Autonomous Navigation through the City for the Blind

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ABSTRACT

Autonomous navigation in the city has become a necessity for people with visual disabilities, due to the fact that they now enjoy a higher degree of social insertion. As such, several technological solutions seek to assist with this autonomy. In this work, we present a study on the effect of the use of an easy-to-access, audio-based GPS software program on navigation through open spaces, and in particular on the stimulation of orientation and mobility skills in blind people. Results show that the use of the audio-based GPS software allowed blind users to be able to get to various destinations without the need for prior information on the environment, favoring the navigation of blind people in unfamiliar contexts, stimulating the use of different orientation and mobility skills, and finally providing help to users that habitually navigate spaces in the city only in the company of other people.

Categories and Subject Descriptors

K.4.2 [Social Issues] Assistive technologies for person with disabilities

General Terms

Human Factors

Keywords

Mobile technology, People who are blind, assistive technology, orientation and mobility.

1. INTRODUCTION

Navigation is a process inherent to life for all people, and through which we are able to react to and establish relations with different stimuli from the environment, as well as adapt to such stimuli [1].

In navigating through the city, blind people are faced with various obstacles and situations within the urban landscape. Such elements are entirely habitual for most people, but not so for those with difficulties seeing. Often this can create fear for blind people when navigating autonomously, thus affecting their mental representation of the space traveled [3]. Currently, a verbal description of the environment provided by sighted people is the most commonly used aide for blind people to be able to navigate in open spaces [12]. This largely limits safe and independent navigation by blind people both in their homes, in nearby environments and in outdoor spaces [13].

ASSETS'10, October 25 - 27, 2010, Orlando, Florida, USA.

In this way, one of the biggest barriers to overcome for blind people in order to increase their quality of life is the impossibility of navigating freely in open spaces such as the city. This difficulty denies them equal access to certain places, buildings, means of transportation, and even work [9]. For this reason there are some initiatives that seek to provide accessibility for people with visual disabilities, attempting to balance out their general autonomy.

The accessibility project, called GAP (GNOME Accessibility Project) [2] establishes that providing accessibility implies removing barriers that impede disabled people from participating in various social activities. Such activities include the use of services, products and information.

In order to solve blind people's accessibility problems in the context of orientation and mobility, the idea of using navigation-related technology emerges.

Computer technology in support of teaching and learning has traditionally consisted of desktop computers used to access certain learning resources [5]. Currently, concepts such as mobile technology and mobility have emerged, which are strongly connected to new wireless technologies. In general, a mobile worker is conceived of as a person who moves about and executes tasks in any place at any time, using mobile devices with wireless communications technology [14]. New mobile technology devices provide opportunities regarding new kinds of support for the teaching and learning of specific content and cognitive abilities. These devices are starting to make up part of the personal technological resources of every student, with the great advantage of being available at any time and in any place [5],[14],[20].

Basically, technological devices that aid in the orientation and mobility of blind people can be classified into two groups: obstacle detectors and environment locaters [11]. The latter are developed for use in wide open spaces, indicating the path to follow through the use of digital maps that trace appropriate routes and which are supported by techniques based on the use of the Global Positioning System (GPS).

The use of GPS technology has faced numerous problems [23]. One such problem consists of mapping an entire city, which constitutes an additional cost for the user in order to embed the map into the device. Another technical problem is the lack of accuracy of these devices. GPS-induced errors could end up putting a blind user into a dangerous situation, such as standing in the middle of a street while the GPS indicates that he is standing on the sidewalk. In order to eliminate these kinds of errors and to increase accuracy, several different solutions have been implemented, such as adding metering points [22]. As precise accuracy has not yet been achieved, it is safe to say that this problem has not yet been solved, and an additional difficulty arises due to the price increase attached to the solution.

PONTES [16] is a positioning and navigation system for use in an urban environment by blind users. This system is made up of a GPS and a navigational map that contains all the information needed for problem free navigation, including a tracking system for the user. All the information is provided to the user by audio through a specific device at the exact time it is needed. The entire system requires a detailed database that contains information from the navigational map, as well as all the information that would allow for efficient decision-making with regards to navigation.

