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Enhancing Navigation Skills through Audio Gaming

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Abstract

We present the design, development and initial cognitive evaluation of an Audio-based Environment Simulator (AbES). This software allows a blind user to navigate through a virtual representation of a real space for the purposes of training orientation and mobility skills. Our findings indicate that users feel satisfied and self-confident when interacting with the audio-based interface, and the embedded sounds allow them to correctly orient themselves and navigate within the virtual world. Furthermore, users are able to transfer spatial information acquired through virtual interactions into real world navigation and problem solving tasks.

Keywords

Orientation and Mobility; Virtual Environment; Visual Impairment; audio games; videogames

ACM Classification Keywords

K.4.2 [Computing Milieux]; Computers and Society – Social Issues; Assistive technologies for persons with disabilities

General Terms

Design; Experimentation

Introduction

Several different approaches have been developed to assist the blind with orientation and mobility (O&M). One possibility to help them become more autonomous is to provide them with virtual-based training which could ultimately be transferred to real world settings. Along these lines, a number of studies using virtual environment simulators allow a blind user to interact through both audio [1], [4] and tactile cues [6]. Another possibility would be through the use of audio-based games. Some studies have pointed out the importance of gaming for improving problem solving skills [10]. Moreover, the possibility of using games for learning in pedagogical contexts opens up enormous opportunities to bring education closer to students' everyday life experiences, increasing motivation, commitment to learning, and better shaping the students' current learning styles [2].

There have been numerous insights gained from the design and use of videogames for visually impaired people. When legally blind people interact with videogames that include visual cues, they take advantage of whatever residual vision they have in order to achieve better results from the interaction (e.g. through the use of high magnification). Certainly, for a totally blind user this is not possible and it is thus necessary to provide them with relevant information regarding the environment through other sensory channels such as touch and hearing [7]. There are also studies implementing videogames for learning mathematics in blind students [7]. Another study has used audio-based gaming to reinforce science concepts in a ludic environment for visually impaired children [8]. As the child interacts with the game to fulfill the underlying mission, he/she develops problem-solving skills while learning science curriculum. Other videogames assisted the development of spatial knowledge in blind children [5]. Therefore, if videogames can improve the development of different types of skills, can they also improve the development of navigation skills in blind children? The development of orientation and mobility skills (O&M) is essential for the autonomous navigation of a blind user.

The purpose of this research was to evaluate an audio-based virtual environment simulator developed by our group called Audio-based Environment Simulator (AbES) designed to improve orientation and mobility skills in blind users.

AbES

The simulator was developed to represent a real, familiar or unfamiliar environment to be navigated by a blind person. In the virtual environment, there are different elements and objects (walls, stairwells, doors, toilets or elevators) through which the user can discover and come to know his/her location.

The simulator is capable of representing any real environment by using a system of cells through which the user moves. The user has audio feedback in the left, center and right side channels, and all his/her actions are carried out through the use of a traditional keyboard, where a set of keys have an associated action. All of the actions in the virtual environment have a particular sound associated to them. In addition to this audio feedback, there are also spoken audio cues that provide information regarding the various objects and the user's orientation in the environment. Orientation is provided by identifying the room in which the user is located and the direction in which he/she is facing, according to the cardinal compass points (east, west, north and south). AbES includes three modes of interaction: Free Navigation, Path Navigation and Game Mode.

The free navigation mode provides the blind user with the possibility of exploring the building freely in order to become familiar with it (Figure 1). For a beginning user, we found it useful to include the option that all the doors in the building are open, making the navigation simpler. In the same way, for beginners it is necessary to hear all of the instructions that the simulator provides. For this reason the "Allow Text-To-Speech to end before any action" option is necessary.

Path navigation provides the blind user with the task of finding a particular room. The facilitator must choose the departure and arrival room and select how many routes he/she deems it is necessary to take. When all the routes have been selected, the user begins his/her interaction with the simulator and has to navigate all the chosen paths, thus training in, surveying and mapping the building.

