A Mobile Educational Game Accessible to All, Including Screen Reading Users on a Touch-Screen Device

Short Paper†

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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 rely just on specified games. Our aim is investigating how to overcome this gap for visually-impaired people. To this end, in this work a mobile educational game accessible also via screen reader on a touch-screen is presented. 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 cannot see the user interface. A pilot test confirmed a positive impact of the first prototype on the end-users.

CCS CONCEPTS

• **Human-centered computing~Accessibility design and evaluation methods** • *Human-centered computing~User interface design* • **Applied computing~Interactive learning environments**

KEYWORDS

Screen reader, serious games, touch-screen

1 INTRODUCTION

Mobile applications and games are more and more available on the market for several purposes, including those used in the educational 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. General 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 work a serious game as educational tool for all, including 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 proposed a mobile application to be used everywhere and at any time by everyone, including who cannot see the user interface (UI) and must interact via screen reader. A screen reader is a software application, which interprets the UI contents and converts them into a synthesized voice or electronic braille format. The screen reader is fundamental for a blind person to interact with a computer or mobile device. In order to assure a good interaction, the interface should be well-designed in an accessible and usable way.

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-screen. 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 enjoyable for non-sighted and sighted people.

The paper is organized as follows: after some related works, the methodology is introduced in section 3, and in section 4 a description of the game and the proposed solutions for designing the activities on touch-screen are detailed. A short discussion on a pilot test is then reported in section 5. Conclusions end the paper.

mLearn 2017, October 30-November 1, 2017, Larnaca, Cyprus

ACM ISBN 978-1-4503-5255-0/17/10…$15.00
https://doi.org/10.1145/3136907.3136941

2 RELATED WORK

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 out of 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] proposes a framework for mobile educational games, but does not consider students with vision impairment.

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 everybody. Consequently, the choices 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 therefore investigating how to design an accessible game for all, including for screen reader users. Our intention is to preserve the graphical interface while assuring accessibility and usability properties with a unique interface.

3 METHODOLOGY

Our approach is aimed at investigating designing 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 loaded 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 while interacting with games, questions and multimedia contents. In particular, we discussed and analysed multimodal interaction applied 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 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 investigating the WAI-Aria suite support for accessibility of mobile multiplatform user interface. The prototype has been validated in term of accessibility by the users involved during the design cycle.

4 THE PROPOSED APP

4.1 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 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 [14]: **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 [15]. 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 early prepared by teachers and skilled people. As 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.

4.2 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 graceful 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 to adapt the contents with different topics and for various ages. The administrator (e.g. the teacher) can prepare them according 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.

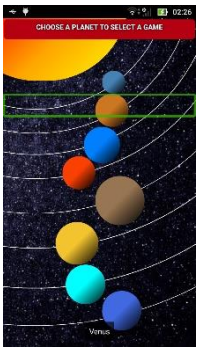

Figure 1: Home.

Figure 2: Multiple-choice question start.

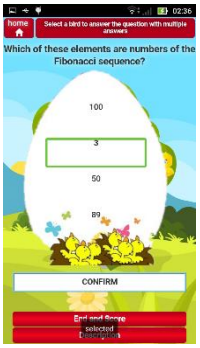

Figure 3: Multiple-choice question.

4.3 The Plays

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.

In our first prototype we developed the following plays.

Play 1: Single-choice.

This play is composed of a set of questions whose answers are in a list of possible choices. For each question only one choice is correct. Therefore, the user has to select one answer to reply.

Theme: the extinguish fire. A helicopter can spout water only when the answer is correct. Sounds of helicopter, fire and falling water are used for an auditory perception of the scenario.

This play has been implemented with a list of possible choices. Just one of them can be selected. The player can select a choice by a single tap (double tap when the screen reader is on). When tapping on an item, the play shows the next question. The play is completed when all the questions have been answered and the player gets the gained score for that session.

Play 2: Multiple-choice.

This play (see Fig. 2) is composed of a set of questions as the previous ones in which all possible answers are in a list. The difference to consider is about how to implement the selection of choices and how to proceed. In the single-choice play when tapping on a choice, the game shows automatically the next question. In this case, the next question is proposed only after the user has selected all the possible choices, since more than one can be correct for that question/exercise.

This has been designed with a list of possible choices. When choosing one of them, via a single tap (double via screen reader), the element is selected. As consequence that choice becomes in bold and the screen reader announces “selected” to inform the user that element has been selected. The user can select other items in a similar way. When finished, the player can confirm and so skip to the next question via the “confirm” button. The score is collected at the end of the game according to the correct answers.

Theme: A tree is on a grassland. Eight birds are on the tree (see Fig. 2). Each bird is a question with more than one which can be correct (see Fig. 3). If the answer is correct (all the right choices have been selected), the bird sings. Otherwise it flies away. The bird flying away or singing are aurally reproduced via the corresponding sounds.

Figure 4: True or false start.

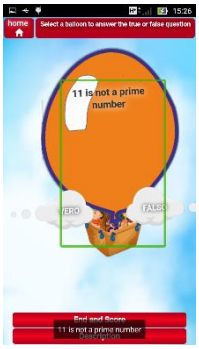

Figure 5: True or false.

Play 3. True or false.

For this type of question, the selection is very simple to do. Only two choices are available (true/false | yes/no | etc.). However, some usability issues have been encountered to locate the two choices in order to be easily identified by a blind user. When selecting True or False, the game shows the next question (as in the play 1). For this play we have a predetermined number of questions, which is limited to the theme designed. In fact, we selected a graphical theme like shown in the Fig. 4.

Theme: There is a Montgolfier composed of eight balloons (see Fig. 4), one per question (see Fig. 5). If the user answer correctly, the balloon becomes bigger; otherwise it bursts. To provide a similar auditory perception, the evocative sounds are reproduced.

Play 4: Matching items.

The exercises consist in matching the elements belonging to two different sets (see Fig. 6). 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 tap one item on the left, and next on the corresponding one on the opposite side.

As 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 element. The user confirms via the specific buttons to be completed the exercise.

Theme: There is a river. The elements to be paired are listed on the left and on the right of the river (Fig. 6). A rope is launched when the matching is carried out (Fig. 7). 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 6: Matching question start.

Figure 7: Matching question.

5 EVALUATION AND DISCUSSION

For our first prototype we prepared a set of questions on topical interests we used to have a first pilot evaluation with two blind (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.

6 CONCLUSIONS

In this work we investigated how to design a potential mobile cross-platform app developed as educational game for all, including screen reading users. We did 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 graphic 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 a fully 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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