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Executive Summary

This study examined the effect that use of Remote Infrared Signage Systems (in particular the Talking Signs® - TS® - product) has on performance of blind or vision impaired people when undertaking a variety of bus user tasks. These tasks included finding a suburban bus stop, identifying a specific bus and boarding it, disembarking at the downtown terminal and finding the entrance, traversing the terminal and learning the location of facilities located therein, and, simulating the exiting of a bus, navigating through the terminal, exiting via a different door and searching for the boarding area of an express bus about 120' away on the frontal street, (the bus transfer task).

Twenty-seven participants were divided into two groups, one of which used TS® first on specific trials for each task, while the other group did not use TS® on the first trial of those tasks. Our hypotheses predicted significant response time (RT) reduction when using TS® plus higher success rates and fewer errors. It was also hypothesized that perceived stress, anxiety and difficulty of tasks would be reduced when using TS®, while perceived independence would be increased.

T-tests on the Response Time differences between use of TS® and non- TS® trials emphatically supported our hypotheses. With TS® all tasks were completed quickly, independently, and successfully. Without the use of TS® participants sometimes failed to complete tasks in the allotted time, gave up, or in some cases had completion times 4 or 5 times longer than the TS® aided times. In the real world, this would have meant that some participants would not have been able to identify a stop or the relevant bus, would not have been able to make a successful transfer, and would not have been able to effectively use terminal facilities. These are significant problems inhibiting the use of public transit by most of the 8-9 million severely vision impaired people in the USA.

In addition, use of TS® was perceived to reduce stress, anxiety, and difficulty of the various tasks associated with use of public transit. And, in post-task evaluations, participants on average strongly agreed that, if the TS® were made permanent on all buses and at the terminal, they would use public transit much more than they do now. They also supplied recommendations as to where TS® could be located throughout the city to make it truly accessible for all their regular activities. Although no direct benefit-cost estimates could be made, our estimate is that, for about $150,000, the Santa Barbara MTD buses and terminal could be equipped with TS® - a relatively small amount to pay for the increased independence and quality of life of this disabled group, although the amount could be doubled when we add TS® at selected downtown and suburban stops. Subjectively, therefore, we suggest a high benefit to cost ratio would result from installation of TS® on urban transit lines. There is no reason to expect that user attitudes would change in larger, more complex environments and current work in the City of San Francisco by Smith-Kettlewell Rehabilitation Engineering Research Institute seems to be confirming this.

Introduction

Signs translate hostile environments into amenable ones. Whether written, numerical, or pictorial in nature, they allow us to determine where we are, to plot paths between known and unknown places, and they describe the functional nature of facilities located throughout an environment. In urban travel, signs are used to identify streets and street intersections, the functional occupants of buildings, transit terminals and transit stops, destinations towards which different transit vehicles are heading, and amenities such as telephones, information booths, or public rest rooms. Signs are part of the taken for granted universe and it is almost impossible to imagine a world without them. However, people who are unable to read signs such as those who are vision impaired or blind, those with brain damage, the developmentally disabled, some dyslexics, younger children, and foreign language speakers, may have difficulty in interpreting traditional signage. The eight to nine million blind and vision impaired people in the United States face perhaps the greatest problems of all of these groups. In addition to being denied the information embedded in signs, they receive few cues from the environment through which they pass. Although they can sense volume and direction of movement if they are immersed in a movement stream, they may not be able to deduce probable destinations, the extent to which the current flow is likely to continue, or to detect obstacles along a crowded path. They are not able to see buses coming, or to identify the route number or destination displayed on those buses. If there is truck traffic using a particular street as well as the buses, the traveler may be unable to differentiate on the basis of sound between buses and trucks in order to signal for pickup. These are some of the reasons freely given as to why only twenty-six percent of those of working age who cannot read newsprint are employed.

