Audio Transportation System for Blind People

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Abstract. The purpose of this study was to design, develop and evaluate audio-based software to assist people who are blind in public bus transportation. The audio-based software for mobile devices Audiotransantiago was designed in order to provide information regarding authorized bus stops for the entire bus service in the city of Santiago de Chile (known as Transantiago). The study was designed to allow users who are blind to build up a mental map that is adjusted to their surroundings while traveling on the bus system. It was found that the use of the software improved information processing skills, tempo-spatial orientation and orientation and mobility skills (O&M), as users were able to navigate from one place to another without having to obtain information prior to their trip.

Keywords: People with visual disabilities, Audio-based interfaces, Orientation and Mobility, environmental perception and cognition.

1 Introduction

The varied and complex scenarios present in large cities have generated the need to implement urban policies designed to modernize transportation services, in order to facilitate movement between different areas within the city and seeking to eliminate the barriers that make traveling throughout the city more difficult [2]. As people who are blind lack a visual channel, they must orient themselves by recognizing their surroundings and establishing their position within their environment by using perceived information acquired through touch and hearing as a strategy [1][6]. In this way, visually disabled people obtain information from the environment and use it to be able to travel effectively and safely when navigating through the city [11], compensating for their lack of vision by obtaining information through other channels of perception as a source of knowledge for learning [1][9].

In taking the need to generate easy access for the use of public transportation by the disabled and elderly population into account [2], research has been carried out in many countries regarding the experiences of such users when using public transportation. Such research has been used in order to implement measures that favor the integration of these people into the system. Some examples are: Brazil (RIT: Red

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Integrada de Transporte, BRT: Bus Rapid Transit) [3][15][16], Colombia (Transmilenio) [7][15], Venezuela (Transbarca) [12], Spain (TMB: Transport Metropolitans de Barcelona) [13], China (PTO: public transit oriented) [17], and Taiwan [18][19]. Based on this research, several state plans have been implemented that seek to facilitate the use of surface transportation by disabled or elderly people. These experiences have coincided in the need to generate a higher level of respect towards this population without distinction, guaranteeing their access to autonomous mobility through the city. One important aspect highlighted by these studies is the inclusion of an operational design that includes elements of accessibility capable of providing solutions to a number of needs, such as: spaces within buses for wheelchairs, tactile guides and signs, ramps, elevators, proper lighting, audio informational services, etc. These elements would provide general comfort and safety for the transportation of disabled and elderly populations.

In the city of Santiago de Chile it has been sought to implement policies and regulations regarding access to public transportation by people with disabilities [4], having established "Regulations on equality and the social inclusion of handicapped people" so that these individuals are able to utilize public transportation safely and independently. These regulations incorporate the concept of "easy access", accounting for and attending to the capabilities and the nature of each different mode of transportation based on its location and geography. In this way, changes in patterns of urbanization and the integration of the visually disabled into a variety of activities within society geared towards autonomous navigation with equal conditions among a wide variety of urban sectors and spaces, represents a special challenge and need for the population [5][8].

The purpose of this study was to design, develop and evaluate audio-based software to assist in public bus transportation for people who are blind. It is in this context that the Audiotransantiago [10] software has been developed. Audiotransantiago is an audio-based software program for mobile PocketPC devices. The purpose of the software is to provide information regarding authorized bus stops for the entire bus service in the city of Santiago de Chile (known as Transantiago), in addition to the streets around each stop and places of interest near to the scheduled routes. The idea is for the software to allow users who are blind to build up a mental map that is adjusted to their surroundings while traveling on the bus system. A synthetic voice, together with the commands available through the buttons on the PocketPC, allow a person who is blind to plan several different routes in an urban environment by establishing a point of departure and a destination point within the software.

2 Audiotransantiago Software

Regarding the interaction, the Audiotransantiago software provides sound-based information based on circular menus, with color contrast and the use of both synthesized voice and non-verbal audio cues. It makes use of a Text-To-Speech engine and an audio-based interface through which it conveys information to the user, complemented by non-verbal sounds that help to identify the navigational flow within the application menus. The software also utilizes a minimalist graphic interface, which includes only the name of the selection that is being used and the option that has been selected, using a strong color contrast that can be useful for those users with residual vision who can only distinguish shapes when displayed with highly contrasting colors.

