs, VIF was slightly above 1 and below 3, thus indicating an absence of collinearity between items.

The results of the PLS algorithm with significance of weights are depicted in Table 7. The model explains 45.1% of the variance for CorfuAR behavioral intention, 29% for pleasure, 12.5% for arousal, and 24.7% for dominance.

Our findings suggest a positive association between the technology properties of CorfuAR and the examined emotional scales. In effect, the functional qualities of CorfuAR primarily evoke feelings of pleasure ($\beta = 0.358, p < 0.001$), followed by feelings of control over the application ($\beta = 0.301, p < 0.001$) and arousal ($\beta = 0.296, p < 0.05$). The enhanced usability provided by MAR interaction modalities induce primarily emotions of control over CorfuAR ($\beta = 0.269, p < 0.01$) followed by feelings of pleasure ($\beta = 0.258, p < 0.05$). The path analysis did not show any statistical association between effort expectancy and arousal.

Furthermore, our analysis revealed that not all of the affective elements of MAR-centric interactions are likely to influence users' intention to continue using the application. Only pleasure ($\beta = 0.257, p < 0.05$) and arousal ($\beta = 0.223, p < 0.05$) were found to be statistically significant predictors of usage behavior. This outcome is consistent with past technology adoption studies, which displayed that pleasure and arousal can adequately capture the range of appropriate emotional responses [77]. Based on the above, we suggest that manipulating the MAR application in such a way that evokes feelings of pleasure or excitement will likely lead to increased usage intention. In contrast, incorporating functional elements that generate feelings of potency do not seem to positively influence usage intention. Moreover, the path analysis indicated a positive association between personal innovativeness and usage behavior ($\beta = 0.372, p < 0.001$); the more prone an individual is to experiment with a technology innovation, the more likely he/she will continue using CorfuAR. Finally, we did not find any positive relationship between price value and usage behavior. We attribute this result to the fact that CorfuAR is offered free of charge.

Table 5
Confirmatory factor and reliability analysis results.

Construct	Standardized item loadings	Composite reliability	AVE	Cronbach's alpha
Performance expectancy (PE)		*0.856*	*0.668*	*0.749*
PE1	0.779			
PE2	0.921			
PE3	0.742			
Effort expectancy (EE)		*0.914*	*0.727*	*0.876*
EE1	0.905			
EE2	0.809			
EE3	0.878			
EE4	0.815			
Price value (PV)		*0.905*	*0.827*	*0.799*
PV1	0.871			
PV2	0.946			
Behavioral intention (BI)		*0.920*	*0.794*	*0.870*
BI1	0.900			
BI2	0.867			
BI3	0.904			
Personal innovativeness (PI)		*0.891*	*0.732*	*0.821*
PI1	0.924			
PI2	0.769			
PI3	0.866			
Pleasure (P)		*0.912*	*0.634*	*0.886*
P1	0.837			
P2	0.767			
P3	0.827			
P4	0.832			
P5	0.789			
P6	0.720			
Arousal (A)		*0.876*	*0.542*	*0.836*
A1	0.601			
A2	0.772			
A3	0.761			
A4	0.692			
A5	0.761			
A6	0.810			
Dominance (D)		*0.884*	*0.563*	*0.845*
D1	0.813			
D2	0.824			
D3	0.794			
D4	0.762			
D5	0.717			
D6	0.559			

Table 6
Factor correlations and square root of AVE of final measurement model.

	PE	EE	PV	BI	PI	P	A	D
Performance expectancy (PE)	**0.817**							
Effort expectancy (EE)	0.524	**0.853**						
Price value (PV)	0.394	0.425	**0.909**					
Behavioral intention (BI)	0.749	0.451	0.170	**0.891**				
Personal innovativeness (PI)	0.308	0.389	0.027	0.461	**0.856**			
Pleasure (P)	0.455	0.413	0.194	0.491	0.214	**0.796**		
Arousal (A)	0.306	0.237	0.032	0.446	0.203	0.582	**0.736**	
Dominance (D)	0.390	0.308	0.225	0.414	0.273	0.656	0.505	**0.750**

Table 7
PLS results and significance levels.

Paths	B	C.R. (t-value)	Path significance
Technology properties → Emotional states			
Effort expectancy → Pleasure	0.258	2.264	Significant at $p < 0.05$
Effort expectancy → Arousal	0.093	0.567	Not significant
Effort expectancy → Dominance	0.269	3.018	Significant at $p < 0.01$
Performance expectancy → Pleasure	0.358	3.914	Significant at $p < 0.001$
Performance expectancy → Arousal	0.296	2.143	Significant at $p < 0.05$
Performance expectancy → Dominance	0.301	3.738	Significant at $p < 0.001$
Emotional states → Usage behavior			
Pleasure → Behavioral intention	0.257	2.171	Significant at $p < 0.05$
Arousal → Behavioral intention	0.223	2.136	Significant at $p < 0.05$
Dominance → Behavioral intention	0.022	0.186	Not significant
Cognitive traits → Usage behavior			
Personal innovativeness → Behavioral intention	0.372	4.551	Significant at $p < 0.001$
Price value →Behavioral intention	0.085	0.839	Not significant

