Videogaming for wayfinding skills in children who are blind

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ABSTRACT

There are several problems faced by people who are blind when navigating through unfamiliar spaces, and especially open spaces. One way to mitigate these problems is by getting to know the spaces prior to actual navigation, through the use of virtual environments represented through audio and haptic interfaces. In exploring the possibilities for further improving navigation through such spaces; it was especially interesting to study the option of simulating the real body movement of a learner who is navigating through their own body movements and use of the Wiimote controllers of the Nintendo Wii console in order to navigate through unknown virtual spaces. The results demonstrated a videogame that allows for the development of orientation and mobility skills in learners who are blind, as it serves as a supporting tool for the construction of a mental map of the virtual space navigated through the integration of its audio and haptic components. In addition, learners could transfer the information obtained from virtual to the real world physical space, through which they were then able to navigate autonomously and efficiently.

1. INTRODUCTION

Through virtual environments, people who are blind can become familiar with real-life, unfamiliar, closed spaces before actually physically navigating them. The user’s interaction with these virtual environments can occur through spatialized sound and audio-based interfaces (Sánchez and Elías, 2007; Sánchez et al., 2009, 2010a), and/or through haptic-based interfaces (Sánchez and Espinoza, 2011; Sánchez and Mascaró, 2011; Sánchez et al., 2010). During this interaction, the user receives information from the virtual environment that facilitates his navigation through these spaces in the real world, as the experiences enhance the user’s orientation and mobility (O&M) skills (Lahav and Mioduser, 2008, 2008a; Sánchez and Espinoza, 2011). In addition to this, serious videogames contribute significantly to the development of various cognitive abilities in both sighted and visually impaired learners (Sánchez and Elías, 2007; Sánchez and Espinoza, 2011; Sánchez et al., 2010, 2010a; Yuan, 2009; Yuan and Folmer, 2008).

Based on this, it is relevant to research how the development of O&M skills is fomented in learners who are blind, through a tool that integrates the characteristics of serious videogames and virtual environments. This paper presents the design, implementation and cognitive impact evaluation of an audio and haptic-based videogame called MovaWii, in which a real-life, physical space is virtually represented, and with which learners who are blind interact through their own body movement and use of Wiimote controllers of the Nintendo Wii console in order to navigate through unfamiliar virtual spaces. The objective of this videogame is to develop O&M skills in learners who are blind; supporting the construction of a mental map of the virtual space navigated through the integration of its audio and haptic components, in order to then transfers this information to the real world physical space, where learners are able to perform autonomous and efficient navigation.
2. RELATED WORK

If real-life surroundings are represented through virtual environments, it is possible to create several training applications that allow a user who is blind to interact with the elements in the simulated environment during navigation (Sánchez et al., 2009, 2010a). Videogames, when integrated with virtual training environments, represent an important tool for the development of various abilities, and O&M skills in particular (Squire, 2003; Steinkuehler, 2004). For example, AbES (Sánchez et al., 2009, 2010a) allows the creation of videogames that integrate virtual environments, focused on the mental construction of real and fictitious environments by users who are blind navigating through virtual environments, using the keyboard of a computer in order to execute actions and receive audio feedback to support O&M.

Haptic interfaces have come to represent a significant contribution to the cognitive development of learners who are blind. There is previous evidence from work with interfaces that provide force-feedback by using different technologies, and provide the user with differing haptic sensations, generating a higher degree of realism in the user’s interaction with virtual environments (Sánchez, 2008). Through the use of Novint Falcon and Sensable Phantom haptic devices, a learner who is blind can recognize surfaces, objects and graphics by just using his hands (Lutz, 2006; Sánchez and Espinoza, 2011; Sánchez and Mascaró, 2011; Yu and Brewster, 2002). In this way, the user receives haptic feedback, which allows him to recognize objects, walls and hallways in the virtual environment (Lahav and Mioduser, 2004, 2008, 2008a; Sánchez and Espinoza, 2011; Sánchez and Mascaró, 2011).

It is also possible to allow for a user, either blind or sighted, to interact with a software program or videogame by using the movement of his own body as input, increasing the degree of interactivity and encouraging mobility (Lange et al., 2010). MOVA3D is a videogame in which a real-life, closed space is represented virtually, through which the user navigates by turning around his own axis, over a specially adapted carpet that detects movement (Sánchez et al., 2010).

