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Audio Haptic Videogaming for Developing Wayfinding Skills in Learners Who are Blind

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Abstract

Interactive digital technologies are currently being developed as a novel tool for education and skill development. Audiopolis is an audio and haptic based videogame designed for developing orientation and mobility (O&M) skills in people who are blind. We have evaluated the cognitive impact of videogame play on O&M skills by assessing performance on a series of behavioral tasks carried out in both indoor and outdoor virtual spaces. Our results demonstrate that the use of Audiopolis had a positive impact on the development and use of O&M skills in school-aged learners who are blind. The impact of audio and haptic information on learning is also discussed.

Author Keywords

Haptic and Audio Interfaces; Orientation; Mobility; Navigation; People Who Are Blind

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI); Miscellaneous

General Terms

Human Factors; Design; Measurement

INTRODUCTION

The demand for innovative teaching and learning approaches has called for focused scientific research in the use of spatial audio and haptic interfaces as a means to facilitate teaching and the promotion of skill development. In particular, these technological approaches have been shown to provide both useful and contextual information needed for correct navigation and independent mobility in daily school-life contexts [8, 9, 10, 19, 20, 21]. In this direction, we aimed to develop a novel approach to allow for the development of skills/senses so that people with visual disabilities can determine their own position in the space and understand their relationship with objects that are within that space.

To orient in a certain environment and move through it efficiently and independently requires developing basic cognition, psychomotor and emotional prequisites, including perception, attention and concentration, coding, memory, and others [2, 5].

The purpose of this research was to evaluate the impact of an audio and haptic-based videogame designed to promote the development and use of orientation and mobility (O&M) skills in both indoor and outdoor spaces by learners who are blind. The study is unique in combining and integrating interfaces based on audio + haptics for developing O&M skills. There are some studies for developing O&M skills based on just audio and other few studies based on just haptics, but the novel point of our study is the large scale and complexity of the outdoor virtual environment explored. This has not been done in previous studies.

The videogame, Audiopolis [21], requires a user to explore a fictitious environment that contains places habitually navigated by learners who are blind during their school day as well as typically prohibited places that do not include key indications needed for safe navigation. We can state that the most novel aspect of Audiopolis is the combination and integration of audio and tactile information for the purposes of exploration and navigation.

Our previous studies concentrated on audio videogaming for cognition in the blind [13][19]. Basically studies on spatial audio and the development of cognitive skills in the blind such as navigation, problem solving, memory, tempo-spatial skills. Few existing games focus on audio or haptics for this purpose, almost none of them focus on audio and haptics combined and integrated.

RELATED WORK

Orientation and mobility Problems

The ability to understand the environment, to recognize the space and relationship with other objects evolves from day to day. However, to avoid risk and to move about safely, people who are blind will typically follow the perimeter of an environment rather than move through the middle of a room. While effective, this way of exploring the environment can lead users to generate inefficient solutions to their navigational challenges [7]. It is easier for them to navigate a route by following the wall, find access points more easily, and derive a route that they would not otherwise use if moving through other spaces [8]. When a user who is blind has more time to explore and dedicate time to familiarizing themselves with an environment, they can dedicate more time to capturing relevant descriptions used to identify details that would allow for a more precise level of navigation [8].

In this navigation process, some authors such as Mazzaro [12] highlight some stages to follow to facilitate O&M in people who are blind: perception, that allows the user to perceive the information from the environment from the sensory channels; analysis, concerning the organization of the perceived information according to different degrees of confidence and familiarity; selection, to determine what information is more important to meet a navigation need in a certain moment; planning, refers to an action plan for an adequate navigation and considers the previous stages; and execution, that implies executing an action plan to navigate.

It takes that some spatial concepts are constructed by the person who is blind so he can move from one point to another safely. Masi (2003) [11] highlights the concepts of body space, action space, objects space, geometric space, and abstract space. Still, according to the same author, the child who is blind has difficulties to build spatial concepts, which interferes directly in his orientation and mobility.

Based on these issues, it is essential to establish an accurate mental map of a space in order to generate efficient O&M skills, even involuntarily. It is well known that most of the information required to form such a mental representation is generally obtained through visual channels [10, 17]. In contrast, users who are blind must rely on other sensory channels such as audio and tactile information, in addition to other strategies for efficient exploration and navigation [9, 13].