Purpose of research

Written and iconic signs guide us through unknown environments. When trying to access urban services such as public transit, we use them to identify street intersections, buildings, transit stops, different transit vehicles, and amenities such as telephone, fare and information booths, rest rooms, and specific stores. People who cannot read signs experience difficulty when traveling through unknown territories because of their inability to access the information on signs. The eight to nine million blind or vision impaired people in the United States face this problem when attempting to independently use public transit. They have limited access (e.g. via mobility assisting devices such as canes, dogs, or sonic beams), to information about pathways, traffic flows (both vehicular and pedestrian), as well as an inability to identify vehicles by route number or written destination. It is difficult to find the appropriate entrance or exit door either to vehicles or to the terminal. Necessary facilities within buildings such as elevators, escalators, or stairs, either have to be remembered by rote learning after repetitive trials or searched for exhaustively with the assistance of an obstacle avoider (e.g. cane) or found by asking passersby. The question is how can we change accessibility to public transit such that travel independence can be increased and the potential for searching for and holding employment at some distance from a place of residence is enhanced.

While the Americans with Disability Act of 1990 mandated equal access to transit and public buildings for disabled groups, the problem is far from being solved. For wheelchair users, entrance ramps, curb cuts, and lifts for obtaining access to transit vehicles have replaced structural barriers such as curbs, stairs, and steps into a bus. However, the wheelchair population is still disadvantaged in terms of travel, for not all street corners have curb cuts, not all buildings have easily accessible ramps, and not all amenities such as elevators or bathrooms lend themselves to independent use by wheelchaired persons. However, while substantial steps have been made in the public domain to meet the demand of the one million wheelchair users in the United States, very little has been done to help mitigate the problems of the eight to nine million blind or vision impaired persons in this country. Print handicapped and vision impaired people still face major functional barriers to equal access. If they cannot find a bus stop, identify their transit vehicle, find a building entrance or exit, or cross a street safely, they can be denied equal access both to public transit and to public buildings. Our research attempts to identify and evaluate the potential of auditory based Remote Infrared Signage Systems (RISS) as a means of reducing the disadvantages faced by print handicapped or blind or vision impaired travelers.

The TS® receiver must be pointed roughly in the direction of the transmitter and be within the cone of transmission to be activated. Because it is directional the TS® signal provides orientation information for the wayfinder as users travel towards signals by homing in on the strength and clarity of the message being transmitted. The TS® infrared system is a line-of-sight system; there must be a clear and uninterrupted line-of-sight between the receiver and transmitter. Obstacles (including people or construction pillars, walls, and so on), can inhibit reception.

Hypotheses

1. If a person can walk directly to an unknown location and not stop or hesitate for any time or make errors in this task, then this means he/she has been given enough information to make their performance equivalent to a sighted person's performance on the same task. We hypothesize the use of Remote Infrared Signage Systems (RISS) based on directionally constrained auditory messages, provides this suitable level of information.

2. The use of auditory information available from RISS allows the blind traveler to accumulate layout information about paths, cues, and the spatial relations among them that is not significantly different from that which can be obtained by a sighted traveler experiencing the same environment.

3. The use of auditory based RISS will substantially increase the blind traveler's confidence and reduce anxiety when faced with the task of traveling in a novel environment.

4. The use of auditory based RISS will substantially improve the blind traveler's ability to solve all facets of the task of independently using bus transit systems (i.e. in finding suburban bus stops; in choosing the correct bus; in finding and using terminal facilities; and in choosing the appropriate bus to which to transfer to complete a journey).

5. We hypothesize that the use of auditory RISS can substantially reduce the "cost" or "penalties" brought about by lack of vision when traveling the environment and using transit facilities. These costs or penalties can be measured in terms of <u>reduced</u> response times to

perform tasks, and measures of self-assessed willingness to undertake periodic travel for purposes (and in situations) where travel previously had not been deemed feasible.

6. We further hypothesized that access to RISS would substantially reduce perceived stress, anxiety and difficulty of the various task involved in using public transit.

