An Inclusive Educational Game Usable via Screen Reader on a Touch-screen

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Abstract

Serious games are increasingly used for supporting education and many other activities via entertainment. Unfortunately, they are not accessible to visually-impaired people who have a very limited selection for games, especially in the mobile context. Usually they can only rely on specific games. Our aim is to investigate how to overcome this gap for visually-impaired people. For this, we are presenting a mobile educational game accessible also via screen reader on a touch-screen. Through the app we investigated: (1) a gesture-based interaction modality to perform exercises on a touch-screen when a screen reader is running; (2) an equal opportunity in enjoying perception also by those who cannot see the user interface. A pilot test confirmed a positive impact of the first prototype on the end-users.

Introduction

A combination of increasing interest in learning through games together with advances in information and communications technology (ICT), have led to the development of a number of digital (computer-based and mobile) educational games. Their use is likely to increase. There is also increasing recognition for the needs of disabled students and the importance of integrating them into mainstream education, as well as the importance of doing this appropriately with adequate resources of support. This makes it imperative to consider the requirements of disabled students (and staff) to ensure their full inclusion at a relatively early stage in the dissemination of educational computer-based games. This raises a number of issues, including the conditions to be met for educational digital games to be accessible to and usable by disabled students, so that the same games and environments can be used by disabled and non-disabled students.

Mobile and desktop applications and games are hence increasingly available on the market for several purposes, including those used in the educational and rehabilitation context. Although several apps are available for users interacting via assistive technologies, an adequate amount of accessible and usable games is not available for people with vision impairment. This occurs especially for blind children and students. Generally speaking, there are few educational games designed for visually-impaired people for both computer and mobile devices. There are many educational smartphone games for children, but few are accessible to blind children. BraillePlay, a suite of accessible games for smartphones that teach Braille character encodings to promote Braille literacy, is an example of specialized games for blind children [1].

In this paper a serious game as an educational tool accessible to visually-impaired users interacting via screen reader on a touch-screen device is presented. The main goal is to fill in the gap existing for visually-impaired people in the entertainment field, especially about the serious games in the mobile context. For this reason, the authors propose a mobile application to be used

everywhere and at any time by everyone, including those who cannot see the user interface (UI) and must interact via screen reader.

The designed app is an educational game composed of various activities (e.g., matching questions, single or multiple choice questions, etc.) to be performed on a mobile device. Blind people interact via screen reader and specific gestures which may differ from those commonly used on touch-screens. For this reason, blind users often encounter several issues with the common interaction modalities used for exercises and questions (e.g. drag-and-drop). Thus, through the proposed prototype we intended to investigate: (1) a gestured-based interaction modality on a touch-screen to perform various types of tests which are commonly used for exercises and questions in the education context for practicing / assessing specific topics; (2) an auditory perception equivalent to a visual representation in order to make the game more inclusive for non-sighted and sighted people. In order to assure a good interaction, the interface should be well-designed in an accessible and usable way. In this perspective accessibility guidelines and WAI-Aria techniques have been considered when developing the mobile interface.

Games in the education of blind people

Numerous serious and entertaining games have been proposed in literature. Unfortunately, they are mainly visually-oriented [2] and do not offer alternative perception modalities. Therefore, blind people are excluded from the opportunity to choose any type of game available on the market. Several studies started to investigate how video games requiring different input and output modalities can be designed for people with different disabilities [3, 4]. Thus, various design suggestions and frameworks are proposed [5, 6]. Shoukry et al. [7] propose a framework for mobile educational games, but students with vision impairment are not included.

For visually-impaired people, predominantly auditory games (i.e. the UI is mainly based on the audio feedback) are developed, such as those proposed by [8] and [9], which are not commonly used by everyone. Consequently, the choices available for a blind person are dramatically limited. Song et al. [10] developed two audio-based learning games on TeacherMate, an inexpensive mobile device designed for people in developing countries. Although audio games certainly improve the abilities and special skills (e.g. orientation in the space, etc.), a blind person would prefer to be able to choose among various types of games as much as possible, like a sighted user can. This is a main reason why a universal design should be encouraged and further investigated [11]. Our approach is hence investigating how to design an inclusive game, accessible to screen reader users and touch-screen gestures as well. Our aim is to preserve the graphical interface while assuring accessibility and usability properties with a unique interface.

Our approach

Our approach is aimed at investigating the designing of an educational game suitable for sighted and non-sighted people by (1) overcoming some issues encountered in the interaction via gestures when a screen reader is running and (2) providing a user interface with a similar aural and visual perception. Two blind people (with a long experience of smartphones) were involved from the early phase of prototype design in order to discuss potential issues and multimodal aspects. During brainstorming activities, they described some problems they usually encounter based on their experience on a touch-screen when interacting with games, questions and multimedia contents. Specifically, the discussion was focused on the multimodal interaction related to the

following aspects: (1) appropriate method to perform specific tasks (e.g. drag-and-drop) via gestures; (2) the design and perception of the user interface (e.g. audio, labels and messages).