A simple and low-cost way to detect the user’s movement is to utilize the Wiimote controller of the Nintendo Wii console, and specifically there is evidence of a “finger-tracking” system by using the Wiimote (Williams, 2010). Research has also been done regarding the use of virtual environments that people who are blind can explore by using Nintendo Wii devices, with audio and haptic feedback, facilitating and supporting the construction of cognitive maps and spatial strategies (Evett et al., 2009).

As such, it is relevant to research the development and use of serious videogames based on audio and haptic interfaces that integrate virtual training environments in which users who are blind interact through their own body movement, allowing for the development of O&M skills.

3. MOVAWII VIDEOGAME

MovaWii was proposed based on these interface elements, consisting of the virtual representation of a real-life plaza through audio and haptic interfaces, in which a learner who is blind has the objective of finding a lost jewel by using the Wiimote controllers.

In navigating through a virtual plaza searching for the jewel, the learner must be able to avoid various obstacles in addition to sectors that are off limits. To find the jewel, the player can consult a compass, which indicates in which direction the jewel is located. To change direction, the learner must stand and turn over his own axis to the degree considered necessary, and the game automatically detects the player’s change in direction.

MovaWii was developed using C# language and .NET Framework 4.0, through Microsoft Visual Studio 2010 Ultimate development environment. To integrate the characteristics of the Wiimote controller into the videogame, the WiimoteLib v1.7 library was utilized.

3.1 Design

The videogame virtually represents a real, physical place, through which learners who are blind must navigate in order to find a lost jewel. This real-life, physical place consists of a plaza that is made up of navigable sectors, sectors that are off limits, and obstacles such as trees, playground equipment, light posts and benches. In order to model the virtual environment, two public plazas were used: the Ovalle Plaza in Santiago, Chile, and the Izidor Handler Plaza in Viña del Mar, Chile. These plazas were diagrammed and scaled with their respective components, in order to incorporate them into the videogame. It is important to point out that as part of the videogame’s design the grass was considered as an obstacle (or restricted area), in order to limit the learners’ movements. This allows learners who are blind to navigate only over the graveled and paved paths, as in each of the respective plazas such paths are clearly demarcated.
To navigate through the physical surroundings, a user who has to use the clock orientation system (Sánchez and Elías, 2007), turning around his own axis according to the indications provided by the software. In order to detect the user’s turns, a wireless bar with infrared LEDs was utilized together with a Wiimote controller (see Fig. 1). The Wiimote controller hangs from the ceiling in the room where the software is utilized, so that the infrared detection area is facing downwards. The user must stand directly below the controller, wearing a jacket that has the wireless infrared bar attached to the back. In this way when the user turns, the infrared LEDs turn with him, and the Wiimote controller detects the variation in the position of the infrared LEDs. In order to aid the user in determining the correct position in which it is necessary to stand, a plastic circle was placed on the floor that serves as a guide to demarcate the space where the players must stand in order to be appropriately detected by the Wiimote controller.

In addition the use of a second Wiimote controller was incorporated, which the player holds in his hand and uses like a cane for users who are blind (see Fig. 1). Through the use of two specific buttons (the A and B buttons), the user can consult the compass (obtaining a clue regarding the clock direction to which he must turn in order to find the jewel) and move forward a step in the user’s current direction (direction that is detected by the other Wiimote based on the position of the LEDs). It is important to point out that these actions can only be performed if the learner is holding the Wiimote controller at an angle that is similar to the common use of a cane (at least 45°, between the axis of the body and that of the arm).

3.2 Interfaces

3.2.1 Audio Interface. Consists of a set of iconic sounds associated with the objects and actions performed by the user. Every time the user moves forward, a sound representing a step is heard; similarly, when the player bumps into objects or obstacles, a sound representative of a collision is heard. In order to provide the player with an audio clue regarding the location of the jewel, an alarm sound is used that increases in volume as the players gets closer to the jewel, and decreases in volume as the players moves farther away from it. In addition, there is a component of recorded speech using AT&T’s free web Text-to-Speech engine. These recorded speech phrases are used to indicate to the player the direction in which the jewel is located when he consults the compass. Also, speech was recorded that is used to provide feedback regarding the relative direction in which the player has advanced compared to the previous direction in which the player had moved.