Along these same lines, a system of audio-based spatial representation called CASBLiP [15] was developed. This system interprets information from different sources, turning them into audio maps translated from real settings. In order to achieve this, the information is picked up by a CMOS (Complementary Metal Oxide Semiconductor) image sensor. Afterwards, the information is transformed into audio when it is sent to an FPGA (Field Programmable Gate Array), thus transforming and transmitting information with spatialized sound from the environment through the use of headphones. This information allows blind people to identify the dimensions of objects distributed in space, and to navigate freely through the environment.

Trekker [6] is a system that uses digital maps to provide information on a route to be followed by a user who is blind. In addition to the actual route, it can also provide contextual information on places of interest near to the user's position on the map. Technologically, the system consists of Bluetooth GPS and a specific handheld device, with which the user interacts through a menu using the button pad on the handheld device. In the same way, the device can be used as a PDA.

Loadstone GPS [10] is an application that operates on a Smartphone Symbian OS. In order to provide information to users who are blind it is necessary to have a handheld device that supports this OS, together with Bluetooth GPS hardware and a TTS engine. Just as with Trekker, users must load digital maps in order to be able to digitally represent the space around them.

Another innovation in the use of GPS-based technology is represented by a device called Kapten [4],[8]. This GPS device does not have a screen and provides information to the user through audio alone. Through the use of voice commands, the user can navigate the different menu options. Unlike the traditional use of GPS, this use of this system is centered on walks or taking bicycle routes. In addition, it includes other applications such as a calendar and MP3 audio file player.

In this way, the efforts to put technology within reach of blind people as tools to improve their quality of life and to provide them with contextual information on their surroundings have become one of the essential objectives for the adaptation of technologies and mobile devices [11].

Based on all that we have described so far, certain questions arise: Can the use of audio-based software stimulate and strengthen navigational skills for users who are blind? Can audio-based software support decision making for a user who is blind during navigation?

It is within such a line of work that this study presents an audio-based GPS software application, and its effect on navigation through open spaces in the city by blind people.

2. DESCRIPTION OF THE AUDIO-BASED GPS SOFTWARE

The software consists of a simple and low cost software and hardware solution that helps blind users to navigate and carry out their daily outdoor mobility tasks in both familiar and/or unfamiliar environments. Basically, the tool consists of an audio-based software application that is integrated into a mobile device, which together with the help of GPS satellites and a GPS device, provides blind users with information in order to be able to orient themselves and navigate through various points of interest in the city.

2.1 Design

During the design of the software, different hardware alternatives and methodologies for presenting the information were studied. The primary hardware used in our study is a small GPS device that includes Bluetooth. During the analysis of different GPS devices available in the market, we sought out one that would be able to satisfy the requirements of the system itself, and that would be appropriate for blind users. The pros and cons of the different alternatives were analyzed.

Finally, we opted for the use of a device that only sends information to another device, but does not interpret that information. This is because such devices are smaller than those that have interfaces for the interpretation of data, which also mostly utilize visual interfaces.

For the interpretation of the data a handheld device was used due to its versatility, portability and our previous experience with the use of such devices for users with visual disabilities [17],[18],[19]. This device is more appropriate for these users due to the ease with which essential tools can be integrated when interfaces are created for people with visual disabilities, such as a text-to-speech (TTS) human voice synthesizer.

The importance of this research is not the use of GPS in and of itself, but is rather based on the possibility for people with visual disabilities to be able to navigate freely in an outdoor environment. Therefore, there is no need for specific information such as speed, routes, and points of interest or other aspects related to the GPS device. We only need to obtain the latitude and longitude at a specific time. The NMEA (National Marine Electronics Association) protocol for the transmission of information is more than enough for our needs. This is a specification that defines the interface for several marine-based electronic devices. Taking this into consideration, we transformed the GPS into a tool that only sends information regarding the current position of the mobile device. The device resolves all the rest of the information provided to the user with visual disabilities by using the coordinates obtained from the GPS. The coordinates of the destination points that the user will visit must be loaded into the device prior to navigation.

