Videogame for improving orientation and mobility in blind children

J Sánchez, J P Rodríguez

Department of Computer Science and Center for Advanced Research in Education (CARE)
University of Chile, Santiago, CHILE

jsanchez@dcc.uchile.cl, jurodrig@dcc.uchile.cl

Abstract — **This work presents an evaluative study on the usability of a haptic device together with a sound-based videogame for the development and use of orientation and mobility (O&M) skills in closed, unfamiliar spaces by blind, school-aged children. A usability evaluation was implemented for a haptic device especially designed for this study (Digital Clock Carpet) and a 3D videogame (MOVA3D) in order to determine the degree to which the user accepted the device, and the level of the user's satisfaction regarding her interaction with these products for O&M purposes. In addition, a preliminary cognitive evaluation was administered. Usability results show that both the haptic device and the videogame are usable, accepted and considered to be pleasant for use by blind children. The results also show that they are ready to be used for cognitive learning purposes. Results from the preliminary cognitive study demonstrated significant gains in the development of tempo-spatial orientation skills of blind children when navigating in unfamiliar spaces.**

I. INTRODUCTION

In order to move around safely in closed spaces, blind people avoid moving through the center of rooms and navigate by touching the walls around the perimeter of the room ("shorelining"). This form of navigation is inefficient. However when a blind person has time to familiarize himself with the environment, he gets more confident and is able to find and navigate more efficient routes (Sánchez and Elías, 2007).

Virtual environments can be used to provide blind people with virtual training exercises that allow them to improve their navigation skills and to later transfer such skills to the real world. The user can create a mental map of a virtual environment and make him more confident when navigating through the real environment.

Several studies have used virtual environments with blind people using audio (Tzovarus, et al, 2002) and haptic cues (Crossan and Brewster, 2006) to help the player navigate through the game. Studies have also been designed to determine and validate attributes that are necessary to create accessible virtual environments for blind users (Trewin, et al., 2008).

When trying to teach or develop skills in a child, serious videogames have shown a great potential (Gee, 2003) and are also highly motivating, which is a key advantage when trying to teach something to a student (Gee, 2003). These characteristics make videogames a great tool when working with blind children to develop complex skills such as navigation. Several research projects use audio-based videogames to teach school content and learning skills to blind students (Sánchez and Elías, 2007) (Trewin, et al., 2008).

In this paper, we present the results of a usability evaluation study and the impact on the development of orientation and mobility skills as a result of using a haptic-based device (Digital Clock Carpet) and a 3D sound videogame (MOVA3D) in unfamiliar, closed spaces by school-aged, blind children.

II. SOFTWARE

For this study we have used a videogame called MOVA3D. The game was designed and developed to work with children who are both totally blind and those with low vision (see Figure 1).

Figure 1. *Graphical interface of the MOVA3D videogame.*

In the videogame the player has to navigate through an environment in order to find a certain number of pocket watches on the map. Once he finds and grabs a pocket watch, he has to keep it for 30 seconds while running away from the enemies who try to steal it from him. When navigating, the player's movements are discreet; each step corresponds to a 40 cm movement in the real world, and each turn is at a 30° angle. This was done to allow the user to orientate himself in the environment, because as the user is in continuous movement it is difficult for the player to be able to know for certain the degree of his turns or how far he has walked.

A. Interface

The software incorporates attractive 3D graphics that are representative of the real world, as well as stereo sound. The 3D graphics are used to motivate and to provide extra cues for low vision users; however, the software was developed in a way that it is possible to navigate without using the visual cues.

The 3D graphics map the real world into the game. Special care was taken to incorporate the most significant elements of the environment into the videogame to allow the players to create a correct mental representation of the real environment. The colors of the walls and floors in the videogame are also the same as in the real environment.

Stereo sound that emulates 3D sound was used to allow the players to detect each of the elements in the videogame. Different sounds were used to represent different objects (walls, doors, enemies, benches, etc.) and actions (walk, turn left, turn right, open door, go up stairs, etc.). Also, radar was incorporated to help users find the watches when they are located in the same room.

B. Interaction

To play the game users can use the keyboard or a haptic device, which was specially created for this project, called the Digital Clock Carpet (DCC) (see the section below). This device does not allow the player to see the display device at all times while playing, which is why for the first part of the project both input devices were used with the game. However, in the next phase of this research we are only interested in working with totally blind users who are not able to see the screen, so only the DCC will be used.