Golledge (1999) [5] use the term cognitive maps to refer to the internal spatial representation of environmental information. He discusses the relationship between cognitive maps, the actual process of cognitive mapping, the internal handling of information in the form of spatial choice and decision making, and people's actions with regard to the spatial orientation through simple and complex environments.

Lahav & Mioduser [8, 9, 10] have studied the relation between the mental representations of space generated by users who are blind through the use of virtual environments with haptic interfaces as well as the transfer of such representations to the real world. To achieve this, they utilized a virtual environment similar to a real-world environment that users who are blind habitually navigate to train them to improve their real-life navigation skills. Similarly, Merabet et al. [13] have researched the construction of mental maps and the improvement of O&M skills through the training of learners using audio-based virtual environments.

Audio and Haptic-based Videogames

AudioLink [19] is an audio-based videogame that was designed and developed to investigate the use of videogames for the development of problem solving and O&M skills.

Terraformers [24] is a videogame for players with low vision that uses high contrast 3D graphics and spatialized sound. This game was developed to test the use of such tools and to replicate experiences in other areas such as virtual reality, e-commerce and distance learning.

The videogame Access Invaders allows users who are blind to play a version of the classic Space Invaders arcade game [6]. The design takes the mental model of users who are blind into account and allows them to play together with other users (users who are blind or users who are sighted) online through a graphic and audio interface. The main objective of the study was to make areas of technology that are often inaccessible to certain people (such as the people who are blind) more accessible.

The Tactile Interactive Multimedia (TIM) project [1] is an effort to develop editing software in order to create videogames for people who are blind. This software allows designers to define the interaction that the user will have with the videogame and the interfaces that will be utilized. Some aspects that the editor strengthens are the temporal elements of the sound, the association between objects, and the sense of spatiality. One of the videogames designed with TIM is X-Tunes [3]. This game allows players who are blind to compete in various tasks such as musical composition, recording, sound manipulation and creating collections of sounds. Another videogame is Tim's Journey [3], which allows users who are blind to navigate through virtual spaces defined by specific sounds, stimulating spatial representation.

Finger Dance [14] is an audio-based videogame that allows a user who is blind to develop temporal skills through sound sequences that must be synchronized with other audio beats in order to achieve the highest possible score.

Finally, Audio-based Environment Simulator (AbES) has been developed to train and improve O&M skills in learners who are blind, promoting the construction of mental maps of indoor real spaces. In this software, two modes of interaction are highlighted. Specifically, there is a mode using directed navigation through different points in the virtual environment (with the help of a facilitator), and a videogame mode that allows for self-exploration and navigation while interacting with solving activities and tasks [13].

Haptic interfaces have also been developed to contribute to the cognitive development of learners who are blind. Interfaces include virtual reality gloves, vibrating joysticks, the Phantom Omni and the Novint Falcon. Georgios and his team [4] developed an interactive virtual reality tool by integrating the Phantom Omni and CyberGrasp (virtual reality glove), allowing users who are blind to study and interact with various virtual objects specially designed for this purpose. These devices also allow for the development of cognitive abilities [23], content specific learning [18] and writing skills [16].

Devices such as the Phantom Omni and the Novint Falcon provide a high level of feedback during interactions with virtual objects. With these devices, surfaces, objects and graphics can be represented and recognized by users who are blind through the unique haptic information that is transmitted [15, 20, 21, 22, 25]. Another use of these devices is the representation of virtual spaces for training users who are blind to navigate with more autonomy [20, 21, 22]. With both the Phantom Omni and the Novint Falcon, the user receives haptic feedback from the virtual environment so as to recognize objects, walls and hallways allowing for the generation of a mental map of the space that has been navigated [9, 10, 20].

AUDIOPOLIS

The Audiopolis videogame was designed to represent in principle any urban environment for navigation by learners who are blind. This environment can be real or fictitious, being relevant that a person who is blind can experience the space to better understand it. Various elements and co-experiencing components of a city can be included in the environment such as streets, opens spaces, and buildings. In Audiopolis, a bank, museum, jewelry store, hospital, restaurant, shops, city hall, parks, plazas, library, bookstore, school, university, hotel, supermarket, houses, apartment and office buildings can all be included in the virtual environment.