3.2.2 Haptic Interface. This consists of vibration feedback provided by the Wiimote controller that the player holds in his hand, and which acts as a cane for user who is blind. Every time the player bumps into an object, he feels an intermittent vibration in his hand. In addition, when the player moves his hand and no longer holds the controller in the position of the “cane” (at least 45° between the axis of the body and that of the arm).

Figure 1. Hardware montage to interact with the videogame.

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arm), he feels a continuous vibration in his hand in order to alert him that the cane is not in an appropriate position for use.

3.2.3 Graphic Interface. This interface was designed so that a facilitator (an aide who provides on site support during the interaction with the videogame) can observe the player’s location when navigating through the virtual environment. Consists of a bird’s eye view of the virtual space (see Fig. 2), in which it is possible to distinguish the navigable areas (beige colored areas in Fig. 2) and non-navigable areas (all that is not beige in Fig. 2) in the plaza represented by the game, in addition to the user’s position and direction at any given moment (red dot in Fig. 2), as well as the location of the jewel (yellow dot in Fig. 2).

Figure 2. Graphic interface of the videogame.

4. METHODOLOGY

4.1 Sample

The sample was made up of 20 learners (7 female; 13 male), in which 11 of them are between 6 and 8 years old, from the first years of primary school at the Santa Lucia Educational Center in the city of Santiago de Chile. The 9 remaining users are between 9 and 15 years old, from primary school at the Antonio Vicente Mosquete Institute in the city of Viña del Mar, Chile. Among the total sample, 4 learners are totally blind and 16 possess residual vision. All of them are legally blind.

4.2 Instruments

4.2.1 Evaluation Guidelines for O&M Skills. This is an evaluation instrument that serves for gathering data and the collection of information regarding O&M skills. This Evaluation Guidelines was utilized as both a pretest and posttest during the study, and is made up of 5 dimensions: Sensory-Perceptual Development, Psychomotor Development, Development of Techniques without Mobility Aides, Development of Initial Cane Techniques, and Development of Concepts. In order to evaluate these dimensions, 40 items were evaluated on a scale from 0 to 2, in which 0 implies that the item was not achieved (NA), or that the learner was unable to perform the requested behavior; a value of 1 corresponds to an item in process (IP), or that the behavior requested of the learner was inconsistent; and a value of 2 corresponds to an achieved item (A), which implies that the learner performed the requested behavior successfully.

The dimensions measured by the Evaluation Guidelines for O&M Skills are:

- **Sensory-Perceptual Development**, made up of the sub-dimensions Audio Sensory-Perceptual Development and Tactile Kinesthetic Sensory-Perceptual Development. These dimensions allowed the researchers to measure the development of audio senses (audio recognition and discrimination, origin of sounds, direction and following of sounds) and tactile senses (recognition of textures, perception of obstacles).
- **Psychomotor Development.** This dimension allowed researchers to measure motor activities regarding O&M, in addition to navigation through real and virtual spaces.
- **Development of Techniques without Mobility Aides.** This dimension allowed researchers to measure the use of information that can be extracted autonomously from the environment, and which depends on the user’s own behavior and the way in which the information is used for mobility.

- **Development of Initial Cane Techniques.** This dimension allowed researchers to measure the learners’ skills in using the mobility cane as an aide for navigating through open or closed, real or virtual environments.

- **Development of Concepts, made up of the sub-dimensions Development of Geometric Concepts, Development of Spatial Concepts, Development of Environmental Concepts and Development of Temporal Concepts.** These dimensions allowed the researchers to measure the conceptualization of parameters and concepts needed to attend to and understand instructions, actions and situations within the virtual environment, and later in the real-life environment.

4.2.2 *Questionnaire.* This is an evaluation instrument made up of five questions: 1) What did you like about today’s activities?, 2) What did you NOT like about today’s activities?, 3) What was difficult for you to do? Why?, 4) What was easy for you to do? Why?, 5) What did you learn today? The criteria considered for the construction of these questions were: satisfaction with the intervention, which is related to questions 1 and 2; complexity of the intervention, which is related to questions 3 and 4; and learning from the intervention, which is related to question 5.