The process for the provision of directions is based on an "hour system" that is used to inform the user on specific directions in order to get to a destination. The hour system is a metaphor used to indicate directions, and basically consists of situating the user in the middle of an analogue clock. The user is always facing 12:00 (see Figure 1), in such a way that if we want him/her to move to the right, we say "go to 3:00; to go left, we tell him/her "go to 9:00", and to go backwards we say "go to 6:00" [21].

Figure 1. The hour system for directions

This system has the advantage of providing intermediate points that are easily interpolated. For example, if we say that the direction is 1:00 sharp, the user understands that this corresponds to a position slightly to the right of his current direction.

Other ways of providing directions were also studied. One of these was the cardinal points system. This system has two main disadvantages: 1. The user has to be aware of his current direction regarding north, and 2. It is difficult to provide and understand intermediate directions, such as south-south-east. Another system reviewed in our study was the use of indications such as left, right, forward and backward, but these were found to be too limited regarding the freedom of movement.

Figure 2 describes the process of the audio-based GPS software's system. The GPS constantly sends data to the device, and the latter obtains the current position from the information provided by the GPS. If the current position is used as a starting point, it is saved in the device; to the contrary, the device compares this new point with the starting and destination points, and calculates the distance and direction necessary to get to the destination. While there is no change in the starting or destination points, this calculation continues constantly in real time. A change to the destination point results in a calculation taking this new destination into account, and a change in the starting point causes a new calculation based on this new starting point.

2.2 Development

The software was implemented by using Microsoft Visual Studio 2005 and the C# compact framework for the development of mobile devices. The GPS used in this project was a PRETEC BT MINI, which uses Bluetooth as its only means of communication. The mobile device utilized was a DELL AXIM x50 pocketPC with a 520 MHz processor, 64MB of RAM, 128MB of ROM and the Windows Mobile 2003 second edition operating system.

The development of the software involved the creation of an input interface, an output interface (TTS and GUI), serial communication and an NMEA data parser. The mobile devices utilized were pocketPCs.

The GPS constantly sends the current location of the pocketPC in NMEA format through a Bluetooth connection. The information is then received by the pocketPC, associating it with a serial port. The parser isolates the information, comparing the current position to the rest of the data. This information can be compared at any time with the saved information regarding the starting point, thus obtaining the distance and direction to the destination in real time.

For the correct operation of this software, it is necessary to have a pocketPC device with at least the following characteristics: Microsoft® Windows MobileTM 5.0, an Intel® XScaleTM PXA270 processor at 520 MHz, 802.11b wireless technology and Bluetooth 1.2, 64 MB SDRAM and 128 MB Flash memory. Together with this, it is necessary to have an Acapela Text-to-Speech engine and a GPS device with a Bluetooth connection.

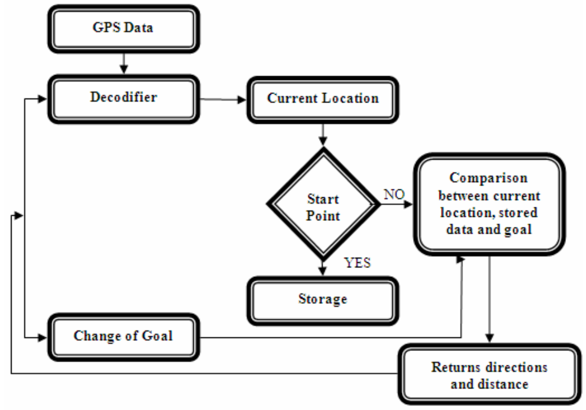

Figure 2. Process flow of the audio-based GPS software

2.3 Interface

The input interface consists of using 3 buttons on the pocketPC (Figure 3). The first button is used to sign in and search for a destination. When the user presses this button, he navigates through a circular list with different destinations that are spoken by the TTS. The second button is used to ask for information from the system. When the user presses this button, the TTS answers with the distance and direction (using the hour system to express the direction) to the destination. Finally, the third button is for changing the starting point of the route.

