Enabling interactive exploration of cultural heritage: an experience of designing systems for mobile devices

C. Ardito, P. Buono, M.F. Costabile, R. Lanzilotti, A. Piccinno

Dipartimento di Informatica, Università di Bari, Italy

{ardito, buono, costabile, lanzilotti, piccinno}@di.uniba.it

Abstract: Interaction design of mobile systems is a complex activity because it requires to consider new usability and user experience aspects in order to exploit the peculiar characteristics of mobile devices, such as their pervasive and ubiquitous nature. This paper discusses issues about designing, developing and evaluating mobile systems. Italy has a rich cultural heritage and the focus here is on the design of systems that enable interactive exploration of historical sites, not only for enhancing the user experience but also for learning purposes. It is reported the experience of researchers of the Interaction, Visualization and Usability lab at the University of Bari, Italy, in designing a mobile learning system, called Explore!, that supports young students learning ancient history during a visit to archaeological parks. The evaluation of Explore! through systematic field studies shows that the adopted approach is able to transform the visit to archaeological parks into a more complete and culturally rich experience.

Keywords: interaction design, mobile learning, cultural heritage

Corresponding author:

ardito@di.uniba.it

tel. +39 080 544 3289

fax. +39 080 544 3196

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Introduction

Interaction design aims at "designing interactive products to support the way people communicate and interact in their everyday and working life" (Preece et al. 2007, pag. 8). This is a highly complex activity that must focus interaction designers' attention on a wide variety of factors: who is going to use the products, how they will be used, where they will be used, etc. Moreover, interaction design must create engaging user experiences, so it is necessary to understand how emotions work, what is meant by aesthetics, desirability, etc. It is difficult for one person, or for several people with the same cultural background, to be well versed in all of these different areas. As a consequence, interaction design requires a multidisciplinary team that includes experts in areas such as human-computer interaction, software engineering, psychology, entertainment, sociology.

The interaction design process involves four basic stages: 1) identifying the needs and requirements for a fulfilling user experience; 2) developing alternative designs that meet those requirements; 3) building running prototypes that can be tested with real users; 4) evaluating what is being developed throughout the process and the user experience it offers (Preece et al. 2007). To create a successful product, real users have to be involved in the design process so that interaction designers can correctly understand what users find easy or hard when working with electronic devices, consider what might help them with the way they normally do things, and involve users in the evaluation carried out during the design process.

Mobile technology has introduced a set of additional challenges in the interaction design process (de Sá and Carriço 2008). Given mobile devices peculiar features, especially their pervasive and ubiquitous nature, the small size and the interaction modalities (e.g. touch-screens, stylus, fingers, and combinations), a new range of interaction paradigms has emerged. As a consequence, new usability and user experience aspects have to be considered in the design of this new kind of systems.

The chance to interact with a mobile system when and where the users want, freeing them from ties to a particular location, is very valuable in the context of learning. Mobile learning *(m-learning)* is the combination of e-learning and mobile computing (Holzinger et al. 2005). It provides opportunities to interact with learning materials in different ways while exploring a physical environment both outdoors (e.g. archaeological parks, woodlands) and indoors (e.g. lab, home) (Rogers et al. 2005).

In this paper, we report our experience in designing, developing and evaluating Explore!, an m-learning system intended to support the visit of middle school students to archaeological parks. Italy has a rich cultural heritage, with plenty of archaeological parks and historical sites dating back to centuries B.C. Among current visitors to these parks, young students accompanied by their teachers account for 80%. We show that, by exploiting the imaging and multimedia capabilities of the latest generation mobile devices, it is possible to create electronic games that can support young students learning ancient history, transforming a visit to archaeological parks into a more complete and culturally rich experience.

The paper is organized as follows. Next section discusses issues concerning design and evaluation of mobile systems. The design and development process of the Explore! m-learning system is then illustrated. Last section provides the conclusion.

Issues about interaction design of mobile systems

The process of system design and development is very costly, from both the time and the economic standpoints. This is even more evident in the field of mobile devices, especially when the aim is to experiment new interaction techniques, or to take into account the surrounding environment, requiring the integration of sensors and actuators.