This questionnaire was administered after each cognitive task solved by the user, by reading the questions to them and recording their responses. The purpose of this instrument was to collect the learners’ opinions regarding their experience with the videogame interfaces.

4.2.3 *Evaluation Guideline for Transfer to the Real World Environment.* This is an instrument to support the observation of the activity designed to transfer what was achieved in the virtual experience to the real world environment. In this guideline, the same dimensions from the Evaluation Guidelines for O&M skills were used. However, this guideline is made up of some additional items (44 in total), which were used to evaluate these dimensions on a scale of 0 to 2 points, in which the values for 0, 1 and 2 correspond to the same criteria described in the Evaluation Guidelines for O&M Skills.

This guideline was administered during the observation of the video recordings that were made of all the movements made by each participating user in the corresponding plaza, according to the version of the videogame that they worked with. The *Evaluation Guideline for Transfer to the Real World Environment* served to demonstrate the transfer of the lessons and tasks learned by the users during the virtual interaction with the videogame to their navigation through the real plaza.

4.3 *Procedure*

Before the intervention with the videogame, the *Evaluation Guidelines for O&M Skills* instrument was administered in order to learn of the initial state of each user’s O&M skills. Afterwards, two training tasks were performed during independent work sessions in which each task lasted 45 minutes per learner. In the first training task, the objective was to incorporate the clock orientation system, which is a metaphor utilized within the O&M training skills, and which consists of situating the user within an analogue clock so that directions are associated with the position of the hour hands in which the user turns (see Fig. 3). In this way, if it is desired that the learner move to the right, he is instructed to “turn to 3 o’clock”; if the user is to turn left, he is instructed to “turn to 9 o’clock”; and if it is desired that the user moves backwards, he is instructed to “turn to 6 o’clock”.

In the second training task the users interacted with the hardware devices, specifically on exploring and utilizing the Wiimote controller buttons associated with certain actions in the virtual environment. Based on these tasks, an experimental laboratory was implemented in a room, consisting of a laptop computer, two Wiimote controller devices and speakers.

Once the training tasks were performed, the learners performed seven cognitive tasks through the use of the videogame, during seven different 45-minute sessions. Once each of these tasks had been completed, the questionnaire was administered to each learner.

Cognitive tasks 1 and 2 corresponded to the perception of and relation to iconic elements. These tasks consisted of the learners relating the audio and haptic stimuli to actions and/or elements that make up part of the interaction within the videogame, in addition to the use of these clues for moving about through the virtual space. Cognitive tasks 3 and 4 corresponded to the dynamics of the interaction with the videogame. The objective of these tasks was for the learners to establish a temporal-spatial structuring of the virtual environment, and to determine the distances within the virtual plaza regarding the elements that they encounter while navigating.
Cognitive tasks 5, 6 and 7 correspond to navigation activities and the representation of the navigated environments. These tasks were based on the work performed during tasks 1, 2, 3 and 4, with the objective of integrating this knowledge into the planning of navigational routes. After each task, the learners had to represent a mental map of the virtually navigated plaza by using concrete materials (legal blocks and play dough). In this way, the facilitator was able to demonstrate the users’ progress regarding their mental constructions of the social environment represented by the videogame.

Afterwards, a work session was performed with the learners in which the O&M skills instrument was administered in order to compare the results obtained before having participated in the intervention with the videogame. In this way, it was possible to evaluate the impact that the videogame had on the users’ navigation through the virtual environment.

After finalizing these tasks with the use of the videogame and the evaluation of its impact on the learners’ navigation through the virtual world, a cognitive task designed for the transfer of the skills learned virtually to the real world environment was applied (see Fig. 4).