Figure 3. Audio-based GPS software interface. Button 1. Enter the destination, Button 2. Ask the system for information, and Button 3. Change the starting point.

The output interface is made up mainly of the TTS. As was previously mentioned, the TTS responds to the requests made by the users when pressing a button, in such a way that the only output provided to the user consists of the distance and direction to the destination, and the names of the destinations. The users are not provided with routes. The user must decide the routes to follow in order to get to the destination. There is also a visual interface that constantly provides information regarding the destination, the distance and the direction needed to get to the destination. This interface is used to help the facilitators (special education teachers) so that they can support blind users in their learning for navigational purposes.

The TTS is a service integrated into the pocketPC, and allows for transforming written words into sound waves. In other words, it is a human voice synthesizer that provides information to users without the need for pre-recorded sounds, which makes the system's expansion easier.

The system activates when it receives a GPS signal with valid information. This information corresponds to data from at least 4 satellites, and any information received from a lesser number of satellites is not valid.

Once the first valid signal has been received, the system begins to provide the distance between the user and the different destinations that have been loaded. This is done by calculating the difference between the user's current coordinates and the coordinates that correspond to the destination. Thus, the system transforms this distance, which is based in degrees, minutes and seconds, into meters, which can be easily understood by any user.

Different focuses for providing the user with the information regarding distance were tested. The use of meters for this information was chosen once it had been verified that blind users could easily understand this measurement.

When the system begins to operate, the user must take some steps in any direction in order to initially configure the GPS and thus obtain the direction in which he is moving. This is because not all GPS devices available are equipped with a compass. Once this has been configured, the GPS is capable of providing the user with information so that he can navigate autonomously.

In order to calculate the direction to the destination, three points are used: starting point, current point, ending point. Using these three points we can obtain the angle between the user's trajectory and the route that leads to the destination. The problem with this focus is that it does not consider whether the projection of the angle is taken from the left or the right; thus, an additional estimate must be made in consideration of the angle between the direction that the user is facing and the user's route.

The stored destinations were obtained by the GPS reporting the geographic coordinates of the point where the pocketPC was located on a screen. To achieve this, the software developers visited different locations in order to perform usability evaluations for software improvement. These locations were stored as multiple points of interest in a file that is then read by the software when it is used by users with visual disabilities. This procedure allows for the future integration of new points in an efficient way, independent of the software. The geographic coordinates can be obtained by using other digital media such as GoogleEarth. In fact, during the usability test, the coordinates of interesting places were loaded using GoogleEarth, eliminating the need to visit the actual destinations prior to the trip. Destinations can be added to the software without changing it, due to the fact that they are saved in separate files.

3. COGNITIVE EVALUATION

3.1 Sample

In order to obtain the sample group participants, it was necessary to identify that the users fulfilled the requirements of having had experiences navigating through the city, in addition to being able to correctly use the handheld device. Thus, an intentional sample of seven participants with ages between 17 and 35 years old was formed. The sample consisted of six males and one female, all of whom are from the Metropolitan Region of Santiago (Table 1). Three of them are from the Hellen Keller School for the Blind, another three are from the Blind Corporation (book) Record Center, and the last one is from the National Union of Blind People in Chile. Five of them were professionals and another two were students (one high school and one university student). The requirements to make up part of the sample group were the following: 1. To be between 17 and 35 years old, 2. To have some kind of visual disability, either total blindness or low vision, 3. To be registered on the national Disability list [6] in order to work with people who are legally disabled within the context of Chilean legislation, and 4. To be able to manage basic orientation and mobility techniques.

Table 1. Detailed list of the sample

#	Genre	Age	Ophthalmological Diagnostic	Degree of Vision
1	M	35	Pigmentary retinitis	Totally Blind
2	M	17	Retinopathy of prematurity	Totally Blind
3	F	21	Pigmentary retinitis	Low Vision
4	M	28	Glaucoma	Low Vision
5	M	21	Pigmentary retinitis	Totally Blind
6	M	26	Pigmentary retinitis	Low Vision
7	M	32	Retinal detachment	Low Vision

3.2 Instruments

Three evaluative instruments were used in the study: Route Evaluation Guideline, Self-Evaluation Survey and a Check List.