The game mode provides blind users with the task of searching for "jewels" placed in the building. The purpose of the game is to explore the rooms and find all the jewels, bringing them outside one at a time and then going back into the building to continue exploring. Enemies are randomly placed in the building, and try to steal the user's jewels and hide them elsewhere. There is a verbal, audio warning when the user is facing two cells away from a jewel or an enemy. The enemies always remain inside the building. In this game mode, the facilitator can choose the number of jewels to find (two, four or six) and the number of monsters (two, four or six).

Preliminary Cognitive evaluation

Sample

The first part of the study included the participation of seven children aged ten to twelve years old who attend the Santa Lucia School for Blind Children in Santiago, Chile. None of the participants had any other neurological deficits and their visual status was confirmed by their medical records or an ophthalmological evaluation.

Instruments

Checklists were designed for each of the activities. These checklists were based on standard orientation and mobility instruments [3] and contain both common and specific indicators that measure different aspects of the students' levels of progress (spatial orientation, spatial knowledge and spatial representation) when working on the various activities. A Likert-type scale with scores ranging from 1 (never) to 4 points (always) was used to quantify the results and calculate percentages of achievement for each indicator.

Procedure

All the activities with the children were carried out in 6 sessions lasting three hours and fifteen minutes each. During this time, five activities were performed in which the children participated by interacting with AbES. Each of these activities was evaluated by considering the attainment of three navigation skills: **Spatial Orientation**, is the ability to locate oneself within the simulated map and direct efficiently from one point to another; **Spatial Knowledge**, is the ability to recognize, identify and remember the location of the elements that can be found in the environment; and **Spatial Representation**, is the ability to create a mental image of the space that has been navigated.

1. **Initial interaction with a Concrete Model**. Previous studies have shown that children are likely to understand certain processes more fully when modeling and solving tasks using concrete materials that supplement interactions with a virtual environment [7]. In this study, this cognitive task consisted of exploring with a concrete tactile model of the environment that would be navigated using AbES for the remainder of the time. This model contains the building’s main structural divisions, as well as the names of the different spaces written in Braille (Figure 2). Once the exploration of the model had been completed, the students had to construct a spatial representation of the space through the use of concrete materials such as plasticine, LEGO or by making a drawing. In order to not contaminate the sample, the maps used in this stage were different from those used in later stages.
2. **Free Navigation**. To explore the environment, the students’ interacted AbES using free navigation mode, traveling at their own pace through all of the spaces represented. Once they had finished exploring the virtual model, the students had to recreate the spaces they could remember using concrete material of their choice.
3. **Path Navigation Mission**. In this activity the students had to start from a predetermined start point (the computer room) and travel to four different destinations distributed throughout the first floor of the building (the massage therapy room, the fourth grade classroom, the front hall and the early childhood intervention room). They were instructed to take the shortest possible route (Figure 3). Once they had finished exploring the virtual model, the students had to represent the spaces they could remember through the use of concrete material.
4. **The Game**. In this activity the students had to interact with AbES in the game mode, seeking out the hidden jewels and bringing them to the school’s inner yard. This activity allows the students to take different routes from those used in the “Path Navigation Mission”, as they now knew of other rooms and were constructing a mental image of the spaces traveled. In this activity, the students interacted for half of the time with the simulator and during the other half of the time they performed the same task in the real environment (Figure 3). This way of interacting increases the participation and motivation of the children, thus facilitating their learning [9].
5. **Concrete Representation.** In this activity the students interacted freely with the environment (just as they had done in activity 2). Once this free navigation was completed, they were asked to represent the spaces traveled with concrete material (Lego® bricks and drawings) (Figure 4).

