Audio Haptic Videogaming for Navigation Skills in Learners Who are Blind

Jaime Sánchez
Department of Computer Science and Center for Advanced Research in Education (CARE), University of Chile
Blanco Encalada 2120, Santiago, Chile
jsanchez@dcc.uchile.cl

Matías Espinoza
Department of Computer Science and Center for Advanced Research in Education (CARE), University of Chile
Blanco Encalada 2120, Santiago, Chile
maespino@dcc.uchile.cl

ABSTRACT
The purpose of this study was to determine whether the use of audio and a haptic-based videogame has an impact on the development of Orientation and Mobility (O&M) skills in school-age blind learners. The video game Audio Haptic Maze (AHM) was designed, developed and its usability and cognitive impact was evaluated to determine the impact on the development of O&M skills. The results show that the interfaces used in the videogame are usable and appropiately designed, and that the haptic interface is as effective as the audio interface for O&M purposes.

Categories and Subject Descriptors
K.4.2 [**Computers and Society**]: Social Issues – *Assistive technologies for persons with disabilities, Handicapped persons/special needs.*

General Terms
Human Factors.

Keywords
Haptic and Audio Interfaces, Orientation, Mobility, People Who Are Blind.

1. INTRODUCTION
For people who are blind, navigation through unfamiliar spaces can be a complex task compared to a sighted person. In order to achieve orientation & mobility (O&M), people who are blind need to use other resources to receive feedback from the environment, such as sounds or textures (haptic feedback). Various virtual environments have been designed in order to train people who are blind, and to assist them with the development of O&M skills [1][2][3].

The purpose of this study was to determine whether the use of an audio and haptic-based videogame has an impact on the development of O&M skills in school-age learners who are blind. A video game untitled Audio Haptic Maze (AHM) was developed from previous video game design experiences [2][3]. AHM was designed to be used by school-age learners who are blind either autonomously or with the supervision of a facilitator in contexts of research and practice. Initially, we evaluated the usability of AHM to determine how well it maps the mental model of users who are blind. Then, we evaluated the cognitive impact of using AHM on the development of O&M skills.

AHM allows a school-age blind learner to be able to navigate through a series of mazes from a first-person perspective, obtaining feedback from the game through the use of three kinds of interfaces: haptic, audio and haptic plus audio. In order to escape from a maze, the player must find jewelry boxes spread throughout several corridors and rooms, which contain keys and treasures. The interaction with AHM is carried out through the use of a standard computer keyboard. In the case of the audio-based interface, all of the user's immersion is achieved through the use of stereo sound. In the case of the haptic-based interface, the Novint Falcon device was used for haptic feedback, which works as a three dimensional pointer that allows for an interaction with 3D volumes and generating force feedback.

2. USABILITY EVALUATION
A second set of usability evaluations of AHM was implemented. An initial usability evaluation was previously implemented during the development of the videogame [3]. A sample consisting of 10 school-age learners who are blind with ages ranging from 9 to 17 years old was selected. None of these research participants have any additional associated disabilities other than visual impairment. All the users' prophile fitted the the target user of AHM.

Software Usability Elements (SUE) questionnaire allowed to quantify the degree to which the sounds and haptic feedback used in the videogame were recognizable.

The Open Question Usability (OQU) questionnaire allowed to collect knowledge regarding aspects related to O&M that represent the focus of the AHM videogame, as well as regarding the use of the controls, the information provided by the software, and the user's navigation in the virtual environment.

In general, the videogame was well accepted by end-users. One relevant aspect regarding the use of the audio-based interface was the user comments mentioning that the interaction experience was very enriching, but not necessarily because of the capacity to convey information from the virtual environment to the user; rather users noted that, in part, the sound provided by AHM helped to generate a context and environment that is more associated with what they would expect from a videogame.

Once the corrections and redesign of the software had been carried out considering the results obtained from the administration of the SUE and OQU questionnaires, Sánchez's Software Usability for Blind Children (SUBC) questionnaire [4]

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was administered. This questionnaire allowed to perform an evaluation of the software's usability according to the user's satisfaction. In order to perform the evaluation, the three kinds of interfaces involved in the videogame were analyzed: haptic, audio and haptic plus audio.