3.2.1 Route evaluation guideline

This instrument contains 17 observable behaviors evaluated by a teacher. Five indicators that would allow for the collection of information on some aspects of the development of navigational skills by the participants were defined. They were evaluated qualitatively according to whether or not such behavior was displayed. These indicators make up a guideline in which the maximum score that the users could obtain for each of the routes taken was 17 points.

These indicators imply comprehension of the route that the participants had to take: (i) Identify starting points and destinations (includes statements such as "Manages prior information on the route, such as streets, intersections, different levels and reference points"); (ii) Analyzes the route regarding the relevant information that is needed or that can be known (includes statements such as "Checks information regarding distance, position and other aspects related to the destination"); (iii) Proposes a way to be able to successfully navigate the route (includes statements such as "Is able to anticipate obstacles or problems by considering them in his plan"); (iv) Successfully carries out the trip (includes statements such as "Orients him/herself correctly based on the clues provided by the audio-based GPS software" and "Moves about safely, adequately resolving the problems that come up"); and (v) Evaluates the trip taken ("Determines whether the decisions made along the route were the most appropriate").

3.2.2 Self-evaluation

This instrument consists of open questions answered by each participant. The user is asked to evaluate his own performance for the route taken. To do this, he must answer a brief survey applied orally by the facilitators. This survey contains eight open-ended questions: What did you think about the route? What problematic situations did you encounter during the trip? Could you have taken another route in order to get there/here? Did you receive any additional help by any pedestrians? If so, what was it? How did you know that what people told you was correct? Did you use any reference points? If so, which ones? Did you know about the starting and destination points for the route beforehand? Was this route familiar to you? How would you assess your performance on the route?

3.2.3 Check list

This instrument consists of open-ended questions answered by each participant. This was the instrument applied during the preparatory activities, in which the participants had to carry out a series of tasks based on the clock technique, associating meters with the number of steps taken, and identifying the buttons on the pocketPC.

For training in the clock technique, the users performed three sequences of turns. The scale of evaluation consisted of "achieved" or "not achieved", depending on the user's precision or inaccuracy in locating the hours that were asked of him. For each activity or task, 1 point was granted if it was achieved and 0 points were granted if it was not achieved. The activities included an initial sequence in which the users were asked to locate the axis hours (3, 6, 9 and 12 o'clock), which was evaluated with a total of 4 points. A sequence of high degree turns was evaluated with a total of 11 points (the hours with the most distance between them). Finally, a sequence of low degree turns was evaluated with a total of 9 points (hours that are closer together). In total the user could obtain 24 points as a perfect score. They were evaluated based on their achievement, depending on whether they got the location of the hours requested of them right or wrong.

The association of steps to meters consisted of identifying whether the users were able to transform the information provided by the audio-based GPS software in meters into the correct number of steps, which differed for each user. This was evaluated by asking each user to declare the number of steps taken in the past 15 meters traveled out loud, and verifying if this number was correct.

Finally, to evaluate the users' identification of the buttons, each user had to locate the correct position of a particular function on the pocketPC device. This was evaluated by asking the participant to press the button that corresponds to a specific function, and identifying whether the action was achieved or not.

A special education teacher that specializes in visual disabilities identified the correct or incorrect execution of all these tasks.

3.3 Cognitive Tasks

A group of cognitive tasks were designed and presented with concrete materials to represent structural and functional aspects of virtual navigation, in order to develop and enhance navigational skills. Each participant, together with the team of teachers, performed all of the cognitive tasks in order to guide his learning and to construct the prior concepts needed to use the audio-based GPS software.

Two cognitive tasks were carried out with the users. These consisted of Initial Tasks, which were made up of three stages (Clock technique, Estimation of distance and use of the audio-based GPS software) and Navigating Santiago. These tasks are described in the following sections of the paper.