To navigate between the various software functions, the user must utilize the buttons located on the inner part of the PocketPC (PPC), which allows the user to access the different functionalities of the software application. The software includes two main modes of interaction: (1) “Travel Planning”, in which the user is able to plan a trip by using the various functions of the PPC keypad to select an area to navigate, the kind of transportation service to be used (bus), and then defining the direction in which the trip will be taken, establishing an initial bus stop and a final destination. Afterwards, the programmed trip remains stored in the “Execute Travel” option, in which the user is finally able to select the previously planned trip. The advantage of this option is that it allows the user to save multiple trips without having to reprogram the same trip every time it is taken. In selecting a pre-programmed trip, the user utilizes the PPC to anticipate the bus stops included on the planned route, and also has the option of requesting contextual information regarding streets and places of interest around each stop. This aids the user in creating a mental map of the environment through audio-based information, and in making decisions when faced with problems, which also implies reprogramming the initially planned route in real time. In this way, the user has a high degree of autonomy in navigating through different areas of the city by using the bus system, in order to arrive at his final destination.

In making comparisons, there are cities that provide interactive transportation guides for people. PoaTransporte [20] is an on-line system that allows users to access surface public transportation lines based on the direction of travel. Using the interactive map generated by the system, the user can also locate bus stops and taxi service locations. The user is also able to ask questions based on the specification of the names of each bus line. Despite the fact that PoaTransporte represents an efficient and practical information service, it does not possess the characteristics of digital accessibility that would make it beneficial for use by people with visual disability.

In allowing users with visual disability to be able to access information in a dynamic fashion, by constructing and generating questions regarding different routes, Audiotransantiago provides for a perception of the environment, mainly regarding collective public spaces. In this way, it seeks to appropriate space in the way that the user generates a symbolic identification with his surroundings, allowing the user to perform actions and change his plans during the bus ride. This implies a high degree of interaction with the environment and a mental (re)construction of the surrounding areas, providing for personal meaning in the user’s interaction with the urban area.

3 Cognitive Evaluation

The experiment performed to evaluate Audiotransantiago was designed to determine whether an audio-based system favored autonomous navigation by people with visual disability on surface public transportation (buses).

3.1 Sample

The sample was made up of 14 individuals, including 10 men and 4 women, of whom 3 were totally blind and 11 had low-level vision. The sample selection was performed by using a non-probabilistic quota sampling method based on the following criteria: (a) being between 14 and 55 years old, (b) being blind or having low-level vision, (c) being registered in the National Registry of Disability, and (d) having previously been trained in orientation and mobility techniques. The sample was divided into 2 groups, one control group (CG) (Table 1) and one experimental (EG) (Table 2).

Table 1. Control Group (CG)

#	Genre	Age	Ophthalmological Diagnosis	Degree of Vision
1	F	20	Microphthalmia	Low Vision
2	M	20	Pigmentary retinitis	Low Vision
3	M	21	Pigmentary retinitis	Low Vision
4	F	22	Pigmentary retinitis	Low Vision
5	F	23	Retinopathy of prematurity	Low Vision
6	M	29	Glaucoma	Low Vision
7	M	33	Advance astigmatism	Low Vision

Table 2. Experimental Group (EG)

#	Genre	Age	Ophthalmological Diagnosis	Degree of Vision
1	M	14	Congenital Amaurosis	Totally Blind
2	M	16	Congenital retinopathy	Low Vision
3	M	26	Retinal damage - immature optic nerve	Low Vision
4	M	32	Retinal detachment	Low Vision
5	M	34	Retinopathy of prematurity	Low Vision
6	M	52	Pigmentary retinitis	Totally Blind
7	F	54	Myopic retinopathy	Totally Blind

The EG navigated the routes by using information provided by the software regarding which bus line to take, the initial bus stop, official bus stops between the point of departure and destination point, streets around the stops, and streets around the destination point. The users in the CG performed the same routes, by using only information regarding the point of departure and destination of the route. This latter group navigated the routes by using the navigational strategies that they utilize very effectively on a daily basis when using this mode of transportation.

3.2 Tasks

Three routes were developed between different geographic points in the city. The varying levels of difficulty were based on the number of stops and the distance (measured in meters) between the point of departure and the destination point. In order to provide for a higher degree of flexibility and to offer alternatives for navigation to the blind users, each route was designed in such a way that there are two possible bus routes to arrive at the destination. In addition, a third route incorporated changing from one bus to another in order to continue on the desired route.

3.3 Instruments

The evaluation of the tasks (routes) was carried out through the use of two different instruments: a “Route Evaluation Guideline” and a “Self-Performance Evaluation”.