The videogame is played from a first person perspective. The user can move freely throughout the environment, including forward, backward and turning left and right. The user recognizes the various surfaces through which he or she is traveling either through audio or haptic feedback, as well as the various obstacles while moving through the virtual city. Through virtual exploration, the user can familiarize themselves with the entire map and established routes. Basically, the user had to solve problems and answer some questions.

Turn angles of 30 degrees were defined as well as a standard length of each step taken as the user moves through the environment.

The game consists of 3 different levels of difficulty: easy, medium and advanced. These different levels are determined by the level of geographic complexity of the corresponding virtual city. In order to do this, the city was divided into three sectors. Level 1 considers tasks in sector 1. Level 2 considers tasks in sectors 1 and 2. Finally, level 3 considers tasks in sectors 1, 2 and 3 (see Figure 1). Each level implies a gradual and more difficult level of spatial information, presenting streets with different addresses and having available a wider number of buildings to explore.

For each level, the map of the city expands out on four sides, leaving more free space for the player to move about. In addition, the map integrates new elements that increase the level of complexity as the user moves through the environment.

There are 3 stages within each level. In each stage, a thief steals an object and the goal of the game is to find the thief. In each stage, the player begins at the scene of the crime and must find 3 different places within the city while “chasing” the thief. The player must also solve a series of questions that are presented in order to receive the next clue and continue moving throughout the city. Once the stolen object has been found, the player passes on to the next stage.

To execute the game, a user needs a standard desktop PC or notebook running the Microsoft Windows XP operating system, the Novint Falcon haptic device, and a pair of speakers or headphones.

Interfaces

The videogame possesses 3 interface options for interaction (haptic, audio, and haptic plus audio) which operate in combination with the graphic interface. The latter graphic interface is designed for use by the facilitators that support the experiment.

Audio Interface—This interface has two main modes; environmental and instructive. The environmental component consists of a set of sounds that simulate both the indoor and outdoor environments in which the player is located. It also serves to provide information that allows learners to recognize the shapes of different geometric objects. The environmental component corresponds to sound associated to a location, and its intensity depends of the position and orientation in the game. Iconic sounds and spatial localization were used. The instructive component is made up of the questions that provide clues and the instructions from the main menu, such as: “quit”, “save game”, etc. In addition, during the game the player can query his or her current position, or ask for the direction in which he or she is facing. All of this is answered through the audio interface.

Haptic Interface—The Novint Falcon device was used as a haptic-based force-feedback interface. With this device, we sought to simulate haptic information that could be obtained through direct touch (i.e. with the hands) and indirect touch (i.e. with a cane). The force feedback generated by the Falcon provides information regarding the physical characteristics of the place where the user is located. As the player moves about through the city (by pressing the arrow keys on the device and by dragging the cane on the floor to feel different textures that signal different paths), the user can find his or her way on a route with different levels. The player can also identify objects (e.g. a cube) by exploring their shape using the device. In this case, an object is modeled in 3D and the haptic control simulates a hand.

Haptic and Audio Interface—This interface combines the two previously mentioned sensory inputs in order to provide the user with more robust information regarding position and to provide more ample support for navigation tasks.

Graphic Interface—This interface represents a high contrast rendering of the virtual environment so that the facilitator can observe where and at what point in the game the learner who is blind is located and help the user if necessary (see Figure 2).

COGNITIVE IMPACT EVALUATION

Sample

In selecting the sample, we considered studies of Espinosa et al. (1998), who argue that the spatial knowledge of a person depends on several factors. Among these, the personal characteristics (age, cognitive development, perceptual modality used for encoding spatial information), environment characteristics (size, structure) and factors related to learning processes in relation to spatial information.

The study sample was made up of 12 learners (8 females and 4 males) between 10 and 15 years of age, with special educational needs due to visual impairment (11 learners who are blind and 1 with low vision). All were from within the first or second cycles of General Elementary Education from the Helen Keller School and Santa Lucia Educational Center in Santiago, Chile. The sample was divided into 3 groups of 4 learners and randomized to each of the three possible interfaces of the videogame (audio group, haptic group, and haptic +audio group). These participants, because they study in the same schools, take part of the same methods to teach people who are blind to construct spatial concepts.