Results

In general, the students obtained high scores on all the activities held. For Spatial Orientation, the five activities with the AbES simulator demonstrate very high achievement percentage scores (Concrete Model: 74%, Free Navigation: 84%, Path Navigation Mission: 81%, The Game: 77%, Concrete Representation: 80%), with free navigation representing the activity that obtained the best results (Figure 5) (*Chi Square= 1.895; dof=4;* $p > 0.05$) showing no evidence of significant difference. By navigating freely, the students are focused only on the task of moving through the environment. At the same time, the students ask themselves more questions about the virtual surroundings, which allow them to become even more oriented. Spatial knowledge also has high scores for all the activities held (Concrete Model: 81%, Free Navigation: 87%, Path Navigation Mission: 80%, The Game: 88%, Concrete Representation: 79%), with The Game activity having the highest achievement percentage score *(Chi Square= 9,714; dof=4;* $p < 0.05$*)* (Figure 5) showing evidence of significant difference. In playing, the students had to travel through the space while concentrating and paying close attention to details, as the activity implied locating the jewel and bringing it to the schoolyard. To do this, they not only had to know where they were but also remember well the paths to be able to get out and leave the jewel in the right place, without being caught by the monster. All this information was successfully transferred when they played in the real environment.

Finally, the activity with the highest spatial representation scores was The Game (Concrete Model: 42%, Free Navigation: 52%, Path Navigation Mission: 53%, The Game: 86%, Concrete Representation: 59%), which resulted in much higher scores that those obtained for the other activities (*Chi Square= 5,837; dof=4;* $p > 0.05$) (Figure 5), showing no evidence of significant difference. In playing at finding the jewel, the students travel throughout the entire environment, picking up information on the spaces and the objects within the environment, and thus being able to successfully play the game in the real spaces. In this way, they are able to obtain more information from the space and to improve their mental representation, which is then successfully transferred to the real world spaces.

In summary the global activity that generated the best results is The Game (84%) (Figure 6), (*Chi Square= 4.000; dof=4;* $p > 0.05$), although there is no evidence of significant difference. When the students played, they obtained better scores than when they performed other activities with AbES. When playing, they remained more concentrated and focused on fulfilling the goals of the game, being able to pick up on more information provided by the simulator, and in a more efficient manner.

Conclusion

The purpose of this research was to evaluate an audio-based virtual environment simulator developed by our group called Audio-based Environment Simulator (AbES) designed to improve orientation and mobility skills in blind users. O&M training remains a mainstay in blind rehabilitation and with systematic and rigorous training, individuals with visual impairment can gain functional independence. Here, we show that the creative use of interactive virtual navigation environments such as AbES combined with other strategies may provide for flexibility adjusting for a person's own needs, strengths and weaknesses to supplement their O&M training curricula.

Of particular note was the robust nature of spatial cognitive information that could be obtained by interacting with AbES the gaming mode. We intended for users to be able to play and enjoy the game and in doing so, learn to navigate their surrounding environment, understand the spatial organization and layout of its spaces, its dimensions and the corresponding objects Key to this approach is the fact that this information is learned implicitly though gaming interactions rather than explicit route learning. As users became more skilled at playing AbES through navigating freely at their own pace, they were in fact laying the foundations for transferring virtual learning to real world navigation. This game mode has been the activity that generated the best results as far as the students' spatial representations (although there was no evidence of significant difference), showing that this kind of interaction requires them to focus on the tasks that they are carrying out. It makes them more attentive careful and resourceful through constant inquisition about the places they are traveling through. They thus obtain more robust information regarding their surroundings translating to better results in the transfer of this knowledge to the real physical world.

Future Work

We continue to investigate the feasibility, effectiveness, and potential benefits of training and learning to navigate unfamiliar environments using virtual auditory-based gaming systems. In parallel, we are also developing methods for quantifying behavioral gains as well as uncovering brain mechanisms associated with navigational skills. A key direction for future research will be to understand what aspects of acquired spatial information are actually transferred from virtual to real environments, and the conditions that promote this transfer. This implies the use of experimental designs in order to clearly determine the impact that the use of this technology has on the development of navigation skills. We further propose that understanding how the brain creates spatial cognitive maps used for navigation and over time, as well as a function of an individual's own experience and motivation will have potentially important repercussions in terms of how rehabilitation is carried out and, ultimately, an individual's overall rehabilitative success.

