Audio and Haptic Based Virtual Environments for Orientation and Mobility in People Who are Blind

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ABSTRACT
This study presents the development of a videogame with two audio and haptic interfaces that allow for the stimulation of orientation and mobility skills in people who are blind through the use of virtual environments. Our idea was to test the hypothesis regarding the use of audio and haptic interfaces together, allowing for the creation of a better mental representation of a virtual environment, compared to that which results from the use of each kind of interface separately. The videogame's icon usability has been evaluated, as well as a posterior cognitive analysis of the skills acquired through its use. The preliminary usability results show that the people correctly describe the textures and shapes used in the software.

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

General Terms
Human Factors.

Keywords
Haptic and Audio Interfaces, Orientation, Mobility, Icon Usability.

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 and mobility (O&M), people who are blind need to use other resources in order to receive feedback from the environment, such as sounds or textures (haptic feedback). We can use virtual environments to train people who are blind, and to assist them with the development of O&M skills. To achieve this, we have used spatialized sound and haptic interfaces.

The haptic interfaces are provided through the use of devices that are capable of creating feedback through interaction with muscles and tendons. In this way, the feeling of applying force over a certain object is provided [1]. Lately, studies of haptic interfaces are becoming increasingly relevant, and in particular the use of Novint Falcon is one of the more pertinent. This tool is a device that provides force feedback, and when it is used the user can feel the volume and force of a virtual object in his hand. This device is quite useful for representing virtual environments [2].

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The purpose of this study was to design, implement and evaluate the AudioHapticMaze (AHM) videogame. This game, based on AudioDoom [3], allows for a blind user to be able to navigate through a series of mazes from a first-person perspective, obtaining feedback from the game through the use of spatialized sound, haptic interfaces, or both of these simultaneously. Through this videogame, we seek to validate our hypothesis that the joint use of audio and haptic interfaces allows for the creation of a better mental representation of virtual environments, compared to the use of each interface separately.

2. DESCRIPTION OF AHM
AHM is a first-person videogame in which the user must escape from a maze. In order to fulfill the mission, the player must find jewelry boxes dispersed throughout the various hallways and rooms of the maze, which contain keys and treasures.

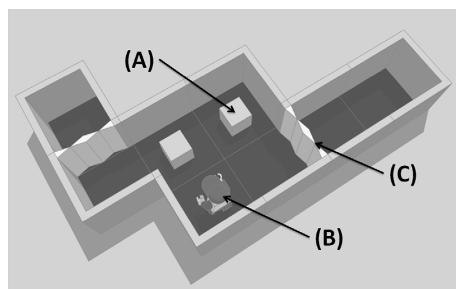

Figure 1. Sketch of an AHM maze.

The keys have geometric shapes that correspond to certain doors in the maze. The user must pick them up and try them one at a time, until he identifies which key can be used to open the doors needed to get out of the maze.

A sketch of the elements that make up a maze in AHM can be found in Figure 1, in which: (A) represents a jewelry box, which can have a key or a treasure inside; (B) represents the character controlled by the user; (C) represents a door in the maze.

In order to add another entertaining component to the game, the score of the game increases with each treasure that the player finds, and the time that the player takes to get out of the maze is also a factor, in which the less amount of time taken implies a higher score. We now present the methodology used to evaluate the AHM interfaces and the cognitive impact that this game has on people who are blind.

3. METHODOLOGY

For the evaluation of AHM we have considered a sample consisting of 17 blind people with ages ranging from 9 to 17 years old. None of these research subjects have any additional, associated disabilities other than visual impairment.