Compared to desktop computers, mobile devices have many other restrictions that researchers must consider when developing mobile applications (Chittaro 2006), for example, input peripherals such as tiny keypads, micro-joysticks, and rollers are often inadequate for complex tasks. Mobile devices have small size screens that limit the amount and the organization of the information that can be displayed at one time.

The mobility context itself introduces further complications. The physical environment is extremely variable; external circumstances or activities in which mobile users are participating can make it difficult to focus attention on the device. A person has fewer cognitive resources available while hustling through

an airport or driving a car than when sitting at a desk in an office or at home; in mobile situations, using the device often becomes a secondary task rather than a primary one. A mobile system that generates too many distractions can be confusing and unmanageable. Notification cues must be designed so that they minimize the attention overload of the intended recipient and surrounding people, otherwise such cues may prove to be ineffective or may be ignored completely.
Mobile computing also presents new challenges in terms of evaluation techniques. While task-centric evaluation approaches may be well applicable to the desktop computing paradigm, where tasks are usually structured and almost predictable, they are not directly applicable to the often unpredictable and unstable mobile settings. Mobility requires that various factors in dynamic/surrounding environment have to be considered, such as lighting conditions, noise and distractions, user mobility, manipulation of other physical objects during interaction (Danesh et al. 2001; Kjeldskov and Skov 2003).

Field-based evaluations seem an indispensable approach for evaluating the usability of mobile systems. Yet, evaluating usability in the field is not easy (Brewster 2002; Nielsen 1998). Firstly, it can be complicated to establish realistic studies that capture key situations in the use-context (Pascoe et al. 2000; Rantanen et al. 2002). Secondly, it is far from trivial to apply established evaluation techniques, such as observation and think-aloud, when an evaluation is conducted in a field setting (Sawhney and Schmandt 2000). Thirdly, field evaluations complicate data collection and limit control, since users are moving physically in an environment with a number of unknown variables potentially affecting the set-up (Johnson 1998; Petrie et al. 1998).

For laboratory-based usability tests, the difficulties in conducting and collecting data are significantly reduced as compared to field based usability tests. However, these tests cannot address factors and issues that occur in the field. The comparison of laboratory and field test reported in (Duh et al. 2006) demonstrates that there are many more types and occurrences of usability problems found in the field than in the laboratory. Some of these problems are only related to the device being used in the field and could not be found using conventional laboratory tests. Some users' behaviours can only be observed in the field, where there is an impact with the real life and practice. People tend to be more severe in the field: they are not concentrating only on task execution with the system, as in the lab, but they experience how the system interferes with their whole activity, so that they can more rigorously judge the effect of this interference.

Our point of view is that laboratory and field evaluations of a mobile system are complementary. Laboratory tests are cheaper than field tests and can be used in the early phases of the interaction design of a mobile system, because they provide a controlled environment within which researchers can isolate the effect of different variables on the test subjects. Once system prototypes have been positively evaluated in laboratory and the system is almost in a final version, we recommend to test it in the field.

In order to successfully face the interaction design challenges of mobile systems, our design team at the Interaction, Visualization and Usability (IVU) lab of the University of Bari adopts an approach based on user-centred and participatory design (ISO 1998; Schuler and Namioka 1993). Domain experts, representative of end users, and end users themselves have an active role in the whole process. They are involved in the requirement analysis, which is fundamental for developers to understand the domain of interest and the user needs, skills and current working practices. They participate in the evaluation of early paper prototypes and provide feedback; they test the successive system prototypes in laboratory and then in field settings. In this sense, our approach goes beyond classical participatory design in that it stresses evaluation with end users in real field settings. Our experience is in line with what it is discussed in (Wagner and Piccoli 2007): end users provide the most valuable feedback once they put their hands on an almost final version of the system, that they can use in a real environment.

The design of Explore!