Tasks

Three training tasks and 12 cognitive tasks were established. The training tasks were designed to introduce the participants to the concepts and components used in the videogame. The training tasks were: (i) clock technique: to learn heading cues used in the videogame (see Figure 3); (ii) geometric shapes: to develop the interpretation of the shapes used during the interaction with the videogame (see Figure 4); and (iii) the elements of the videogame: to introduce the participant to the integrated use of all the elements involved in the videogame.

The cognitive tasks were focused on developing specific O&M skills based on the software interface. The cognitive tasks were: (i) Level 1: perception and dynamics; (ii) Level 1: movement, directionality and distribution; (iii) Level 1: establishment of distances; (iv) Level 2: perception and dynamics; (v) Level 2: movement, directionality and distribution; (vi) Level 2: establishment of distance; (vii) Level 3: perception and dynamics; (viii) Level 3: movement, directionality and distribution; (ix) Level 3: establishment of distances. Furthermore, the total integration of the game level was scored for (x) game 1; (xi) game 2; and (xii) game 3.

The sequential levels were a progression in complexity of the overall spatial layout of the environment. Each successive level had to be mastered before moving on to the next level. Levels 1, 2, 3 refer to game level. In each cognitive task the percentage of achievement was measured based on the total number of steps to complete a task, which resulted homogeneous all along the tasks and the different interfaces. The two interviews were conducted at the beginning of the study. In each session, the participants went through one game level, one cognitive task.

The objective of the cognitive tasks related to perception of the virtual space through sound, haptics, or both, depending on the interface used. Furthermore, movement, directionality and distribution were promoted through the use of turns connected to the clock system. In this way, users would learn to perceive places and how these places were in spatial relation to one another. In the case of the cognitive tasks regarding the establishment of distances, the purpose was to work on the structuring of Audiopolis and the relation between steps and distance. This means that a higher number of steps implied a longer distance between one place to another.

Instruments

The instruments of evaluation utilized for this research were created by a group of special education teachers who specialize in children who are blind and are integrated members of the research team. These instruments correspond to interviews and O&M tests.

Two interviews were carried out; one in-depth and the other structured. The in-depth interview was applied in order to analyze the O&M difficulties that the subjects faced in their daily lives. In addition, it sought to understand how they perceived the contribution of the audio and haptic-based videogame to the development of their O&M skills. This was determined through statements that were evaluated on an appreciating numeric scale with 4 frequency categories: never, almost never, sometimes, and always. This information was also complemented by a section with open-ended questions. The objective of the structured interview was to understand the perception that the subjects have of themselves regarding their O&M skills and other variables such as their motivation and self-esteem.

The O&M test was designed to estimate the level of knowledge related to this specific area of learning. The dimensions included were: (i) Sensory development (SD) containing 35 indicators which included the sub-dimensions Audio sensory development (ASD) with 12 indicators, and Haptic sensory development (HSD) with 23 indicators, (ii) Tempo-spatial development dimension (TSD) containing 24 indicators, and (iii) O&M Techniques dimension (O&MT) containing 12 indicators, grouping together 71 indicators in total. The evaluation criteria for each indicator were: Achieved (A), In Process (IP), Not Achieved (NA), with scores of 2, 1 and 0, respectively.

Procedure

The procedure involved all of the users in the sample. In addition, two special education teachers specializing in visual impairment played the role of facilitators. These teachers aided the users and recorded their use of the instruments.

The work was carried out in 3 stages: (i) Initiation, before working with the soft-ware; (ii) Process, during the development of the activities using the computer games; (iii) Finish, at the end of the process.

In the phase prior to the use of the software, the O&M test was applied as a pretest in order to record the subjects' initial baseline skills. Interviews were also conducted with the participants. Afterwards, the users performed the 3 training tasks related to the skills that they needed to master before using the videogame.

During the process of the intervention with the videogame, the users performed the 12 cognitive tasks during one session per task (see Figure 5). Each session involved carrying out a series of activities according to the previously described dimensions, and in accordance with the 3 levels of complexity included in the videogame.