Players can ask for information relevant to their navigation by pressing the Page Up key (if using the keyboard) or by using a remote USB wireless presentation laser pointer pen. When navigating through the environment, players need to open doors in order to move from one room to another. To do this, players can use the Page Down key (if using the keyboard) or the previously mentioned presentation pointer pen.

III. HARDWARE

The DCC consists of a round wooden structure divided into 12 cells (see Figure 2). The sections correspond to keys that the user can press with his feet. The DCC also has tactile cues that allow the user to recognize where he is standing on the carpet, which is represented by the yellow circles in figure 2.

The idea behind the DCC is to use the clock orientation system for navigation. This means that the space around the user is divided into 30° sections and, for example, if the user needs to turn by 90° he would have to turn to 3 o'clock; if he needs to turn by 210° then he would have to turn to 7 o'clock, and so on.

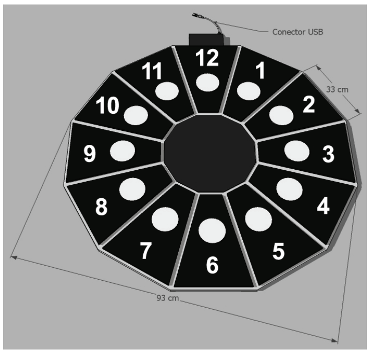

Figure 2. *Diagram of the DCC device.*

IV. EVALUATIONS

An orientation and mobility impact evaluation was performed on a test group of 24 children from 7 to 14 years old, of which 7 were totally blind and the remaining 17 were partially blind with varying ophthalmologic diagnoses.

A. Usability Evaluation

The usability evaluation was performed on 19 end users, all of which were blind children (10 boys and 9 girls) with ages from 6 to 12 years old. Three dimensions were considered: Satisfaction, control and use, and sounds. They were evaluated on a scale of 1 to 10 in which 10 is the highest possible score. The complete results of this research were presented in more detail in a previous paper (Sánchez, Sáenz and Ripoll, 2009).

The end user evaluation of the software shows a high degree of valuation in the 3 dimensions considered, obtaining scores higher than 9 points for all areas. The most highly evaluated scales were satisfaction and sounds, with 9.2 points each. The control and use dimension obtained a score of 9.0 points, while the average evaluation for the three dimensions was 9.1 points.

B. Orientation and Mobility Preliminary Evaluation

Measurements on the O&M skills of the subjects were taken before and after the intervention to measure both their pre and post game levels, in order to study the impact that the system has on their performance. Three dimensions were evaluated: Orientation and Mobility Techniques, Sensory-Motor Coordination and Sensory-Spatial Orientation.

The activities were carried out during a period of three months in eight sessions that lasted 3 hours and 15 minutes each. In five of these sessions the students worked with the videogame, and in the last session, when the students were thought to have developed a mental image of the environment, they were taken to navigate through the real space that was represented in the software. This last task allowed the evaluators to measure the level of transfer from the videogame that the subjects had achieved.

The results obtained in each of the three dimensions measured are presented in Figures 4 and 5. The first presents the results for children between 7 and 9 years old, while the later presents the results for children from 10 to 14 years old.

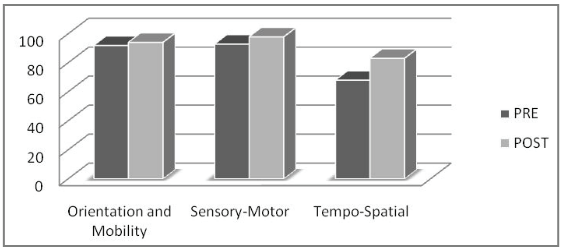

Figure 3. *Pretest/Post-test Comparison in 7 to 9 year old children*.

In the Orientation and Mobility Techniques dimension for 7 to 9 year old users, the pre-test had a mean of 92.0 while the post-test had a higher mean of 94.11 (Figure 3). However, no statistically significant difference was found (Student's t-test = -0.828, p = 0.432, gl = 8). In the 10 to 14 year old group the pre-test had a mean of 78.09 while the post-test had a higher mean of 80.0 (Figure 4). No statistically significant difference was found in this group either (Student's t-test = -0.489, p = 0.636, gl = 10).

For the Sensory-Motor Coordination dimension no statistically significant differences where found either. For the group of subjects from 7 to 9 years old the mean for the pre-test was 92.93, while in the posttest the mean was 97.93 (Figure 3) (Student's t-test = -1.145, p = 0.285, gl = 8). On the other hand, for the group of children with ages between 10 and 14 years old, the mean for the pre-test was 95.55 while the mean results of the post-test was 96.5 (Figure 4) (Student's t-test = -0.726, p = 0.636, gl = 10).

