Toward Designing Mobile Games for Visually Challenged Children

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Abstract—This study attempts to design a mobile learning game for visually challenged children to improve their spatial ability and executive function. Two audible mobile games were designed and tested: (1) Cardinal Direction (CD) and (2) modified Tower of London (TOL). Qualitative (i.e. observational notes and interviews) and quantitative data (i.e. game scores, time logs, and survey data) were analyzed. Results yielded a high level of enjoyment among participants. Findings on collaboration, usability, accessibility, audible feedback, and student success in winning points in the games are discussed in order to provide insights into designing a more comprehensible mobile learning game, with higher collaboration features, for visually challenged users in the future.

Keywords- Mobile learning, Game, Blind, Visually impaired, Spatial ability, Executive function

INTRODUCTION

Mobile technologies have been extensively employed in many educational situations [1, 2]. However, there are many people who do not benefit from this emerging technology. The blind are easy to be excluded from mobile learning opportunities due to their disabilities or socioeconomic issues (see [3]). Since mobile technologies have the potential to have an extensive effect and deep penetration rate with its portability, low cost, and diverse features, if design principles and solutions are well established, handheld devices can create variety of learning opportunities for visually challenged users [4].

Research on users with disabilities showed mobile technologies can be implemented as an assistive technology for them [5]. Visually challenged children can benefit from technology for their psychomotor and cognitive development [6]. Sánchez, Flores, and Sáenz [7] concluded that mobile learning for visually challenged children is highly satisfactory and engaging. In addition, handheld devices represent a learning tool to be used in school activities outside the classroom [8] and allow people with visually impairment to interact in non-static places for learning purposes [7]. However, there are still many problems, such as finding an alternative for graphic display, which is the primary interface of mobile devices. Since visually challenged children have different ways to perceive and imagine the world [4], mobile technologies with graphic display should be critically studied and designed. In order to resolve the problem, user-centered interaction design and pedagogies should be applied to develop mobile learning games [9]. This paper is a part of global action research attempting to provide an accessible, affordable and learner-centered mobile game solution for visually challenged users living in underserved area. The study gives an overview of a user-centered mobile technology solution and addresses the implementation of two audible mobile games.

BACKGROUND

Mobile Learning Games for visually challenged users

Many people with disabilities are excluded from the digital games due to the accessibility issue and lack of visual modality. What is uppermost in the mind is to use the auditory channel. However, audio information for visually challenged users can detract from the interaction experience [10]. Thus, Sánchez [4] draws some conclusions based on the research of audible games for the blind: 1) sound should convey information, 2) should not be used as interface ornaments, 3) should be normalized, and 4) must be coherent with that is being represented. In addition, games have to be designed to match adequate level of the blind’s spatial and cognitive abilities [11]. Congenitally blind people have trouble building spatial knowledge to the level of structural knowledge [12]. In addition, visually challenged people usually lack critical information for understanding the world, facing difficulties in mapping as well as navigating spaces [13]. They recognize objects by an indirect way [14]. Sound feedback can be related to spatial representation and they can have a sound perception of shapes and orientation.

Mobile Device and Technology

There are many people with disabilities who cannot afford obtaining high-tech mobile devices in the underserved areas. Thus, TeacherMate (TM), an inexpensive mobile device that can store and deliver a vast amount of information and provide opportunities to larger population of users in developing world [15], could be employed. As shown in Figure 1a, TM is a battery-operated, handheld mobile learning device running Linux as operating system and powered by ARM 9 processor. The device has 512 MB internal memory and an expansion slot for external 4GB memory. The front features a color screen (11cm x 7.5cm), four directional arrow buttons, three colored control buttons above the display screen, a blue enter button, a built-in microphone, and an integrated speaker. The power button, headphone output jack, a mini-USB, and a charger slot are on the side of the device. TM is
a programmable open mobile learning platform that allows anyone to freely create applications with Adobe Flash and run under GNASH, a Flash player, part of the open source GNU project.

![Figure 1. a. TeacherMate, b. Students enjoyment and collaboration](image)

**Game Design**

Game design strategies for visually challenged users are based on using alternative modalities for the visual channel. Replacing or enhancing visual stimuli with audio input has been widely used as a solution [16, 17]. A Flash based program called “Audible Test Maker” was designed and developed to facilitate, generate, store, and transfer of audio cues and self-voicing speech, the primary audible input and feedback files, to TM devices. Cardinal Direction (CD) and Tower of London (TOL) games were modified, designed, and contextualized through 4 months period of tests. CD and TOL were selected as learning games: (1) to design a mobile game that could be fun, easy to follow, and challenging for blind children; (2) to enhance visually challenged learners’ spatial abilities and cognitive function which are significant factors for the blind when playing games. CD and TOL are structured activities that have goals, rules and strategies. When visually impaired learners use spatial abilities or executive functions, they should utilize appropriate cognitive efforts and abilities. Visually impaired game interaction model [18] was adopted to provide a better usability and accessibility to users. This model consists of three main steps; receiving the stimuli, determining the response, and providing input. The cognition, receive instruction, feedback and iteration phase has been added to the adopted model to build a better sequential audio game following CD and TOL original design.