3.3.1 Initial Tasks

3.3.1.1 Task 1: Clock technique

The participants interacted in the middle of a model clock created with PVC pipes, identifying each of the tactile marks that represent the hours on the clock with their cane. Afterwards, it was explained that 12 o'clock, located directly in front of them, would be the initial time; however, this would change location (unlike a traditional clock, in which the position of the hours is static) as the users body changes its position in space (Figure 4). Then, the participants were asked to identify various hours on the clock. In this way, the relationship between the location of the hours within the clock and the different possibilities for making turns in space was strengthened.

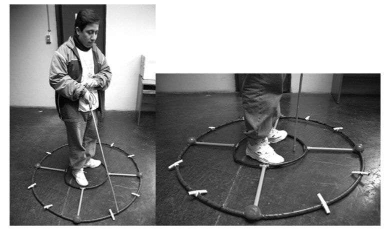

Figure 4. A user performing initial tasks for the clock technique

3.3.1.2 Task 2: Estimation of distance (in steps)

The users walked step by step over a measuring tape laid out on the floor, in order to establish the number of steps in one, five and ten meters. This was later used as a reference when establishing distances based on the information provided by the software.

3.3.1.3 Task 3: Use of the Audio-Based GPS Software

The participants were asked to identify all of the buttons on the pocketPC device, making it clear what buttons execute which actions within the system, as well as where the buttons are located on the device. In the same way, they had to explore the GPS device in order to become familiar with its shape and size (Figure 5).

In the case of the participants with low vision, who are able to identify and differentiate colors, these users were asked to observe the color that the GPS generates when it is turned on (green) and when it is connected to the pocketPC via Bluetooth (blue).

3.3.1.4 Task 4: Navigating Santiago

A total of eight different routes were established, with which the users participated by navigating through the city of Santiago de Chile (Table 2). These routes respond to two general characteristics:

1. They include places with cultural and/or personal value that the participants want to get to know and to which they want to be able to establish a navigational route in order to use it in the future.

2. The routes include various levels of complexity, as defined by the distance, streets and the coordinates provided by the software.

These characteristics allow us to provide the user with a motivation that emerges from his own need to know of and navigate in unfamiliar environments. At the same time, it is possible for this research to prove the effectiveness of the system for developing orientation and mobility skills.

Figure 5. Users identifying the buttons and functions of the PocketPC

Table 2. Definition of distances on all routes

	Route	Distance (m)
1	From the Plaza de Armas Metro Station to the Estación Mapocho Cultural Center	544
2	From the Parque Bustamante Metro Station to the Plaza Italia	830
3	From the Baquedano Metro Station to the San Cristóbal Hill	932
4	From the corner of Rancagua avenue with Seminario street to the Salvador Hospital	684
5	From Las Hualtatas street to Arauco Park	789
6	From the Cumming Metro Station to the Natural History Museum	1506
7	From the corner of Pucará avenue with Hamburgo street to the Hoyts La Reina movie theatre	751
8	From the Santa Ana Metro Station to the Bandera street branch of the Banco Estado	960

3.4 Procedure

First, a plan for preparatory work with the clock system and the use of the audio-based GPS software was established. During this preparatory stage, the users worked on the initial tasks in which they become familiar with all of the basic aspects needed to interact with the system.

Secondly, before taking a definitive route, the users had to apply the learning they had achieved from the preparatory tasks with an initial test route taken within the system. As such, it was possible to prove whether or not the users could execute the clock technique and the instructions provided by the software correctly.

Finally, the users went out to navigate and execute the previously defined routes. At the beginning of each route, the participant received the device with the audio-based GPS software in order to initiate a route. At this time, he is informed of the starting point and the destination for the route that he chooses from the software's menu. Once this is done, the user begins to use the tool autonomously, planning a navigational route that allows him/her to reach the destination and then executing that route (Figure 6).

Figure 6. Users taking routes through the streets of Santiago de Chile

The implementation and development of the various proposed activities was carried out during seven months, due mainly to the users' lack of availability (free time) to be able to participate and take the routes assigned. For this same reason, it was not possible to follow the order of execution established for the routes, in that some required more time than others, and it was not always possible to perform the corresponding route due to the users' lack of time. This issue did not have an impact on the research design.