Finally in the final stage, the O&M test was applied to the users as a posttest, in order to determine whether or not there was any change on the previously evaluated skills.

RESULTS

Interview

The interview included two sections. In the first section, 5 statements were presented related to O&M in which the participants had to respond using the frequency scale. Their answers to these statements are summarized in Table 1.

The second section included 8 open-ended questions, of which 5 were related to O&M difficulties in daily life and 3 related to the users' perception of the contribution of the videogame to their skills. In general, the users claimed experiencing difficulties in the use of cane techniques. In addition, despite knowing certain techniques, they did not always use them as a problem solving strategy. Regarding the use of their remaining senses, they preferred to use hearing as a first option in order to obtain information from their everyday surroundings. In general, to perform tasks involving independent movement through unfamiliar spaces, they required the support of third parties, which was also the case in familiar spaces when they decided to change their habitual route.

In this way, the users in the sample represented homogenous characteristics in accordance to the results of the interviews.

Training Tasks

The results obtained from the impact tests regarding the 3 training tasks (TT) are summarized in Table 2. According to these results, the participants obtained a satisfactory performance in the training tasks, attaining an average score of over 90%. In general, the positive development of the proposed activities prepared the learners for the application of the cognitive tests during the following stage, and thus fulfilled the objective. In addition, the results of the training tasks are very similar between the different user groups, which imply that the users' initial skill level was homogenous.

Cognitive Tasks

The results obtained from the impact tests through the 12 cognitive tasks (CT) are shown in Table 3.

The results show that throughout the development of the cognitive tasks, the level of achievement remained high and homogeneous, which is important when considering that the degree of complexity increased with each task.

O&M Test

For this test, the entire set of participants was analyzed according to the videogame interface group. The following dimensions and sub-dimensions of the O&M test were analyzed. Each dimension was evaluated through the sum of indicators that contained: Sensory development (SD, min-value=0, max-value =70), which included the sub-dimensions Audio sensory development (ASD, min-value=0, max-value=24) and Haptic sensory development (HSD, min-value=0, max-value=46); also the Tempo-spatial development dimension (TSD, min-value=0, max-value=48), the O&M Techniques dimension (O&MT, min-value=0, max-value=24) and the Global Indicator (min-value=0, max-value =142). The Global is the sum of SD plus TSD and O&MT. The SD dimension is the sum of ASD plus HSD.

In obtaining the results for the 12 users in the sample, a t test was performed to compare the means of the indicators obtained for the pre-test and the post-test of the entire group (see Table 4).

All of the dimensions presented increased in their post-test means com-pared to the pre-test means. However, these differences in the averages were statistically significant only in the ASD dimension (pre-test mean=21.420; post-test mean=23.250; $t=-4.005$; $p<0.05$), HSD dimension (pre-test mean=42.830; post-test mean= 44.500; $t=-3.079$; $p<0.05$), SD dimension (pre-test mean=64.250; post-test mean=67.750; $t=-5.326$; $p<0.05$), O&MT dimension (pre-test mean=16.170; post-test mean=19.080; $t=-2.907$; $p<0.05$) and the Global Indicator (pre-test mean=120.170; post-test mean=132.000; $t=-4.366$; $p<0.05$).

Complementary to this, a MANOVA test was applied to the posttest data, considering the three user groups (audio, haptics and haptic+audio) as factors. According to the MANOVA analysis, the mean vectors for the different groups did not present statistical differences between them. That is, the results for the different dimensions do not differ in function of the interface that defined the groups. It is possible that our study sample size was underpowered to detect such differences.

On this basis, we can infer that in general, the use of the videogame allowed for improving the associated cognitive skills to the dimensions ASD, HSD, SD, O&MT and the Global Indicator. This happens in all the interfaces studied.

DISCUSSION

As we had no true “control” group (ie. a group not playing Audiopolis), it is complex to demonstrate the beneficial effect above and beyond the training procedure. We concentrated on the pre-post assessments. Since we had a baseline of performance, our analysis is essentially a within-group comparison.