The Route evaluation guideline was used to collect information regarding the mobility, orientation and travel skills utilized on each of the scheduled routes. The guidelines were structured around the following dimensions: (a) Time, (b) Autonomy, (c) Spatial Orientation, (d) Navigational Efficacy, and (e) Problem Solving. In order to evaluate the items included in the guideline a 4-point scale was utilized, ranging from “always” to “never”.

After having applied the Route Evaluation Guideline, which was carried out by a teacher-facilitator through direct observation, the “Self-Performance Evaluation” was administered to each user once the bus route had been successfully navigated. This instrument was designed to collect information on the effects of the user’s experience during the bus rides, and the orientation and mobility strategies that had been used in order to face and solve the challenges that the users confronted. In the case of the EG, the application of this guideline allowed for the collection of information regarding the evaluation that the users themselves made of the software’s effectiveness for aiding in autonomous and efficient navigation through the city by bus.

This latter instrument consisted of 9 questions, applied to each user once the route had been completed: “What did you think of the assigned route?”, “Were you familiar with the starting and ending points of the route beforehand?”, “Was this route familiar to you?”, “What strategies did you use to take the trip?”, “Did you experience any problematic situations during the trip? If so, what were they? What solution did you come up with for these difficulties?”, “Were you able to anticipate situations or difficulties while you were taking the bus route?”, “What information is useful in order to orient yourself and take a trip on the bus?”, What kind of technologies would you use in order to help make better use of the transportation system? Why?”, “On a scale of 1 to 7, how would you evaluate your performance?”.

These questions point to issues related to concepts of perception and environmental cognition [21], regarding the way in which information on different places is organized, stored and remembered, including distances, the position of objects and spaces [22]. In this way, the instrument allows researchers to verify the users’ arguments regarding how and what he learned during the interaction with Audiotransantiago.

3.4 Procedure

Initially, a facilitator provided the user with information on the route that was to be taken, informing the user of the starting point and the destination. Afterwards, the facilitator asked the user to interact with the buttons on the PPC, and by following the audio information through the use of headphones, to configure the “Travel Planning” mode by defining the bus to take, the starting bus stop, the direction of the trip, and the destination bus stop. This creates the trip file needed to initiate a bus travel route.

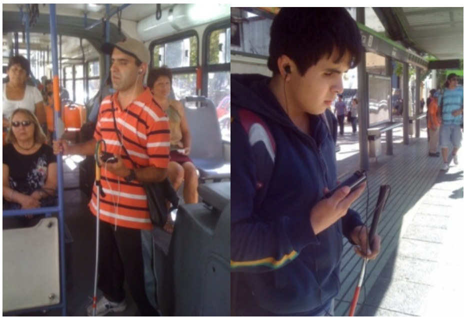

Fig. 1. User taking bus routes using Audiotransantiago

The second step consisted of recovering the trip file from the "Execute Trip" mode through the buttons on the PPC. After doing this and using the headphones in order to obtain the information, the user positioned himself at the bus stop, guided by the tactile patterns on the ground, in order to wait for the bus. Once the bus arrived, the user got on, aided by the facilitator, as the system does not provide information on the bus route prior to its stopping at the starting point.

Finally, the user entered the bus, executing navigational actions within the Audiotransantiago system through the buttons on the PPC, anticipating the bus stops that occur throughout the entire route. To complement their travel, many users consulted the system regarding streets or places of interest near the various bus stops. This was done in order to establish a mental map of the route navigated and to facilitate in the learning of information needed to reach their final destination (Figure 1). In this way, the users were able to better understand, structure, and learn about the environment through which they traveled.

During each route, the users were accompanied by a facilitator who supported them during any situations throughout the trip that they could not resolve, such as getting off the bus in the case that the bus was defective in this regard, setting another route in the case of excessive traffic, among other situations. In the same way, the facilitator collected information on the user's experience through direct evaluation, utilizing the Route Evaluation Guideline, and applied the Self-Performance Evaluation at the end of the route.

The implementation and development of the various activities lasted approximately 6 months, and was subject to the time availability of the participants. In this way, in several cases there were prolonged intermittent periods between the different stages of the experiment.

4 Results

All of the participants in both groups (CG and EG) were able to plan and execute the proposed routes using the Audiotransantiago software. However, in order to reach the destination the participants experienced difficulties that were unrelated to the use of the software, and were instead related to the bus transportation system itself. In this way, the evaluation was centered mainly on judging whether or not the user's interaction with the software favored autonomy, efficiency in travel, and the necessary problem-solving skills for selecting and managing the information needed to plan and execute a trip autonomously using the bus system in the city.