**METHOD**

TM was equipped with CD and the modified TOL, named Skewer in Seoul (SIS). The study was conducted in two phases with 25 total blind children (i.e. CD and SIS).

**Mobile Learning Game 1: Cardinal Direction**

**Participants:** 25 total blind (age: 13–17) children participated in this study. All participants were recruited from a special education school in Malaysia. They have already understood the concept of cardinal directions and have not used TM before.

**Procedure:** Participants were divided into groups of 3-6 to be able to conduct the study with 6 TMs. They were able to figure out how to operate the device using self-exploration. Time log data was collected for further usability testing. Playing the game, participants were guided by the aural instruction of their position and navigation, for example, “You are heading North” and “Take two steps forward and turn 90 degrees to the left”. Then, TM asks about the direction, such as “Where are you facing?”, which was translated to local language. Answers are recorded through TMs when participants click Arrow keys to choose the answer (i.e. North, South, East or West) and Enter key to confirm their answer. Qualitative data was collected through semi-structured interview and focus group sessions.

**Mobile Learning Game 2: Skewer in Seoul**

TOL has three sticks on each board and uses concept of colors. Game has been modified based on inputs received from participants in 3 pilot test sessions. The concept of food and barbeque party storyline was added to the original TOL. As shown in Figure 2, the scenario was invented to SIS. Sticks in TOL has been changed to skewers, balls to the foods (i.e. the red ball to the prawn, the green to the chicken, and the blue to the lamb).

Participants were supposed to have a barbecue party and to receive orders from virtual customers. The subjects heard that players have already put some foods on the skewers, but they have to rearrange the food based on customers’ order. Participants were guided by the instruction that three foods have to be moved from a start position to a goal position in a minimum number of moves. Skewers are of unequal height. The left skewer is long, so it can hold up to 3 foods. The middle (medium) can hold up to 2, and the right (short) can hold up to only 1. If one skewer holds 2 or 3 foods, players can move the uppermost food only. Participants can move only one food at a time (see Figure 2).

![Figure 2. a. Skewer in Seoul scenario start position, b. goal position](image)

**Participants:** Participants were 12 total blind (age: 14–17) children. Blind children were recruited from the special education school in Malaysia. Participants were given a chance to play SIS individually, and time log data and game score were recorded. Observation notes were collected by 3 researchers and facilitators during the data collection session.
Procedure: The present study implemented 2- to 4-move problem sets. Participants had enough time to explore the mobile device. Participants were guided by the aural instruction of the start and goal position, for example, “Start position. The left skewer holds up two foods, chicken and prawn. The chicken is at the bottom...” and “Goal position. The left skewer holds up nothing. The middle skewer holds up two foods, lamb....” Then, TM asks about the minimum number of moves. Additional questions were presented, such as “What food do you move firstly?” and “To where do you move this food?” Qualitative data was collected through semi-structured interview and focus group sessions to measure enjoyment factors and participants reflections.

RESULTS AND DISCUSSION

Usability

Collected time log data and observation notes from 25 participants in CD study showed participants take average of 276000 millisecond to figure out how to turn the devices on. All of them had competent motor skill to control all the keys and could navigate. Usability problems, such as not being able to skip cutscenes or incompetent control, were reported. Two participants were observed that they held their TMs with 90 degree rotation. Four children used their mouth and nose for exploration smelling the device. Further investigation on device operation level of difficulty reported. All participants are agreed it was easy/very easy for the participants to learn about the button function and they could follow the instruction and answer the questions.

Performance

Data on participants’ scores in 3 different levels (L1 to L3) of difficulty in CD game reported the L1 mean for the CD task (M = 2.6) was higher than the mean of L2 (M=2.3) and L3 (M = 2.3). In order to analyze the 12 participant’s performance result in SIS, two different scores were considered: (a) Success score (SS): 1 point is given for the correct response in each problem and 0 for failure. (b) Complexity score (CS): the percentage of variation in the difficult task (numbers of success in 4-moves) in comparison to easy tasks (2- or 3-moves). SS is a measure of global planning efficiency and CS quantifies the ability to cope with more and more complex tasks (see [19]). The mean for SS in this study was 1.69, with a standard deviation of 1.03 and the complexity score was 57% in average.