Interaction with the Audiopolis videogame led to markedly high performance levels in the users during the training tasks. This denoted a high mastering of the users concerning the concepts and components that the videogame is mainly based.

In relation to the cognitive tasks, it is important to mention that the level of complexity increases from task 1 to task 12. This is mainly due to the ramping up of the map size, producing an increase in difficulty for the activities involved in the tasks.

The virtual environment, as a simulation of a space with urban characteristics, allowed learners to work within a “safe environment”. When performing the search tasks, the learners applied their prior knowledge to test and reinforce previously acquired concepts. In this way, their predisposition to learning was favored by using the videogame. The learners were observed to be highly motivated while performing the various activities.

The learners were also able to create new strategies for solving the problems regarding movement through a virtual space with Audiopolis. Such strategies included going backwards to become reoriented while on a route, circling around different objects, and guiding movements by sound or touch in order to get to know the boundaries of a space. In general, the group of learners displayed an increase in navigational skills by using the videogame, which can be observed through the speed with which they surpassed the various stages, moving through the game with increasing efficiency.

The use of different interfaces in the videogame helped to generate a positive effect on the learning of O&M skills. The statistical results regarding the difference in the means obtained between the pre-test and the post-test of the entire group resulted in an increase that was statistically significant for some dimensions. These dimensions included the Sensory Development dimension (in addition to the Audio Sensory Development and Haptic Sensory Development sub-dimensions), the O&M Techniques dimension, and the Global Indicator of O&M dimension. A second statistical analysis determined that the results did not differ by segmenting each interface group.

The level obtained in pretest indicators can be considered high, if we take into account the maximum possible values. This left a small margin for improvement in posttest indicators consistent with a possible ceiling effect for performance (see Table 4).

Consequently, an increase in the sample of users employed eventually could yield would be needed to validate these findings.

CONCLUSION

The purpose of this research was satisfactorily achieved by evaluating the impact of the use of an audio and haptic-based videogame called Audiopolis on the development and use of O&M skills in both indoor and outdoor spaces. The use of Audiopolis had a positive impact on the development and use of O&M skills in school age learners who are blind. Based on this, it can be initially inferred that the videogame's audio and/or haptic interfaces favor and aid in the development of O&M skills in learners who are blind.

The audio, haptic and combined audio-haptic stimuli aided in generating an in-creased understanding of the participants' senses. It was observed that in order to orient themselves, the users preferred the use of hearing rather than touch.

We designed Audiopolis with both, audio and haptics modes to determine the role that haptics and audio-haptics can play in developing O&M skills. The literature does not inform about robust experiences in this line of research. Haptics is relative new in the development of O&M skills. Perhaps the tactile information provided was not optimal and/or did not supplement the information that could be drawn from audio. There is still a limitation of the type haptics skills we can enhance with the devices available and usable for these end users. Future work will be directed to see what types of information are optimally provided by both audio and tactile and how they can be optimally combined.

The results with the audio interface were better perhaps due to the increased complexity involved in the use of the Novint Falcon device (audio+haptic), versus using the standard keyboard (audio interface), which probably resulted in a better outcome in audio interface.

As future work, it is proposed to increase the sample base in order to investigate potential differences between the distinct interface-groups utilized and to analyze the learning of spatial layout of unknown environments.