The participatory design approach described above has been adopted in the design of Explore!, an m-learning system that supports middle school students during a visit to an archaeological park (Costabile et al. 2008). It adopts a learning technique called *excursion-game*, whose aim is to help students to acquire historical notions while playing a game on a cell phone and so make archaeological visits more effective and exciting. The main system components are: the *Game Application*, running on one of the two cell phones given to the group, provides the information necessary to perform the game; the *Oracle*

Application, running on the second cell phone, provides further hints for identifying the places in the park; and the *Master Application*, running on a PC or a notebook, used by the game master (i.e. a teacher) to perform a reflection phase, which follows the game (Ardito and Lanzilotti 2008).

Explore! is played by groups of 3-5 students. Each group is given the two cell phones and the map of the park on a paper sheet. The game is similar to a treasure hunt, where students have to discover meaningful places in the park following some indications provided on the cell phone by the Game Application. After identifying a place, the group receives “God’s gifts”: as a premium for their ability, they can explore the 3D reconstruction of the identified place on the cell phone and visually compare how the place probably once looked with the existing remains. After the game, students participate in the debriefing phase, in which the knowledge which they have implicitly learned during the game is reviewed and shared. During the debriefing phase, using the Master Application, the game master and students play a “collective memory game” where monuments and archaeological objects (previously observed by students as part of the game) are to be placed in the “right” place on the park map. The Master Application permits to show the 3D reconstructions of the historical monuments in a much higher definition than those on the cell phone.

It is worth noting that Explore! is applicable to a wider set of historical sites. The way historical information is presented (time, location, modality) is determined by an XML file and can thus be authored in numerous ways and adapted to different archaeological parks. In this paper, we refer to the implementation of Explore! for a visit to the archaeological park of Egnathia, an ancient city in the Apulia region, in Southern Italy.

In the next sections, the main stages of Explore! development are described, namely user experience requirements gathering, development and testing of the various prototypes, field evaluation.

Requirements for the user experience

Beside human-computer interaction and software engineering experts of the IVU lab, the design team of Explore! was composed of: a) members of *Historia Ludens*, a cultural association in Bari, that has developed the original paper-based version of the game and used it as a learning technique for school visits to archaeological parks (Cecalupo and Chiarantoni 1994, Ciancio and Iacobone 2000); b) experts in teaching history and archaeologists of the *Department of Ancient History* of the University of Bari; c) the director and staff representatives of the *Egnathia Archeological Park;* d) school students and teachers of the middle school "*Michelangelo*" in Bari.

User requirements were collected through various techniques. Specifically, a contextual inquiry technique was adopted (Beyer and Holtzblatt 1998; Druin 1999): students' (11-13 years old) behaviour was observed while executing in the Egnathia park the original version of the game (Ardito et al. 2007), performed using paper-based tools without any support of electronic devices. The observation provided useful information on how the game was actually performed and about the problem-solving strategies adopted by the students. Interviews and focus groups involving Historia Ludens associates, students and teachers were performed in order to capture more details on the game and on the whole experience. Interviews were also performed to the archaeologists and experts of the park in order to capture the history of the park and discuss how to model the 3D reconstructions of meaningful sites for the electronic version of the game.

Developing and testing alternative designs

Different prototypes were developed and several formative evaluations, some involving middle school students, were conducted throughout the interaction design process (Ardito et al. 2007a).

Wizard of Oz (WOz) simulations (Fraser and Gilbert 1991), direct observations, interviews, inspections have been employed. The WOz simulation is very useful in situations where the development of a system is expensive and where it is hard to know beforehand how users will behave. In particular, in the field of mobile systems, researchers wish to experiment with new interaction techniques to understand how to possibly overcome the devices constraints. In a Wizard of Oz study, subjects are intended to believe that they are using a computer system; instead, there is a person behind the scene, the *wizard*, playing the role of the program. The user interaction is logged and/or recorded for further analysis.