![Figure 3. Training activities.](image1)

![Figure 4. Cognitive task for transfer to/from virtual to the real world environment.](image2)

In order to perform this task, the learners were taken to the real world environment corresponding to the plaza that they had navigated virtually in the videogame. Each learner was asked to replicate the movements and routes navigated in the videogame in order to complete the requested missions, according to the mental map of the environment that they had constructed based on their experience interacting with the videogame. Each learner’s experience was filmed, recording all of his movements. Once this activity was completed, the questionnaire was applied to each learner.
Afterwards, each of the video recordings was analyzed in order to identify and describe various practices and behaviors, successful performances and difficulties displayed during the movements through the real plaza. To achieve this, the Evaluation Guideline for Transfer to the Real World Environment was used to support the observation of the recordings. With this information, three main successfully completed tasks were established for each student, as well as the three main tasks that were the most difficult for each learner.

5. RESULTS

The criteria considered for the construction of the questionnaire were translated into three categories (Satisfaction, Complexity and Learning), used to classify the users’ opinions after having performed the Cognitive Tasks. As such, 17 common themes were identified among the opinions, which can be associated with the 3 categories for the classification (see Table 1).

<table>
<thead>
<tr>
<th>Themes</th>
<th>Satisfaction [%]</th>
<th>Complexity [%]</th>
<th>Learning [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looking for the Jewel</td>
<td>48.1</td>
<td>9.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Finding the Jewel</td>
<td>18.6</td>
<td>0.0</td>
<td>3.8</td>
</tr>
<tr>
<td>Losing</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Using the Cane</td>
<td>0.0</td>
<td>1.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Turning</td>
<td>17.1</td>
<td>19.3</td>
<td>11.4</td>
</tr>
<tr>
<td>Hours on the Clock</td>
<td>37.2</td>
<td>25.7</td>
<td>29.2</td>
</tr>
<tr>
<td>Walking</td>
<td>6.2</td>
<td>12.8</td>
<td>10.2</td>
</tr>
<tr>
<td>Cardinal Directions</td>
<td>12.4</td>
<td>9.6</td>
<td>54.6</td>
</tr>
<tr>
<td>Technology (WiiMote, jacket)</td>
<td>31.0</td>
<td>10.7</td>
<td>11.4</td>
</tr>
<tr>
<td>Playing MovaWii</td>
<td>27.9</td>
<td>0.0</td>
<td>6.4</td>
</tr>
<tr>
<td>Everything</td>
<td>7.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Nothing</td>
<td>1.6</td>
<td>17.1</td>
<td>3.8</td>
</tr>
<tr>
<td>Representing the Map</td>
<td>7.8</td>
<td>0.0</td>
<td>12.7</td>
</tr>
<tr>
<td>Bumping into Objects</td>
<td>14.0</td>
<td>5.4</td>
<td>3.8</td>
</tr>
<tr>
<td>Numbers</td>
<td>3.1</td>
<td>2.1</td>
<td>7.6</td>
</tr>
<tr>
<td>Sounds</td>
<td>6.2</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Use of the Compass</td>
<td>0.0</td>
<td>1.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

The students demonstrated great satisfaction with the activities in the videogame, especially looking for the jewel, which is the object used to represent achieving the goal of the videogame (48.1%). Other significant themes for which satisfaction was expressed was the use of the hour hands of the clock as a means for developing the cognitive tasks (37.2%), and the use of the various technologies included in the initiative, such as the Wiimote used as a cane, the jacket with the infrared LED bar, and the use of the buttons on the Wiimote to make decisions (31.0%).

Regarding the elements that were complicated to use (Complexity), the learners displayed a lack of knowledge regarding the hours on the analogue clock (25.7%). As such, the action of “turning” was the second most difficult aspect (19.3%). These two aspects are directly related to the way of using the clock system as a mechanism for spatial location and orientation. The opinion that “nothing” caused any difficulties was expressed in 17.1% of the opinions.

Finally, in the category related to learning, the users valued a set of elements learned throughout the cognitive tasks performed in the intervention. One of these elements corresponds to the cardinal directions (54.6%), which are related to the possibility of identifying North, South, East and West as references for playing the game and navigating when walking. This theme is followed by learning the Hours of the Clock (29.2%), which is related to the use of the clock system for O&M. Finally, there is “Representation of the Map” (12.7%), which corresponds to the capacity to transfer the actions performed in the virtual environment to a physical representation of the desired navigation.