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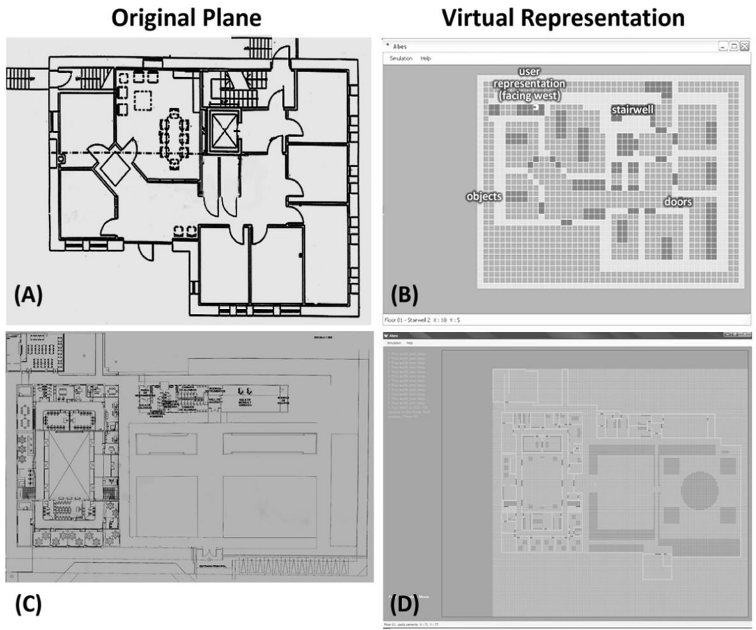

Figure 1.
Real and virtual environments in AbES. (A) The first floor plan of the St. Paul building. (B) Virtual representation of the same floor in AbES showing various objects the user interacts with. (C) Floor plan of the Santa Lucia building. (D) Virtual representation of the first floor of the Santa Lucia building

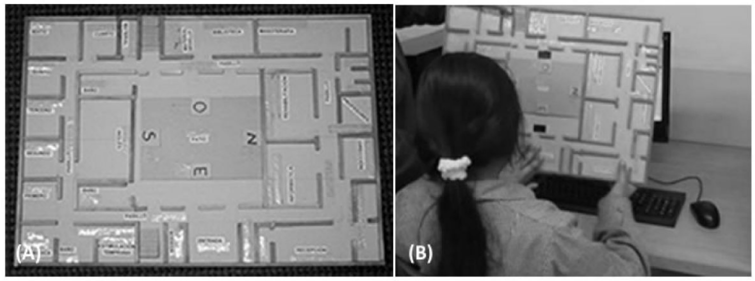

Figure 2.
(A) Tactile model representing the space that the students will travel through virtually using the AbES simulator. (B) Blind participant exploring the model of the real space through touch.