In a preliminary phase of the Explore! interaction design, the WOz technique simulation was exploited. The tool MuMoWOz (MultiModal Wizard of Oz) was used (Giannelli 2006). MuMoWOz has two macro-components connected by a

wireless network: the server component, installed on a desktop computer, allows the wizard to send and manage the running of multimedia content at the client component installed on a mobile device or another Personal Computer. The client component can capture the interaction on the device and send it to the server. It is possible to keep track of the user's interactions and listen to them during the experiment, and thus to simulate the recognition of inputs, including those of multimodal type. In fact, the recognition of the particular input is not carried out by the system but by the human wizard, that interprets the user input and sends the required multimedia material to be reproduced. This material, consisting of digital resources of various natures (images, video files, audio files, etc.), has to be prepared before carrying out the simulation and must be able to satisfy any possible user request in the scenario in question. Reproduction of the files is carried out by the applications installed on the client device.
The evaluation session was performed in a university laboratory, involving four students that have already once played the traditional game during a school visit to Egnathia. Based on photos of the real site posted on the walls, the students were able to recall the site they had visited, thus simulating their presence in it. Students interacted with a prototype of Explore! (Fig 1a), and the wizard, through MuMOWOz interface (Fig 1b), sent all the multimedia materials necessary for carrying out the game.
MuMoWOz allowed us to identify some interaction problems. During the evaluation, the students played the game in two different ways: with and without the audio modality. In the audio modality, the system beeps to capture students' attention, then it uses speech to inform users about application actions, i.e. the start of a new challenge or the transition from one phase to the next. After playing the game, the students were interviewed. They interacted pretty easily with the system and said they greatly appreciated the both electronic versions of the game, particularly the audio version of the system.
On the base of the results of the first evaluation and the students' requests, we developed a running prototype of Explore! by inserting visual and sound messages that warn the user about what is happening, the possibility to undo previously performed actions, the site map on the screen of the cellular phone, and new 3D reconstructions of the site places.

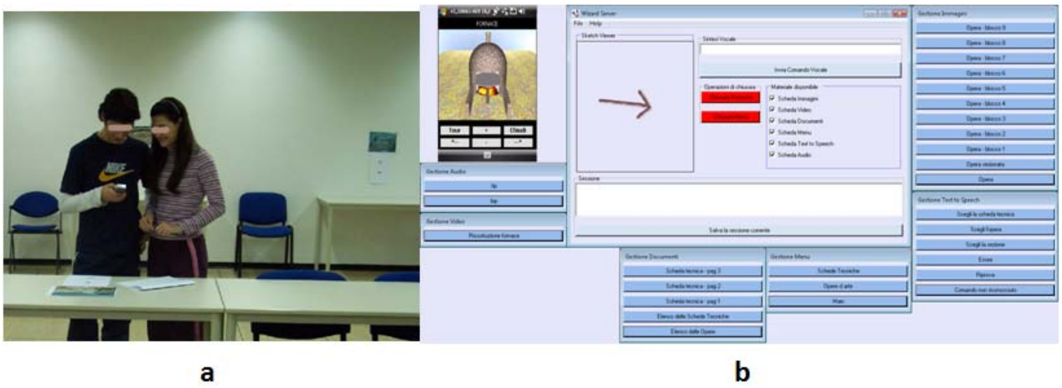

Fig. 1 Example of Wizard of Oz application. 1a. Students are interacting with a simulation of the electronic game. 1b. Interface on the wizard's notebook: the windows on the upper left corner shows what the users see on the cell phone.

A second evaluation with users was performed in a university laboratory and participants interacted with a running prototype of Explore!. A direct observation technique was exploited. Even if the participants had the possibility to interact with Explore! with and without the audio modality, they chose to use only the audio version of the system, confirming their preference expressed during the first evaluation. After the interaction with Explore!, participants were interviewed.