The main issues pointed out by the blind users are especially about the exercises and practices, i.e. Tests and questions. Evaluation activities can be very interactive for the user. When the UI elements are not developed in a standard way, the assistive technology is not able to properly detect them. This can affect negatively the evaluation tests and practicing activities as well. They often are not suitably detected by the screen reader and sometimes item selection is difficult for a blind person, both via keyboard and gestures. This occurs especially when performing drag-and-drop (e.g., for matching) or certain actions such as the ordering or multiple selections.

The proposed prototype is a cross-platform app developed using the Cordova Framework in order to evaluate the accessibility of a User Interface designed for mobile devices. In [12, 13] WAI-Aria suite has been tested with Web-based interfaces. In this study the aim is exploiting the WAI-Aria suite support for interface accessibility on a mobile touch-screen. The prototype has been validated in terms of accessibility by the users involved during the design cycle.

An accessible mobile game prototype

Game description

The game has been graphically and structurally designed, as it is a "solar system" with eight planets. Each planet represents a "play" with a set of exercises / questions. Plays can be chosen from the home (first screen) by tapping on a planet (see Fig. 1). The player (i.e. who needs to practice / assess) must complete each play. According to the correctness and potential errors carried out while performing the game, a score is gained for each play. The plays represent the various types of questions or exercises which are usually used in a test environment. The player can carry out the plays in the preferred order. At the end of each play (and so at the end of the game) the player will have collected a final score which can be used as a level reached.

Based on the issues pointed by the users, to investigate potential interaction solutions we considered some main typologies of techniques used when preparing questionnaires, tests for practicing and evaluating specific educational topics [**Errore. L'origine riferimento non è stata trovata.**]: **Single choice** (just one is right), **Multiple choice** (more than one may be right), **Matching choices** (match the choice on the left to the corresponding choice on the right), **True / False, Ordering, Gap-filling** (complete the sentence by filling in). In designing these typologies of exercises, we relied on simple gestures and VoiceOver-like interaction ways with menus (single tap to hear an option and double tap to select it) in line with earlier accessibility work [**Errore. L'origine riferimento non è stata trovata.**]. Color contrast, auditory and visual renderings have been used to assure different levels of interface accessibility.

The app has been designed to adapt the topics for any age. To do this the content is out of the implementation and stored in specific files. Thus several groups of questions and exercises can be prepared earlier by teachers and skilled people. By consequence the app can be suitable for many topics and different ages.

The main features considered for the proposed educational game can be summarized in: (1) Support for learning and practicing specific topics while enjoying; (2) Different typologies of questions and exercises designed for an interaction via gestures and on a touch-screen; (3)

Attractive visual layout with different graphical themes (applied to the plays); (4) Audio support to provide an alternative and equivalent perception of the visual layout by a blind player; (5) Content customization in order to adapt the exercises and questions for different topics and ages.

Game architecture

Each play is characterized by three components: (a) template, (b) theme, and (c) content.

(a) **Template**. The template indicates what type the questions are, i.e., single-choice, multi-choice, matching, ordering, and so on. Different types of questions have been selected in order to investigate how to make them accessible via screen reader and gestures on a touch-screen. Each type of design structure identified to implement the question typologies is assigned to a template. So when using a certain template, the solution implemented is applied to design for that play. So we have templates like "single" or "multiple choice" to refer to the related typology of questions. As described in Play 1 and Play 2 (see next section), the two templates are very similar; there are just some differences in implementing the selection of one or more choices.

(b) **Theme**. The theme specifies the graphical and audio scheme to use for the UI. Graphical themes have been selected in order to reproduce certain appealing and suggestive scenarios. One of the main features offered by the game consists of reproducing a similar perception of the amusing aspect by a blind and a sighted user. To achieve this, we designed the visual themes so that it was possible applying given evocative sounds to reproduce a similar auditory effect. In the next section some examples are described.

(c) **Content**. The content is related to the questions to be proposed to the player. The questions and related answers are stored in external files which are loaded when selecting a specific play. This allows the adaptation of the contents with different topics and for various ages. The administrator (e.g. the teacher) can prepare them according to the topics, difficulty levels, and target. The game loads a group of questions from the files. This feature will be improved by defining a more structured database for the content s.

Play examples

As mentioned, each play is a set of questions of the same typology. So all questions and exercises related to a play have the same template and theme. Only the content changes.

Play "Gap-filling".

The play "Gap-filling" consists in a set of questions to be completed (template). Each question is shown in a "cloud" (the theme) as in Figure 2. The sentence contains the ellipsis to indicate the missing term. In order to not make the editing too multifaceted, a list of potential answers is reported rather than asking the user to use the virtual keyboard. The terms are visually arranged in a scattered order, but the blind user can perceive them in a list when exploring the interface with the finger. The visual game perception has been equally audio rendered via sounds: "rain" as background sound, "thunder" for a wrong answer, and "bird singing" for a correct choice. Graphical and audio contents represent the suggestive scenario.