The results show that the mean level of the dimension "users' satisfaction" was 7.0, 8.5 and 7.1 points respectively for each kind of interface, on a scale with a maximum of 10 points. Regarding the dimension "Control and Use" the mean scores were 6.7, 7.5 and 7.8 points respectively, using the same score scale. The mean level of the "Audio" dimension was 10 and 7.7 points respectively for audio and haptic plus audio interface (the haptic interface did not apply for this dimension). And finally, the mean level of the "Haptic" dimension was 9.0 and 7.7 points respectively for haptic and haptic plus audio interface (the audio interface did not apply for this dimension).

3. COGNITIVE IMPACT

A second set of cognitive impact evaluations of AHM was performed. A pilot first evaluation for the ongoing study was introduced in [3]. An intentional sample was made up of 7 school-age learners who are blind (3 females, 4 males), all from Santiago, Chile, belonging to the Santa Lucia School for the Blind. These learners were not the same of those that participated in the usability evaluation. The requirements to participate were: Be between 10 and 15 years of age; present total blindness; be enrolled between third and eighth grade. These requirements fitted the user prophile that targeted AHM.

A cognitive impact evaluation instrument was applied individually to each user during the pretest and posttest. In between a cognitive intervention was implemented to determine whether the use of the videogame has impacted the development of O&M skills. This instrument was designed and validated by special education teachers who are specialists in visual disabilities. For this purpose two O&M skills checklists were created for two sample groups: a checklist was adapted to the O&M skills of users between 10 and 12 years of age (4 users from the sample) and a second checklist was adapted to the O&M skills of users between 13 and 15 years of age (3 users from the sample).

The results obtained from the evaluation of the two sample groups showed an increment in the pretest/posttest performance mean scores in all dimensions covered by the checklists: Sensory perception, tempo-spatial development, and O&M skills.

The results of the dimensions for the 10-12 year old age sample group were: "Sensory perception" (scale ranging from 0 to 72 points, pretest mean = 65.75, posttest mean = 70.75), "Tempo-spatial development" (scale ranging from 0 to 34 points, pretest mean = 24.45, posttest mean = 28.75) and "O&M skills" (scale ranging from 0 to 52 points, pretest mean = 32.31, posttest mean = 48.75). A student-t test was applied. The "O&M skills" dimension was statistically significant ($t = -4{,}323$; $p < 0.05$).

The results of the dimensions for the 13-15 year old age sample group were: "Sensory perception" (scale ranging from 0 to 68 points, pretest mean = 59.00, posttest mean = 68.00), "Tempo-spatial development" (scale ranging from 0 to 34 points, pretest mean = 33.33 points, posttest = 34.00), "O&M skills" (scale ranging from 0 to 44 points, pretest mean = 34.00 points, posttest mean = 43.76). A student-t test was applied. The "Sensory perception" dimension was statistically significant ($t = -5{,}197$; $p < 0.05$).

4. CONCLUSIONS

The purpose of this study was to determine whether the use of an audio and haptic-based videogame has an impact on the development of O&M skills in school-age learners who are blind. For this reason, first, the AHM videogame was designed and developed. Second, the usability of AHM was evaluated to establish how well it maps the mental model of users who are blind. Third, the cognitive impact of the videogame in terms of the development of O&M skills was determined.

Regarding the usability, both the haptic and the audio-based interfaces were effective to provide adequate feedback to the user within the virtual environment. The use of the haptic and audio interfaces together allows the blind user who is navigating the videogame's virtual environment to be able to form a better perception of distances, shapes and the orientation of the objects on the map when updating his position. Due to this fact, the users could navigate through all of the areas that make up the maze, making intelligent decisions regarding what direction to follow in order to go from point A to point B thanks to the information provided.

Regarding the cognitive impact, the results of this study show that all the audio and haptic icons were useful for establishing navigational paths in the virtual environment. The users developed their orientation and mobility skills as a result of their interaction with the AHM videogame which is directly related to the efficiency of the user's movements when navigating within the videogame's virtual environment.

Finally, as a future work, more in-deph long-term study evaluations involving a large sample to obtain more deep and complete results in all dimentions studied.

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