4. RESULTS

All of the participants were able to get to the destination for each of the proposed routes. However, it was not possible to execute the routes in the planned order (by the number of streets and metro stations involved). For this reason, each of the activities evaluated by the route taken were directly related to the degree of experience that the user had acquired in the use and integration of the information provided by the audio-based GPS software during each separate navigation. The results show that the mean performance of the group regarding the execution of the routes was 11 points, out of a total of 17.

In order to compare the mean obtained by the subjects for each route, an ANOVA factor analysis was performed, obtaining the results displayed in Figure 4.

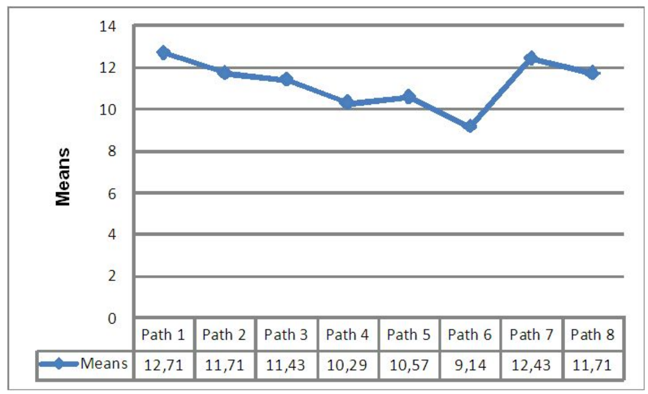

Figure 7. Route performance means

Of all the established routes, the group performed best on Route 1 with a group mean of 12.71 points, while Route 6 reflects the most difficulty regarding execution, with a mean of 9.14 points. Route 1 contemplates a distance of 544 meters between the starting point and the destination (being the shortest route), while Route 6 included 1,506 meters between both points (being the longest route). In this way, the complexity of Route 6 was most likely higher, in that the users had to apply a higher degree of their orientation and mobility skills in order to situate themselves and navigate through the space traveled.

In order to determine whether or not the differences between the means obtained for the different routes are significant, an ANOVA factor analysis was performed, obtaining the result that the differences between the means obtained for the different routes are not statistically significant.

During the execution of each assigned route, it was possible to observe the development of orientation and mobility skills in unfamiliar environments thanks to the information on turns and meters (the clock technique) provided by the audio-based GPS software. From the results of the Route Evaluation Guideline, we discovered that, thanks to the audio-based GPS software, all the users improved their navigation and were able to reach the destinations autonomously, without having to know about the environment or depend on reference points or other people. With this, we demonstrate the utility of the audio-based GPS software as a tool that improves navigation through open, unfamiliar spaces in the city.

For each of these routes, the users had to make use of orientation and mobility skills, and face situations for which the software did not provide much information (for example, crossing streets, obstacles, detours, roadwork and masses of people). For this reason, the information obtained from the five indicators defined for the route evaluation guideline showed that the users define their planned route at the very moment they receive updated information from the audio-based GPS software. They do this in the middle of the route and while walking, and not by analyzing the information prior to their trip. Once they begin a route, they decide which paths to follow, modifying their previous decisions based on the new information they receive, and deciding which steps to take based on this information.

Finally, judging by the results obtained from the route evaluation guideline, we can see that the audio-based GPS software fulfills its purpose of facilitating autonomous navigation for blind people in open urban spaces, eliminating the need to have prior knowledge of the routes. This is, without a doubt, a big help for those users that do not habitually travel through the city without the aid of a sighted person.

5. Discussion

In comparison with our system, Trekker and Loadstone have the disadvantage of using digital maps [10],[6], which are not easily updatable and which can thus provide erroneous information to pedestrians. In many countries, it is also necessary to pay for a license in order to use certain maps. Unlike the GPS system that is used for a car, a system used to guide a blind person must be extremely precise and reliable. A sighted person is able to discern whether or not to consider the information provided. In the case of a blind person, it could even be fatal to follow inaccurate instructions. In the same way, not all the maps are available for such users.