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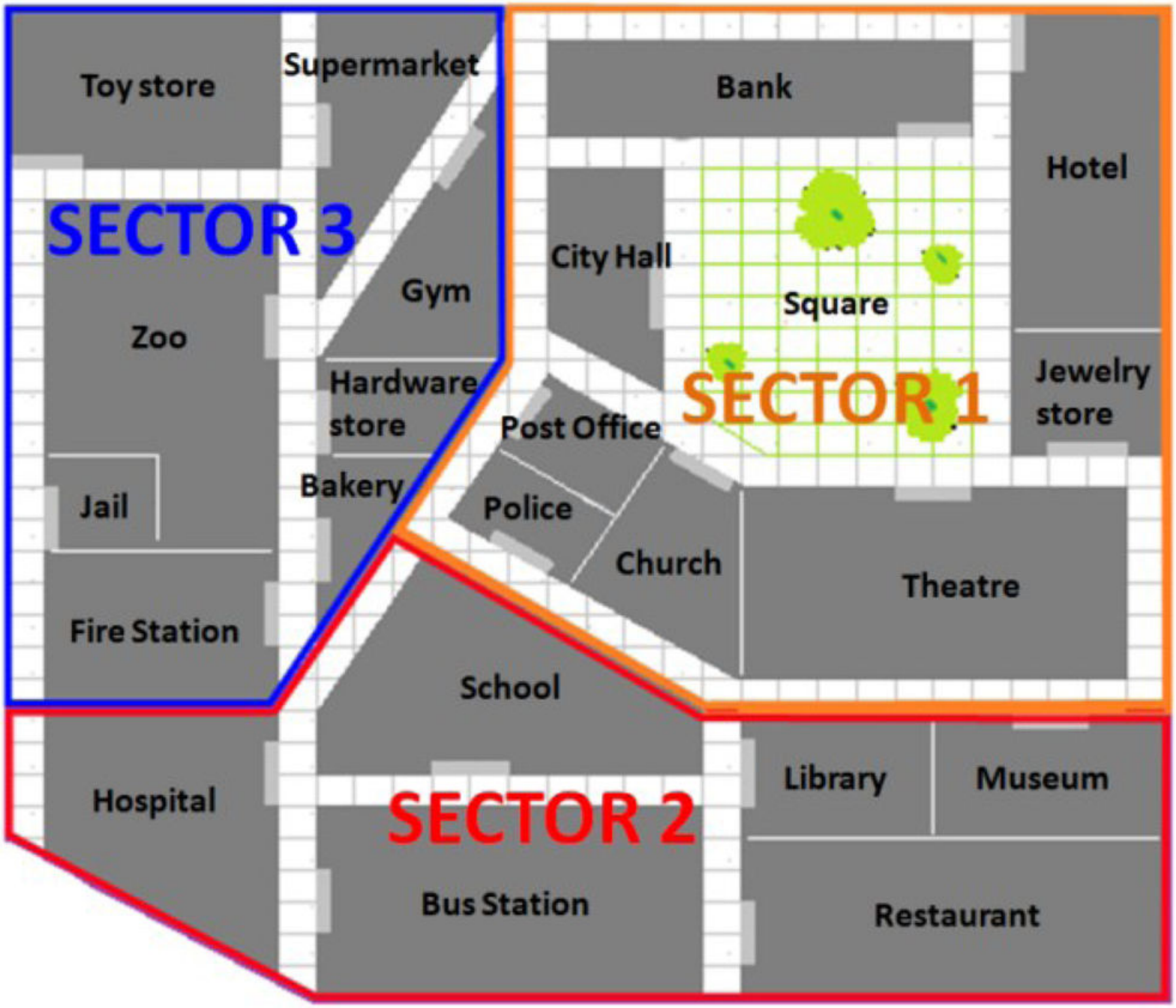

Fig. 1.
Audiopolis level map.