For usability testing we used several key instruments. The Software Usability Elements questionnaire (SUE) allows us to quantify the degree to which the sounds and haptic feedback used in the videogame were recognizable. The Open Question Usability questionnaire (OQU) that was applied to the users included questions such as: Was it possible to perceive the realitve position of the objects? Did you like the sounds/haptic interface used for feedback in the software? The idea was 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. The results of this evaluation allowed us to redesign and improve the user interfaces. Once the corrections and redesign of the software had been carried out, Sánchez's Software Usability for Blind Children (SUBC) questionnaire was administered. This questionnaire consists of 14 items for which the users had to define to what degree each item was fulfilled, on a scale ranging from 1 ("a little") to 10 ("a lot"). The results allowed us to evaluate the usability of the software according to the user's satisfaction, using sentences such as, "I like the software" and "The software is motivating".

To date, the SUE questionnaire has been applied in six, 1.5-hour sessions. In the first two sessions, working with sounds, each learner worked for 15 minutes. Each sound was played sequentially, and at the end of each sound the learner was asked to identify it. In the following work sessions, concrete shapes were evaluated, through a personal work session lasting 15 minutes. In the fifth session, each child worked for 10 minutes with the haptic device. The work consisted of virtually touching the contours of 12 haptically modeled shapes through use of the Novint Falcon, and identifying these shapes. In the sixth and final session, each learner had 10 minutes to evaluate his tactile sensation of the virtually represented textures, through the use of the Novint Falcon. It is important to point out the fact that the students had already been using Tiger Embosser to learn about shapes in school. The evaluations of geometric shapes are only used to support the game.

For the cognitve evaluation, the methodology consisted of three stages for identifying the cognitive impact of using haptic senses to navigate through interfaces such as closed corridors: In the first stage the user interacted with a corridor that was represented through audio only. In the second stage the user interacted with a corridor represented with a haptic interface only, using the Novint Falcon device. Finally, in the third stage, the user interacted with both audio and haptic senses. The idea was to compare the results obtained from the different stages, and obtain data in order to research the real contribution of each sense for navigating through virtual environments.

4. RESULTS

Initially, it was planned that the sounds utilized in the videogame would represent a "metallic" environment, which would create a spatial maze atmosphere in order to make the game more attractive to the students. According to the results obtained from the application of the SUE questionnaire for the evaluation of icon sounds, it was observed that the sounds, which were altered in order to achieve the desired effect, confused the users. For this reason it was decided to use pure sounds. In the usability evaluation of concrete shapes, the results obtained from the questionnaire show that the students correctly identified simple geometric shapes, but had problems identifying complex shapes. In the same way, in evaluating shapes through the use of the haptic device, it was observed that the majority of the people identified regular shapes with the device, but not complex shapes (see figure 2). Finally, in evaluating the usability of the virtual textures represented through use of the haptic device, the results show that most users correctly described the textures. We continue to implement an ongoing study in order to gather additional qualitative and quantitative data regarding usability and the cognitive impact.

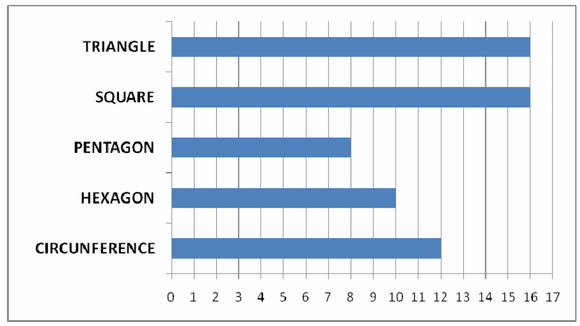

Figure 2. Results of the SUE for haptic figures.

5. DISCUSSION

In this study, a videogame for the improvement of orientation and mobility skills in people who are blind was developed, through the use of virtual environments, as well as audio and haptic-based interfaces. This videogame was utilized in order to test the hypothesis that the joint use of audio and haptic interfaces creates a better mental representation of a virtual environment, compared to using each one separately. The users did not perceive the proposed sounds at an optimal level, for which reason we decided to use pure sounds. A relevant result was that users were able to identify various simple geometric shapes with their hands by touching the contours, but were less effective at identifying complex shapes. For future work, the final software usability evaluation will be applied, along with the cognitive evaluation.

6. ACKNOWLEDGMENTS

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