In order to load a new point of interest into the Loadstone and ambientGPS systems, it is necessary to introduce their coordinates (latitude and longitude). In this way, in the case of Loadstone, the map that had already been loaded is no longer useful and there is no longer a point to using it.

Just as in LoadstoneGPS, ambientGPS was conceived as a low cost tool, as only a PocketPC, Bluetooth GPS (and not necessarily a very expensive one) and a TTS engine are necessary to use it.

AmbientGPS allows users who are blind to use a tool that helps to support their navigation based on the use of audio and the clock technique used to train users in orientation and mobility. Thus, dependence on a third person to be able to become oriented in space is eliminated.

In the same way, in some countries technologies of this kind have not been implemented, and exports of such technology is still quite expensive. It is for this reason that ambientGPS, in addition to being accepted by blind users, is presented as a technological resource that allows users to have access to unknown environments without the need to knowing or establishing point of reference from the surroundings, taking the fact that the city is constantly changing into account. It is for this reason that navigation improved as the users had more practice using the system, and as they were able to integrate their prior knowledge with that which was supplied by the application.

6. CONCLUSIONS

This study presented an audio-based GPS software application and its effect on navigation through open spaces in the city by blind people.

Without a doubt, the development of a navigational system based on GPS technology and the implementation of a mobile, portable pocketPC device that favors blind users' navigation through unknown urban environments resulted in a tool that is very significant for the blind community. This is because such a tool does not only provide the possibility to navigate in the city, but it also allows users to exercise degrees of autonomy that would normally be impossible for them, given their visual disability. In addition, the audio-based GPS system includes information that is easily accessible and easy to use through the implementation of the clock technique metaphor (turns based on hours) and the measurement in meters of the distances involved. Both of these techniques are used in the navigational training of the blind users.

Given the research carried out and the results obtained, it is possible to affirm that the use of the audio-based GPS software favors the navigation of blind people in unfamiliar contexts, as it is not necessary for these users to have any prior information on the route they take. Instead, it is enough for the user to integrate and assimilate the starting point and the destination of the route, navigating only with the information provided by the software. Nevertheless, the software does not provide enough information to be able to detect certain obstacles in the path, such as curbs, roadwork or storefronts.

In the execution of the different routes, the audio-based GPS software was able to stimulate different orientation and mobility skills by presenting each participant with contextual and real scenarios in which they can participate. This was observed in the results of the route evaluation guideline when evaluating the indicators related to the implementation of strategies each time the user received new information. In the end, the information provided allowed them to navigate all eight of the routes included in the study.

Although through this study it can be observed that audio-based GPS software can be useful as a navigational tool, we must also take into account the fact that the implementation of technologies that help blind people with their navigation, and thus a large part of the success of these kinds of programs, will largely depend on the real utility that each user sees in these devices, according to their own personal characteristics and life experiences.

The results demonstrate that the audio-based GPS software application provides help to users that habitually navigate spaces in the city only in the company of other people. These are the blind people that most need tools to be able to navigate autonomously, combining their personal skills with mobile technology that allows them to navigate, just like anybody else, and within the contexts and environments of the world around them.

During the first routes taken, a higher degree of hesitation and an extensive use of time were observed when the users navigated their routes. Observations demonstrated that as they took part in each additional navigational task, such problems were overcome. Having more practice and increased dominion over the system was key to be able to integrate the information provided by ambientGPS, coming to trust the software in order to navigate their way to the destination.

Although the software does not provide assistance for crossing the streets or to be able to foresee obstacles, in following the software's instructions the users were granted more freedom to be attentive to external environmental stimuli, and were thus able to integrate such stimuli into their navigation. These same users argue that the software affords security and autonomy by providing useful and easy-to-follow information that can be used to arrive at a destination.

7. ACKNOWLEDGMENTS

This report was funded by the Chilean national Fund of Science and Technology, Fondecyt #1090352 and Project CIE-05 Program Center Education PBCT-Conicyt.

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