Field evaluation

A systematic study was performed when the system was ready for a summative evaluation. Three classes of the middle school Michelangelo in Bari were involved for a total of 68 children (11-13 age) and 6 teachers. The visit to Egnathia was part of their didactic curriculum. Groups of students performing the game in its traditional version (paper-based) and groups performing the game with Explore! were compared. Details about the study and its results are described in (Costabile et al 2008). In the following, a brief summary of the study is reported. Preliminarily, a pilot study involving a class of 24 students was carried out with the aim to evaluate the system reliability and research methodology. The actual field study involved 42 students of two second year classes. Nineteen students, divided into 5 groups, played the paper-based version of the game; the remaining 23 students, divided into 6 groups, played the mobile version (Fig 2). At the end of the game, participants answered a questionnaire addressing several aspects of the game experience. The paper-based group was debriefed in the traditional way, while the mobile group was debriefed with the support of the Master Application.

At the end of this phase, participants answered a questionnaire for a self-assessment of their learning. The mobile group also answered questions about the 3D sites reconstructions. The next day at school, students were administered a test for a more objective evaluation of the knowledge they had acquired during the game. They also composed essays and drew pictures about the experience at Egnathia.

Fig. 2 A group carrying out the game in the Egnathia archaeological park: the first student on the left carries the cell phone with the information necessary to identify the places, the second student holds a cell phone displaying the help indications; the third student holds the paper map of the park

The analysis of the great amount of data collected during the field study demonstrated that users enjoyed playing the game with Explore! and the introduction of the mobile was appreciated a lot. The very advantage of the mobile version of the game with respect to the traditional version is the overall user experience it provides. Regarding the learning, no significant differences were found between the two versions. This must not be considered a negative result, since it demonstrates that technology does not distract students. Indeed, the fact that the game, even in its original paper-based version, is a valid learning technique was already well assessed by various experiences reported by teachers and members of Historia Ludens, who have performed hundreds of games in the last ten years with several schools in Italy. The main reason for developing Explore! is to exploit current computer technology to enable interactive exploration of cultural heritage with the aim of engaging people and providing a more satisfactory user experience. In particular, students explicitly stated in their essays that they appreciated very much the 3D reconstructions of the historical monuments, that they visualized on the cell phone during the game and, in a more accurate definition, during the debriefing.

An interesting difference between the two versions is in the game behaviour: the sequential order imposed by Explore! affected users problem-solving strategies. Due to the screen limitation of the mobile device, the different missions to be solved during the game are proposed to the players one at a time, forcing children to solve them in sequence. During the field study, we observed that students in the paper-based condition changed the mission order, either firstly performing those missions they perceived as easier or according to a personal strategy; moreover, students could read on paper all items of the Oracle at once, possibly getting more information for identifying the mission target.

The new version of Explore!

According to the results of the field evaluation, a new version of Explore! has been developed, whose aim is to give users more flexibility in problem-solving strategies and to provide more navigational hints. Specifically, players can now choose the missions order. A context/task-aware help is also implemented, whereby the system provides appropriate indications based not only on the current mission, but also on the user position, determined by GPS, and on task related knowledge.

Moreover, to increase the number of cues and enhance the overall user experience contextual sounds are integrated in the new version, as described in (Ardito et al. 2008a). This new version has been compared with the previous version of the Gaius’ Day game electronic game. Preliminary analyses of the collected data show that students very much appreciated the integration of sounds. This is an important result since satisfaction is a significant component of the user experience.

Conclusion

This paper has discussed issues concerning design and evaluation of mobile systems. Interaction design is a complex activity and designers must consider various factors, such as who is going to use the products, how they will be used, where they will be used, but also how emotions work during the interaction with a system. Designing for mobile devices is even more difficult because other aspects, specific of such devices, must be taken into account.

The experience of researchers of the IVU lab at the University of Bari, Italy, in designing a mobile learning system, called Explore!, is reported. Explore! supports young students learning ancient history during a visit to archaeological parks. Human-computer interaction and software engineering experts, domain experts, representative of end users, and end users themselves have participated in the whole interaction design process. Of fundamental importance were the evaluation sessions with end users and the field studies.

As future work, we are extending the system so that, by exploiting all the available information about the park and its history, the 3D models, the audio files, etc., it is possible to provide support for a more complete and excitant experience to any visitor, including adults and families.

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