6. Conclusions and discussion

6.1. Summary and theoretical contribution

This research presented CorfuAR, a fully-functional prototype of a mobile augmented reality tour guide, which supports tourists on the move. CorfuAR displays information about the points of interest (POI) a user selects on the screen of his smart phone; and gives navigation directions to specific, requested POIs. In addition, CorfuAR embeds personalization features, which recommend to the users specific POIs (i.e. the colored icons in the mobile screen) according to their profile and offer an extra social media feature; the users may rate places they have visited and recommend them to other peers in the same cluster. The users' profile for the personalized version is built on static and dynamically updated users' preferences. This is the first time the activity segmentation methodology of the World Tourism Organization is followed for recognizing the visitors' activity profile in order to classify the visitors and provide them with personalized content through an MAR-based travel guide application. The personalized version of our MAR tourist guide updates these static, pre-discovered activity preferences of visitors by tracking their actual behavior during their stay (e.g. if they physically visited a recommended POI). The personalization features are optional. Tourists may opt to use the non-personalized version, which provides the same functionalities with the personalized one apart from the recommendation and social networking features.

Our study assessed the development efforts of our MAR travel guide and, specifically, emphasized on the system's evaluation by tourists visiting Corfu, an island in Greece. By conducting a field study, we assessed the users' intention to use the MAR tourist guide in accordance with their perceived performance, usability and experiential effect of CorfuAR. Now that MAR technologies are considered robust enough to provide valuable, effective services, it is critical for the broad social acceptance of MAR services to investigate what potential users expect and need. Extant research on MAR largely focused on the engineering challenges of the technology and users' perceptions of such services appears to be the least explored issue [44,78]. To our knowledge, this is the first study that provides empirical evidence regarding the performance of MAR applications and relates their adoption potential with experiential attributes.

Indeed, this study paves the ground for developing new theories, tailored specifically to MAR, that incorporate emotional qualities at their core. Extant research on technology adoption (e.g. [68,79]) primarily examines organizational settings, and the selected information technology products are functional products devoid of any hedonic dimension. Researchers adopt this stance because these theories are concerned with explaining individuals' usage behavior towards systems that aid them in work-related tasks. In comparison, our study is set in a setting where users assume a role of service consumers. In this role, technology simply intervenes to augment the user experience and supports personal needs that are both utilitarian and hedonic. Therefore, the usage behavior of such applications will logically be balanced around their functional and experiential qualities. Our research validates this claim by highlighting a direct association of usage attitudes with feelings of pleasure and arousal. Based on these findings, we posit that there is an opportunity for academic scholars to devise emotion-centric theories that address the adoption behavior of highly experiential information technology artifacts, such as MAR services.

Driven by studies that underline a positive effect of personalization on mobile usability (e.g. [61,80]), we probed for differences between users of the personalized version and ones using the non-personalized version. Nevertheless, the field study did not highlight any statistical differences between the two versions of the application. We attribute this finding to our functional operationalization of personalization. On the one hand, personalization in CorfuAR was not implemented as a core feature but rather as an assistive functionality in the form of targeted recommendations. Tourists using the personalized version of the application could distinguish POIs that suited their travel needs through a color-coding scheme and had the opportunity to recommend POIs through a social networking feature. Yet, all content of the non-personalized version was also available to their mobile screen making the differences in functionality between the two versions of the application marginal. As such, we argue that a different implementation of the personalization functionality might produce statistically significant results between the two versions of the application. An indicative alternative implementation would display only the relevant POIs to each cluster and completely hide the irrelevant ones.

6.2. Design implications for MAR travel guides

This research provides useful insights to designers of MAR travel guides. First, we demonstrate that the interaction technology that a designer selects for providing tourism and travel-related services can strongly affect the interaction of a tourist application and the overall use experience. In our case, AR enriched the use with data from several sensors (GPS, magnetic compass, and accelerometer), improving the functionality and fidelity of location-based services, which in combination with the mobile device see-through visualization of the tourism-related content provided a useful and pleasing experience. Since in mobile tourism, there is the need of engaging the user while she is on the go, the combination of aesthetically pleasing and reliable space–time content may lead to high degrees of usability and overall performance [81], as well as provide a user-friendly interaction modality compared to plain mobile computing metaphors. Based on the results of our field study, we acknowledge that individuals' tendency to experiment with new information technologies (i.e., personal innovativeness) plays a significant part in engaging the user to initially adopt the provided tourism services. When the novelty effect wears off, it is the usefulness and consistency of the content that should kick in and further engage the user.