On the other hand, the results obtained from the pretest and posttest, were analyzed using a T-Student test for related samples, for each of the dimensions contained in the instrument utilized (see Table 2).
In comparing the averages obtained for the pretest and the posttest in the differing dimensions analyzed, it was found that the Audio Sensory-Perceptual Development \( (t=-3.322, p<0.05) \), Technique Without Mobility Aides \( (t=-4.841, p<0.05) \), Initial Cane Techniques \( (t=-2.629, p<0.05) \), Geometric Concepts \( (t=-3.337, p<0.05) \), Spatial Concepts \( (t=-3.488, p<0.05) \), Environmental Concepts \( (t=-3.107, p<0.05) \) and Temporal Concepts \( (t=-2.517, p<0.05) \) dimensions presented statistically significant differences, displaying in all cases an increase in the average obtained on the posttest compared to the pretest.

For the Tactile Kinesthetic Sensory-Perceptual Development and Psychomotor Development dimensions, no statistically significant differences were found between the pretest and posttest.

In performing a global analysis regarding O&M skills, an increase in the average of the posttest was found compared to the pretest for the Global O&M Skills indicator \( (t=-5.697, p<0.05) \), and this difference was found to be statistically significant.

The increases in the indicators for which the differences are statistically significant, show that the videogame and its associated activities have an effect on O&M skills.

### Table 2. Summary of the statistical T-Student test results

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Mean pretest</th>
<th>Mean posttest</th>
<th>T</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audio Sensory-Perceptual Development</td>
<td>1.667</td>
<td>1.883</td>
<td>-3.322</td>
<td>.004</td>
</tr>
<tr>
<td>Tactile Kinesthetic Sensory-Perceptual Development</td>
<td>1.825</td>
<td>1.800</td>
<td>.252</td>
<td>.804</td>
</tr>
<tr>
<td>Psychomotor Development</td>
<td>1.900</td>
<td>1.936</td>
<td>-.925</td>
<td>.367</td>
</tr>
<tr>
<td>Development of Techniques Without Mobility Aides</td>
<td>1.280</td>
<td>1.590</td>
<td>-4.841</td>
<td>.000</td>
</tr>
<tr>
<td>Development of Initial Cane Techniques</td>
<td>1.175</td>
<td>1.575</td>
<td>-2.629</td>
<td>.017</td>
</tr>
<tr>
<td>Development of Geometric Concepts</td>
<td>1.463</td>
<td>1.738</td>
<td>-3.337</td>
<td>.003</td>
</tr>
<tr>
<td>Development of Spatial Concepts</td>
<td>1.530</td>
<td>1.750</td>
<td>-3.488</td>
<td>.002</td>
</tr>
<tr>
<td>Development of Environmental Concepts</td>
<td>1.733</td>
<td>2.000</td>
<td>-3.107</td>
<td>.006</td>
</tr>
<tr>
<td>Development of Temporal Concepts</td>
<td>1.850</td>
<td>1.933</td>
<td>-2.517</td>
<td>.021</td>
</tr>
<tr>
<td>Global O&amp;M Skills</td>
<td>1.602</td>
<td>1.801</td>
<td>-5.697</td>
<td>.000</td>
</tr>
</tbody>
</table>

Based on the statistical results, a more in-depth analysis of the dimensions for which the increases were statistically significant was performed, incorporating the analysis of the video recordings and the data obtained from the evaluation guidelines for transfer from the virtual to the real world environment. The analysis of the video recordings was performed in accordance with two criteria: the performances achieved, or those that the learners executed successfully; and the less-achieved performances, or those that the learners did not perform adequately.

In the Audio Sensory-Perceptual Development dimension, the results of the statistical analysis indicated that throughout the experience with the use of the interfaces defined for the intervention, aspects such as following, direction and discrimination of sounds were improved among the participating students. The analysis of the video recordings showed a transfer of audio sensory-perceptual aspects in the learners’ performances during the experience navigating through the real-world plaza, which obtained a 23.5% frequency among the most achieved performances.