The results show the percentage of achievement for each route carried out by the users from each group, determined through the Route Evaluation Guideline. The EG obtained an average achievement rate of 81.7%, while the CG obtained an average rate of 71.8% (Table 3). These results show that the use of Audiotransantiago facilitates navigation through the city by bus for users with visual disabilities.

Table 3. Average percentage of achievement for sample routes

Group	Route 1	Route 2	Route 3	Avg.%
Experimental	84.6	84.7	75.9	81.7
Control	70.3	69.7	75.3	71.8

In the execution of the routes, the CG displayed lower execution results for all of the routes taken compared to the EG. Route 3 represented the highest level of complexity, and similar levels of performance were achieved between both groups. This is mainly due to the need to correctly reprogram the route by both groups, as all users were aided in this case by the help of the facilitators in order to continue with their trip. A T-test comparing the means between two independent samples was performed in order to compare the statistical relevance of the difference between the means of the CG and EG for each route. This test determined that the differences were not statistically significant.

Finally, although the results obtained were not statistically significant, the performance levels achieved for the 3 routes taken both by the Control Group and the Experimental Group represent an initial precedent in order to establish actions based on the use of audio-based technological tools that facilitate autonomous navigation by blind people through different areas of the city. Accordingly, obstacles can be at least partially eliminated, such as the need to depend on other people in order to move about and to actively utilize the public bus transportation system. In this way, Audiotransantiago has been determined to be an effective and useful tool for acquiring knowledge regarding the surroundings that the user has navigated, and at the same time providing necessary tools so that blind people themselves can make decisions regarding alternative routes towards different places in order to meet their travel needs.

5 Conclusions

The purpose of this study was to design, develop and evaluate audio-based software to assist in public bus transportation for people who are blind. As a result, Audiotransantiago allowed users to have access to and manage information on buses and their routes through a variety of urban areas, understand how the bus system works, learn the cost of tickets and, in many cases, to orient users in their spatial configuration of the areas within the bus (seats, sounds, doors). The use of the software improved information processing skills, tempo-spatial orientation and O&M skills, as users were able to navigate from one place to another without having to obtain information prior to their trip.

The main focus of this research was centered on evaluating whether or not an audio-based, technological tool favored autonomous navigation by people who are blind on surface bus transportation in order to travel between different points throughout the city. In this way, it is possible to conclude that the Audiotransantiago software provides information based on the bus service, its routes, bus stops, and streets around the various stops, including places that could be considered to be of cultural, social, economic or educational interest.

The results obtained allowed the researchers to conclude that the use of a mobile device makes putting navigational strategies into practice possible, supported by a system of contextual information in order for the user to be able to orient himself within the bus system, based on knowledge of bus stops, nearby streets and places of interest. As such, afterwards these places can be visited as many times as the user plans, in that the use of the software aids in the creation of a mental map of the environment through which the user travels, in addition to incorporating information that is able to take the surrounding environment into account, thus widening the user's overall knowledge of the city.

Audiotransantiago, as a sound feedback-based technological proposal, provides users who are blind with information that allows them to utilize surface, urban transportation independently. The proposed software supports these users' orientation and mobility skills, providing information on the physical surroundings with an emphasis on contextual information regarding bus stops, route change stations, as well as nearby places of interest surrounding the routes such as museums, public services, and others. Audiotransantiago can be seen as a tool that facilitates the inclusion of people with visual disabilities in interactions with the urban environment, as it allows for the development of strategies that seek improved cognition and environmental perception based on a direct experience with the surrounding environment at any given time. In this way, the recognition of spatial considerations is not the result of a passive process of receiving information, because it involves the interpretation and restructuring of information and actions by the visually impaired user.

Despite showing the effectiveness of using the Audiotransantiago software as a relevant tool for providing useful information for decision-making and problem solving, the public bus transportation system currently presents serious defects and complexities that emerge as variables that the software cannot control. This is the case regarding the frequency and circulation of the buses, the buses not stopping at each of the designated bus stops, and a lack of information on route changes or detours that can occur for various reasons. All of this is in addition to the high congestion during peak travel times, and the scarcity of Braille or audio-based traffic lights or information signs as integrated in the original design of the system, as well as the constant change of bus routes and the specific directions that they take. Often the general public, with or without visual impairment, is not informed of such changes in a timely manner, so that adequate planning measures can be taken to compensate for the diversions from normality.

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