When it comes to interacting with mobile tourism applications, the minimization of cognitive overload is a key design aspect. Naturally, when a tourist is constantly moving, the application should provide relevant-to-the-task content and cultivate semantic associations in users' cognition, in order to minimize the necessary interaction steps, thus not affecting the user's real world navigation and awareness of the physical surroundings. Methods like the ones implemented in this study (personalization based on predefined criteria, location-based filtering, theme-based filtering, use of widely-known icons and symbols) are a few examples of how to eliminate the information 'noise' and support users' procedural and semantic memory. Although our study did not reveal any statistically significant differences between the personalized and non-personalized versions of the application, we posit that the intuitive and user-friendly interaction modality supported by MAR plays the pivotal role in enhancing tourists' user experience. Personalization may be perceived as an add-on that further enhances the user experience with information that is tailored to users' needs and wants.

Finally, our study highlighted the importance of emotions regarding the design of MAR applications. Emotional design is a recent stream of product design which postulates that the design outcome may initiate the users' emotions and induce affective responses that may make them feel happy, annoyed, excited, or frustrated [82]. Designers may manipulate the properties of the artifact to trigger the desired emotional state. At the very least MAR travel guide designers should devise ways that minimize the formulation of negative emotions. Negative emotions may be stimulated through various means, such as lack of real-time feedback regarding user–system interaction, which may leave users in a state of uncertainty [83] and privacy concerns stemming from collection and manipulation of personal information [40]. In CorfuAR we addressed these challenges through infrastructural and privacy-aware schemes, focusing on (a) minimizing user frustration from system slow or unexpected responses during interactions and (b) dealing with mistrust by offering a non-personalized version of the application and by allowing users to de-activate the personalized recommendations should they desired. Moreover, designers should not neglect the importance of reinforcing positive emotions. Our field study showed that behavioral intention to use the system was positively affected through feeling of pleasure and excitement. This provides an indication to MAR application designers to carefully select the functionality provided by the service. Functional elements that reinforce positive feelings (e.g. social media features and content provision based on gamification principles) might constitute the optimal design choices.

6.3. Limitations and avenues for further research

As with any empirical study, our outcomes are subject to certain limitations. First, the findings are based on self-reported data; qualitative methods such as in-depth interviews and observations could provide additional insights regarding specific elements of CorfuAR, which influenced the perceptions of tourists that participated in the user study. Likewise, such methods would allow emotional responses to be captured as soon as they are experienced, minimizing the distortion imposed by time on the recall of feelings. Second, we followed a convenience sampling approach and we acknowledge that our results are subject to this limitation. A longitudinal user study that includes a more stratified sample, especially in terms of mobile experience and education, controlling also for possible novelty effects, would significantly enhance the generalization of the findings. Nevertheless, we posit that our research provides significant value in terms of devising a theoretically rigorous framework that captures user adoption of MAR services. Future research could apply our theoretical framework to explore individuals' adoption of other experiential information technologies, such as online social networks and innovative technology products (e.g. tablets and wearable systems). Indeed, the value of our research model lies in its capability of allowing the prediction and understanding of behavior in an emotions-based context.

Appendix. Measurement instrument

Measurement factor	Coding	Items	Reference
Performance expectancy	PE1	I find CorfuAR useful when navigating through the city	Venkatesh et al. [68]
	PE2	Using CorfuAR helps me getting information about points of interest and better guidance in the city	
	PE3	Using CorfuAR increases my interest for new places	
Effort expectancy	EE1	Learning how to use CorfuAR is easy for me	
	EE2	My interaction with CorfuAR is clear and understandable	
	EE3	I find CorfuAR easy to use	
	EE4	It is easy for me to become skillful at using CorfuAR	
Behavioral intention	BI1	I intend to continue using CorfuAR in the future	
	BI2	I will always try to use CorfuAR in my daily tours	
	BI3	I plan to continue using CorfuAR frequently	
Please note the level that better represents your emotional state after using CorfuAR			
Pleasure	P1	Unhappy ← · · · → Happy	Mehrabian and Russell [28]
	P2	Annoyed ← · · · → Pleased	
	P3	Unsatisfied ← · · · → Satisfied	
	P4	Melancholic ← · · · → Contented	
	P5	Despairing ← · · · → Hopeful	
	P6	Bored ← · · · → Relaxed	
Arousal	A1	Relaxed ← · · · → Stimulated	
	A2	Calm ← · · · → Excited	
	A3	Sluggish ← · · · → Frenzied	
	A4	Dull ← · · · → Jittery	
	A5	Sleepy ← · · · → Wide awake	
	A6	Unaroused ← · · · → Aroused	
Dominance	D1	Controlled ← · · · → Controlling	
	D2	Influenced ← · · · → Influential	
	D3	Cared for ← · · · → In control	
	D4	Awed ← · · · → Important	
	D5	Submissive ← · · · → Dominant	
	D6	Guided ← · · · → Autonomous	
Personal innovativeness	PI1	I like to experiment with new technologies	Agarwal and Prasad [75]
	PI2	If I heard about a new technology, I would look for ways to experiment with it	
	PI3	Among my peers, I am usually the first to explore new technologies	
Price value	PV1	CorfuAR is reasonably priced.	Venkatesh et al. [68]
	PV2	CorfuAR is a good value for the money.	

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