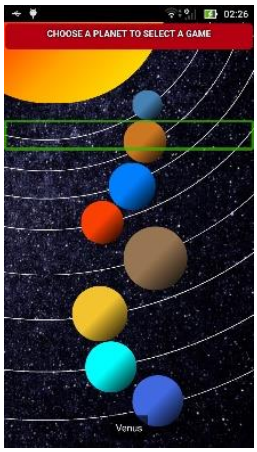

Figure 1: Home

Figure 2: Gap-filling question

Play "Matching items".

These exercises consist in matching the elements belonging to two different sets (see Fig. 3). The elements are arranged in two lists: one on the left and one on the right. To match the corresponding elements, firstly the user selects by tapping one item on the left, and then on the corresponding one on the opposite side. By consequence, the two items are both shown on the left and marked as paired (no more selectable). When finished, on the right side there is no more elements. The user confirms via the specific buttons to complete the exercise.

The theme is a river. The elements to be paired are listed on the left and on the right of the river (Fig. 3). A rope is launched when the match is carried out (Fig. 4). In order to reproduce a similar effect for a blind player, the river sound and rope launch audio effect are used to reproduce a similar perception.

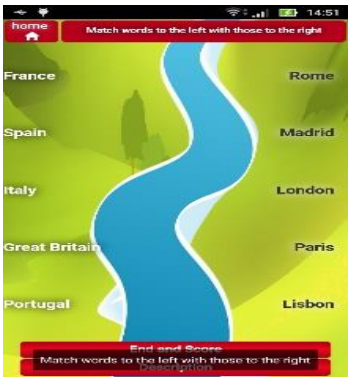

Figure 3: Matching question start

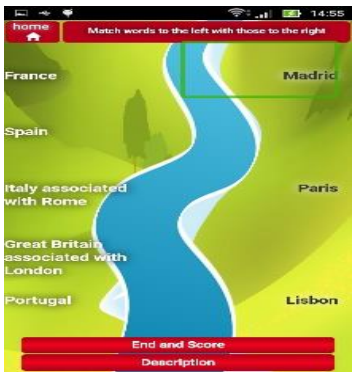

Figure 4: Matching question

EVALUATION AND DISCUSSION

For our first prototype we prepared a set of questions on topical interests we used to have a pilot evaluation with two blind adults (those involved in the design process) and two sighted adults (to verify the graphical and visual layout). Some tasks have been proposed to each user in order to collect feedback and potential issues about the interaction. We observed some problems in detecting the elements by the blind persons due to the object position in the interface and to some contents difficult to identify by gestures and screen reader interaction. The users'

comments have been very positive although some issues have been encountered. The tasks were completed by all the users. The non-sighted users were able to interact with the interface via the screen reader and gestures. Minor inconveniences have been noticed with some gestures differing from those offered by VoiceOver. The users appreciated the sounds used to reproduce the visual scenes: they declared to be able to perceive the game scenarios thanks to the aural reproduction. Sighted users interacted with the app without significant issues and completed all the assigned tasks. Overall, both the sighted and visually-impaired users declared to enjoy with the game and to be interested in extending the possible plays with many other additional contents. The suggestions and the aspects observed during this pilot test will allow us to improve the first prototype and extend it with other features.

CONCLUSIONS

This work investigates how to design a potential mobile cross-platform app developed as an educational game for all, including screen reading users. It does not focus specifically on the educational purpose, but rather than on the methodology to design the user interface and the interaction via screen reader and gestures. A combination of audio and graphics allowed to obtain an equally content perception for both sighted and non-sighted people. This can represent a case study in which the graphical layout is not a limitation for assuring full accessibility. Furthermore, WAI-Aria techniques can support accessibility also for mobile interfaces when interacting via screen reader. Through the proposed UI design and interaction modality, questions and exercises can easily be performed also via gestures on a touch-screen by a blind user. Concluding, designing attractive apps for all is possible. Further investigation about interaction modalities for other typologies of questions and a more structured user testing will be conducted.

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About the Authors:

Barbara Leporini received at University of Pisa her Masters in Computer Science with full marks and honours in 1997 and in 2003 her PhD with a dissertation on accessibility and usability subject related to websites. Since the beginning of her PhD project, Barbara has done her research at the CNR of Pisa (ISTI) where she is now a researcher in the Human-Computer Interaction field, and in specific in accessibility and usability for people with special needs. Barbara investigates techniques and methods to make Web sites, electronic publishing, museum contents, search engines, e-learning, educational tools and identification systems for the electronic signature accessible and usable to disabled users. Generally speaking, she works on accessibility and usability of user interfaces for both desktop and mobile applications.

Beyond research, Barbara has been teaching computer sciences classes. She has also been providing technical support for accessibility and usability at various levels. In particular, she has been participating on boards and groups working on different problems concerning visually-impaired people.

Eleonora Palmucci graduated in Computer Science in 2017 at the University of Pisa. Her thesis was on accessibility of educational tools on mobile devices, and especially via serious games. Currently she is a programmer.