The Development of Techniques Without Mobility Aides dimension, which corresponds to the skills that learners use to turn and walk in different directions using the clock system (which is to say, locating and orienting oneself using the hour hands on a clock as a reference), increased significantly after the interaction with the interfaces included in the intervention experience. During the cognitive task for transfer to the real world environment, it was observed that the learners showed some difficulties in performing turns (19.3% of the performances less-achieved). However, the students pointed to a high degree of learning regarding the Cardinal Directions and their use as a means of orientation. This learning emerged as a process of reconceptualization of the use of the 12:00, 3:00, 6:00 and 9:00 hour hand positions as points of reference for North, East, South and West, respectively.

For the Development of Initial Cane Techniques dimension, the statistical analysis showed that the interaction with the interfaces included in the intervention allowed learners to develop and/or improve skills for the use of the cane as a means of mobility. In this way, aspects such as the handle, the position of the arm, movement, navigating and tracking displayed significant progress after having participated in the experience with the videogame. During the cognitive task for transfer from virtual to the real world environment
performed by the learners, it was observed that the use of the cane as a means of tracking and navigating reached a frequency of 11.8% among the most-achieved performances.

Regarding the Concepts Development dimension, the statistical analysis related to the sub-dimension for the Development of Spatial Concepts showed an improvement in the learners’ abilities to use the cardinal directions and those related to forward, back, sideways and oblique as references for orientation and navigation. In addition, the results regarding the Development of Geometric Concepts sub-dimension showed an improvement in the learners, related to the comprehension of that which is vertical, horizontal, a curved line, an oblique line, a straight line, a circle, a square and a triangle. Finally, the results related to the Development of Environmental Concepts sub-dimension showed an improvement in the learners regarding the connection of being positioned either along the edge of the environment or in the center, in addition to being able to calculate distances. During the performance of the cognitive tasks for the transfer from the virtual to the real world environment, a higher degree of difficulty was observed related to the transfer of concepts, and especially environmental and some geometric concepts, reaching a frequency of 17.9% of the least achieved performances.

6. CONCLUSIONS

The results demonstrated the creation of a videogame that allows for the development of O&M skills in learners who are blind, in serving as a supportive tool for the construction of a mental map of a virtually navigated space through the integration of its audio and haptic components. In addition, the learners were able to transfer the information obtained for use in the real world environment, where they were able to navigate autonomously and efficiently.

The results obtained regarding O&M skills in users who are blind demonstrated the positive impact of the videogame on such skills. The most significant increases were presented in the Development of Techniques without Mobility Aides dimension, and in the Development of Spatial Concepts sub-dimension. At the beginning of the intervention, these dimensions presented high degrees of difficulty, as they included indicators that required the learning of new content provided by the videogame. The increase in the Spatial Concepts sub-dimension was a result of the hardware support that the videogame provided to the users regarding the ability to establish their positions in space using their own corporality, and understanding that their movements generate changes in space. These changes are manageable and modifiable according to their own spatial needs, directly influencing the orientation that the learners chose when navigating the virtual environment in order to develop each of the requested activities, and to eventually achieve the objective of finding the elements that had been placed within the environment.

Regarding the Tactile Kinesthetic Sensory-Perceptual Development sub-dimension, it is possible to affirm that although the incorporation of hardware elements allowed learners to work on behavior related to this dimension, it is necessary to utilize more training time for such skills based on the establishment and integration of the icons proposed to represent a variety of textures, sensations and shapes of the elements present in the virtual environment.

In relation to the development of psychomotor skills in the learners, the limits of the system (based on its abstract components) made it partially more difficult for the user to be able to integrate the necessary behavior into the experience. The majority of the users were more focused on achieving the actions than the way in which they used their bodies and related psychomotor behaviors, and especially those regarding laterality, which were necessary in order to understand the process that they were participating in.

Finally, regarding the interaction and level of acceptance of the proposed software and hardware that the learners displayed, the majority of the students did not express any discomfort or discontent with the system. In fact, the use of the Wiimote device ended up being a motivating element, in relating it with the use of the cane and in understanding that through this device it was feasible to generate an interaction with the videogame through actions geared towards achieving the proposed objectives of the game. Such actions include generating navigation routes that made it possible to find the hidden jewel in the virtual environment. In the same way, it is necessary to mention that a more prolonged work process with the device would make it possible to use as a cane prototype, given that it was used more as a joystick than as a cane during the observed intervention experiences.

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7. REFERENCES


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