Fun and enjoyment

Answer to 1-5 Likert type question of “how much did you enjoy playing the game?” reported M=4.25 and M= 4.66 in CD and SIS respectively. Results of what did they like the most in the activity is depicted in figure 3. Observation notes showed participants asked to repeat questions when the game was getting harder in L2 and L3 and no repetition request was reported in L1. At L3, participants showed more difficulty following the scenario especially when questions had two rotations, more frustration signs were observed.

Collaboration

Participants showed high level of interest in collaboration. Participants have talked to each other while playing game and discussed their solutions and answers (e.g. Figure 1.b). Whenever they received “correct” feedback from the device they were excited sharing their success stories with other participants. However, the level of participation and collaboration at L1 (SIS) was low and participants were concentrating on their tasks separately. After finishing L1, participants understood the game concept and collaboration started. The participants looked more relaxed and seemed having fun with the game in L2. Although, L3 questions were harder and more complicated compare to previous questions, participants showed the highest level of collaboration.

Challengability

Participants suggested new labels for both games: Geography Game (CD) and Mind Game (SIS). Most of participants found Mind Game more challenging and interesting rather than Geography Game. However, contradictory result was reported regarding how users felt the game challenged them. Majority of participants listed this factor as pros of the activity for instance one participant commented: “I like Mind Game to improve my memory so I can remember more, it makes my brain smarter.”, while some of them counted it as a negative factor and requested for “more fun games which doesn’t need thinking”. This factor should be further analyzed in detail.

Audible feedback: SIS provides feedback to players and informs them if they replied correctly or not. Participants showed high level of concern about correct or incorrect feedback from the device. Participants liked to hear different voices, because they felt that they were “getting to know new people”. Since two English narrations with Korean and Malaysian accent, and one sentence in Spanish were provided, participants were excited about new accents and were imitating the accents and laughing.
CONCLUSION AND SUGGESTION

The primary intention of this paper was to design mobile learning game for the blind to improve their spatial ability and executive function. The qualitative results demonstrate that visually challenged children might have spatial intelligence, which is consistent with previous suggestions [20], and they have executive function enough to play mobile learning games provided by audible instructions. Generally, computer games are demanding motor, sensory, and mental skills for interaction control, due to complex procedure and the main emphasis on visual control and attention [21]. These facts make digital games inaccessible to visually challenged people. However, spatial ability enhancement of visually challenged children allows them to have a higher level of learning opportunities as well as to develop psychomotor activities.

The results support the audible version of mobile learning games based on the cognitive abilities measuring tasks are possible. The procedure of these games is readily comprehended even by young children with visual impairment. In addition, they need an authentic scenario based on their daily lives. They enjoy problem-solving questions, and can perform audible tests using mobile devices. Although researchers have to find a technical way to access to all information needed, accessible games must be as interesting and as usable as the original game [22], and the mobile learning experience should be fun, easily available, satisfying, and rewarding for children in all situations and cultures. Educational games need to engage users with learning and it is significant that mobile learning motivates learners’ particular intellectual curiosities [23]. The challenge for educational games needs to be matched to learners’ skill level in order to avoid feeling anxiety and boredom. Thus, the observation that participants enjoyed CD and SIS describes that these applications might be run as authentic games for the visually challenged players.

Participants wanted additional features: more instruction, repeating function, and more control over the game flow. Participants wanted to use mobile devices in every learning situation including their classroom and home. Thus, instructional programs for school curriculums or learning management systems, as well as independent applications, should be paired with easy to use and portable devices benefit to visually challenged children real lives. Sound-based studies for the visually challenged users have been focused on assisting cognitive development, including spatial structures, short-term and abstract memory, haptic perception, problem-solving, mathematics learning skills, and orientation and mobilization skills [4]. The instruction and scenario design, narration language, length, and authenticity should be further studied. Since visually challenged children participated in this study have requested for more aural feedback when they were interacting with the device, it should be possible in future studies to develop and enhance the aural feedback features, such as auditory direct manipulation using sonification (see [24]). In this study, visually challenged children had a strong tendency to collaborate with each other to solve more complicated problems. Further studies on collaborative or participatory learning among visually challenged children, user interface, tactile experience, cognitive abilities and their developmental process are needed. As Sánchez et al. [7] suggest, designing game-based cognitive interventions is advantageous for visually challenged learners to be rehabilitated through handheld learning devices. If we found out ways to enhance visually challenged users’ cognitive abilities by using the inexpensive mobile device based on HCI for them, they would live more independently [5], and would be more hired. Furthermore, this would lead them to have greater self-esteem.

REFERENCES