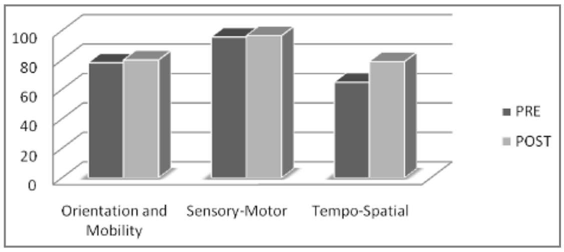

Figure 4. *Pretest/Post-test Comparison in 10 to 14 year old children*.

Finally, for the Tempo-Spatial Orientation dimension, in the group with ages between 7 and 9 years old, the mean of the pre-test was 68.04, which is lower than the mean of the post-test 85.15 (Figure 3). This difference is statistically significant (Student's t-test = -4.973, p = 0.01, gl = 8), which means that there is a higher level of achievement after having used the software. On the other hand, in the group with ages from 10 to 14 years old, the mean of the pre-test was 64.88, which is also lower than the mean of the posttest, 78.91 (Figure 4). This result also presents a statistically significant difference (Student's t-test = -3.648, p = 0.004, gl = 10), which also indicates a higher level of achievement after having used the software.

V. CONCLUSIONS

In this paper, we present the results of a usability evaluation and a preliminary cognitive study on the use of a haptic-based device (Digital Clock Carpet) and a 3D sound videogame (MOVA3D) for the development and use of orientation and mobility skills in unfamiliar, closed spaces by school-aged, blind children.

We believe that the learning progress that was made by each child was favored by positive emotional will, interest in the MOVA3D videogame and in the associated DCC device. This allowed them to strengthen their knowledge, which went in favor of acquiring new knowledge regarding the use of the videogame and the associated haptic device.

Without a doubt, the new knowledge allowed the users to integrate new lessons they had learned regarding the environment into the skills involved in the research. Such skills are not only those associated with the ability to adopt postures in line with visual needs in order to be able to perform actions on the carpet (in the case of the participants with low vision), and the ability to situate themselves in space based on an initial position (in the case of the blind users); rather they refer to the ability to integrate the clock technique by associating the position of their body with a particular time, processing this information and transforming it into a movement that can be made through the use of the haptic device. This generates movements within the virtual environment and strengthens the conceptualization and construction of a mental map of the space navigated in the videogame, in order for them to be able to then navigate the same route in the real world.

The MOVA3D videogame with DCC and cognitive tasks emerge as an audio-based tool that can be used for the stimulation of tempo-spatial orientation skills in blind children. The children who participated in this study were able to transfer what they learned from the videogame to performing the same tasks in the real world, thus achieving a successful transfer of knowledge and skills. This transfer is not easy because the children feel uncomfortable at first; with time, however, the game becomes a significant tool for training.

VI. Present And Future Work

In this research we seek to evaluate the impact of using videogames based on virtual environments and haptic devices in the development of the orientation and mobility skills of blind users. Some previous results have been promising regarding what can be obtained from such research (Sánchez, Sáenz and Ripoll, 2009). However, an appropriate cognitive study and evaluation has not been done, and is needed to prove these preliminary results. An in-depth study is required, so the research strategy will consist of performing a seven-month case study on each of the participating subjects.

The videogame was modified during the development phase of our research, and since we are interested in working with only totally blind users in the near future, a special effort was made to improve the audio cues for navigation. The visual cues from the original version were maintained so that the facilitators would be able to chart the progress of the users in the game.

The sample will consist of 9 totally blind users with ages ranging from 7 to 15 years old, and which will be divided into three groups based on their age. The first group will be made up of subjects between 7 and 9 years old, the second from 10 to 12 years old, and the third from 13 to 15 years old. The abilities we will measure in each group will differ, based on the existing knowledge and cognitive development in each of the previously mentioned age groups. As such, different evaluation forms will also be used.

One of the key aspects of the evaluation corresponds to the users' sensory skills. Since we are using 3D sound to help subjects navigate through the virtual environment, we are particularly interested in evaluating if their ability to perceive, identify, discriminate and locate sound improves with the use of the software. More importantly, we are also concerned with the subjects' ability to navigate with and without the use of a white cane through the real environments, represented in the virtual environments in which the subjects practice. We expect that they will feel more confident in their navigation and will be able to move through the middle of the rooms instead of around its perimeter.

Acknowledgements

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