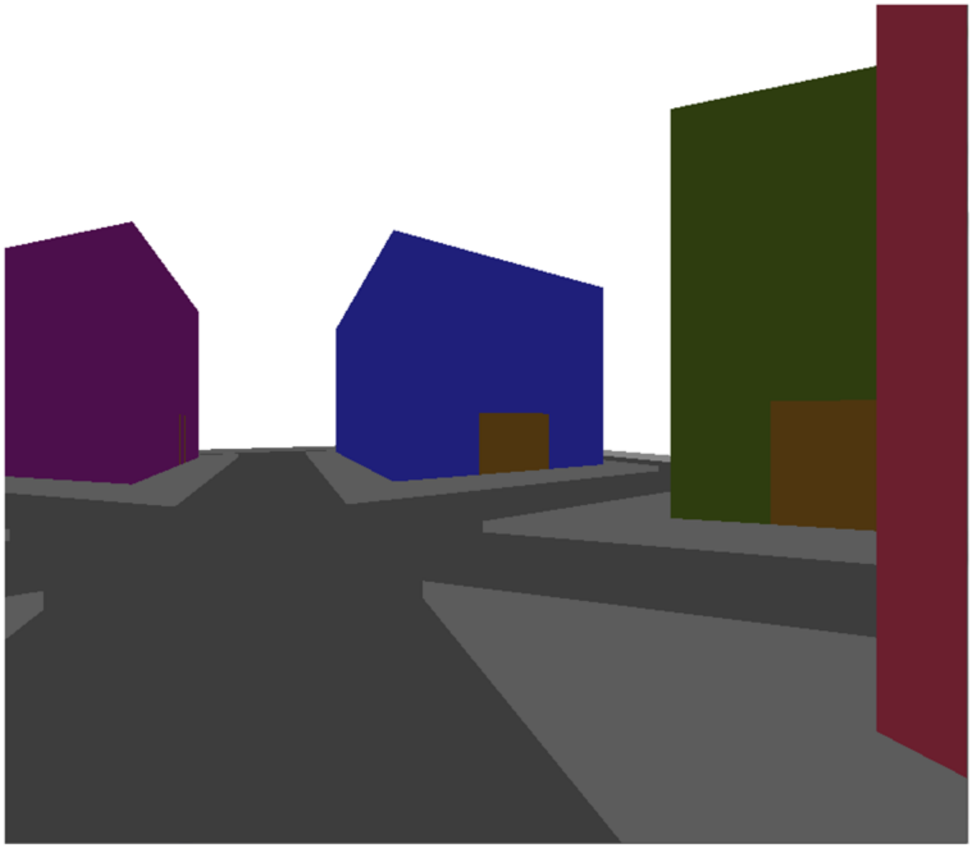

Figure 2.
Graphic interface.

Figure 3.
Training tasks: clock technique.

Figure 4.
Training tasks: geometric shapes.

Fig. 5.
A user performing a cognitive task: playing Audiopolis.

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Table 1

Frequencies of interview responses

Statement	Always	Sometimes	Almost Never	Never
"When I become disoriented, I generally ask for help"	5 (41.67%)	5 (41.67%)	1 (8.33%)	1 (8.33%)
"I like to explore new places"	6 (50%)	4 (33.33%)	1 (8.33%)	1 (8.33%)
"I think that it's important to use O&M techniques to move around"	9 (75%)	2 (16.67%)	0 (0%)	1 (8.33%)
"I try to protect myself if I am in a dangerous situation"	3 (25%)	7 (58.33%)	2 (16.67%)	0 (0%)
"I am attentive to the information that the environment provides me (people, fixed and moving objects)"	6 (50%)	4 (33.33%)	0 (0%)	2 (16.67%)

Table 2

Participant performance in the 3 Training Tasks

N° Training Task	Group 1 Audio [%]	Group 2 Haptic [%]	Group 3 Audio+Haptic [%]	Average [%]
TT 1	91.67	92.19	94.27	92.71
TT 2	93.75	88.22	78.37	86.78
TT 3	90.04	89.31	86.41	88.59

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Table 3

Performance of the entire group in the 12 Cognitive Tasks

N° Cognitive Task	Group 1 Audio [%]	Group 2 Haptic [%]	Group 3 Audio+Haptic [%]	Average [%]
CT 1	82.91	80.54	75.83	79.76
CT 2	81.39	83.77	70.36	78.51
CT 3	83.79	78.76	77.00	79.85
CT 4	84.38	84.21	75.89	81.49
CT 5	86.97	79.88	86.51	84.46
CT 6	84.97	78.88	84.31	82.72
CT 7	87.50	79.02	80.15	82.22
CT 8	89.96	80.86	84.21	85.01
CT 9	79.92	89.86	71.00	80.26
CT 10	74.76	88.86	68.69	77.44
CT 11	86.67	82.34	72.01	80.34
CT 12	82.38	84.38	77.65	81.47

Table 4

T Test Results

Indicator	Pre- test Mean	Post- test Mean	Diff.	t	P
ASD	21.420	23.250	1.833	−4.005	0.002
HSD	42.830	44.500	1.667	−3.079	0.010
SD	64.250	67.750	3.500	−5.326	0.001
TSD	40.080	44.000	3.917	−1.777	0.103
O&MT	16.170	19.080	2.917	−2.907	0.014
Global Indicator	120.170	132.000	11.833	−4.366	0.001