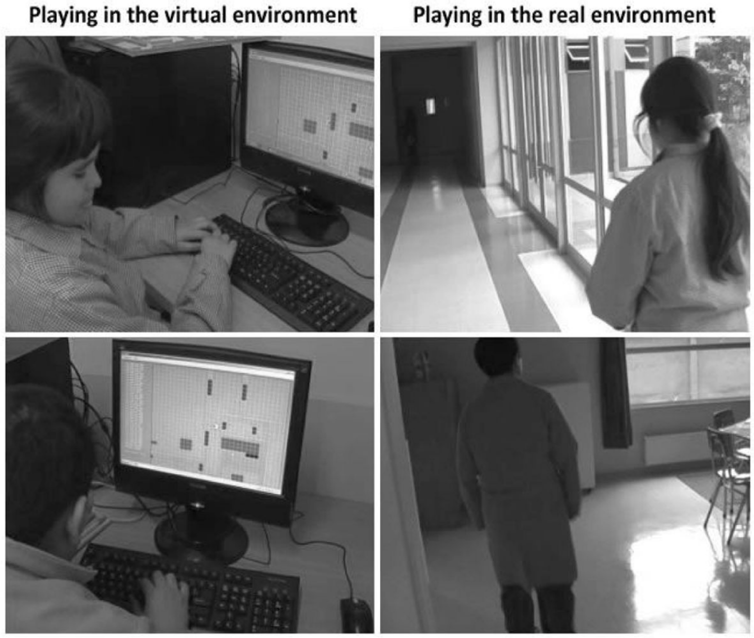

Figure 3.
Students playing to get the jewel in the real environment

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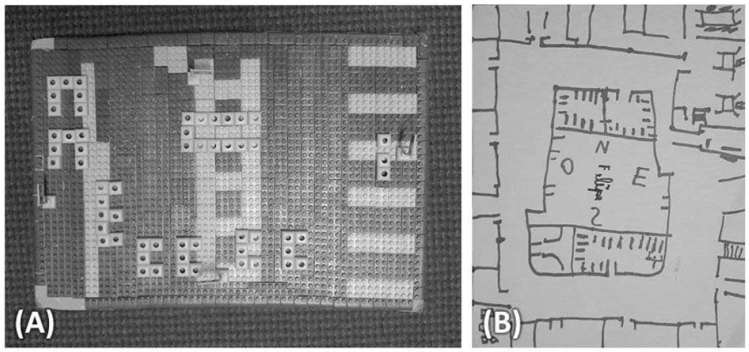

Figure 4.

The students' representations made with concrete material. (A) Representation with Legos® bricks. (B) Drawn representation

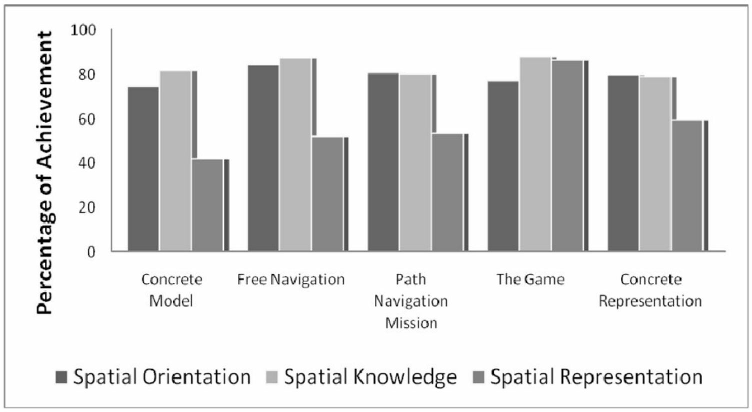

Figure 5.

Graphic shows the results obtained by the students for the three aspects evaluated (Spatial Orientation, Spatial Knowledge and Spatial Representation)

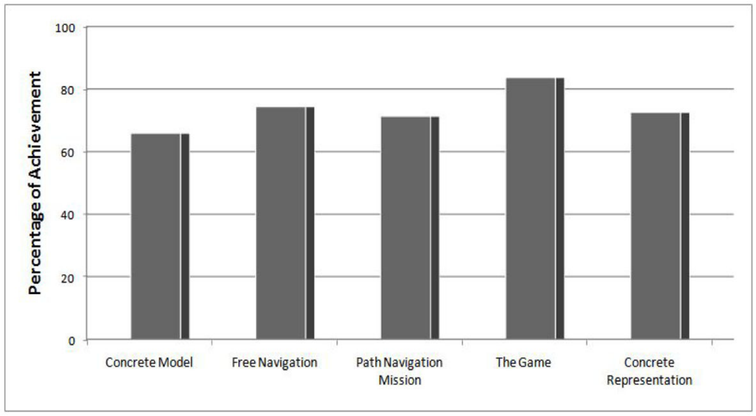

Figure 6.
Total results obtained by the students for each of the activities.