Major problems facing blind travelers when using public transit

1. Finding a bus stop: In suburban areas bus stops are identified in a variety of ways. The most common is for a metal plate to be displayed on a cylindrical metal pole with information about the arrival times of buses, the route name, and the bus number on them. Sometimes these plates are fixed to streetlight poles. Bus stops can be located immediately before an intersection, immediately after an intersection, or somewhere along a specific block face. Some stops have benches and/or shelters: many do not and thus the task of identifying a stop increases in complexity with the presence or absence of associated cues. The blind person has to be able to identify the block in which a stop is likely to be located, and be able to find the bus stop indicator efficiently and effectively on each trip.

2. Selecting the proper bus: When more than one bus operates along a particular route, the blind user must signal the bus to stop, find the entrance to the vehicle, and question the driver as to which bus number and route is being accessed. At key locations such as in some downtown areas, a succession of buses might be stopped at their appropriate signal points along a block face; this presents a particular problem in that the blind traveler must ask for information from each driver in turn or from passersby or other potential passengers. At a terminal when one might expect many buses to be parked in an irregular fashion, sometimes with multiple lanes of vehicles, the problem becomes even more intense. Under these circumstances finding the correct bus is an extremely difficult process and often the time taken to independently search for the appropriate bus exceeds the time which has been allocated for the bus to stay at that station.

3. Finding transfer points and crossing streets: One of the most difficult activities for a blind person using a public transit system is when bus transfers are involved. The former two problems of finding a stop and finding the correct bus are exacerbated by intervening problems such as transfer time constraints, remembering the number and destination of the bus to which transfer must be made, or finding a safe and convenient way to cross a street in order to make such a transfer. In many cases transfers that require the crossing of streets are made in the absence of traffic signals with pedestrian control.

4. Learning bus terminal layout and boarding areas: Even things as simple as finding entrance and exit doorways, information or ticket windows, and using amenities such as bathrooms, stairs, escalators or elevators, drinking fountains, and even change machines, can be extremely difficult and highly stressful for blind travelers. It is often difficult for a sighted person to realize the enormity of the problem faced by a blind traveler in finding and using these amenities because they are so much a part of everyday understanding and activity that it is often not possible to accept that these “simple” tasks represent major obstacles for some people. Using facilities and amenities in a bus terminal obviously gets more difficult as the terminal increases in size and the number of facilities and amenities are increased. Similarly,

finding the appropriate boarding area and selecting the correct bus from a set of possible alternatives is stressful, time consuming, and often the task cannot be completed within an appropriate time window.

Blind or vision impaired travelers are often taught strategies for dealing with these problems as part of Orientation and Mobility training or as part of survival skills taught by friends or well-wishers. The problem in each case, however, is that the environment must be learned before it can be used and a considerable amount of locational, orientational, directional, and distance information has to be remembered, recalled, and used for each specific task. Vision, of course, allows all these problems to be handled with ease in that spatial information and the geometry of the task situation can be perceived and assessed almost simultaneously. Traditionally, travel aids for blind and vision impaired travelers (such as the long cane and guide dogs or electronic aids such as laser canes and ultrasound sensing devices) have been developed primarily for obstacle avoidance purposes and not for learning routes or layouts or the spatial relations embedded in those layouts. Thus, in many cases, the mental maps of blind persons are disconnected, and are linearized and incomplete renderings of an environment when compared to the richer information incorporated into the mental maps of those with vision.

The research task

The major aim of this project was to evaluate the extent that auditory signage as represented in a particular system (TS®), can materially assist blind travelers in reducing stress and anxiety, reducing search and exploration time, reducing errors in usage of facilities, and in general, increasing the benefits and reducing the costs associated with independent travel on public transit systems.

Thus, the purpose of this research is to establish an auditory based Remote Infrared Signage System (RISS) at selected locations in the Santa Barbara Metropolitan Transit District, and to evaluate the comparative performance of blind and vision impaired travelers undertaking tasks related to catching buses and using the system with and without the auditory RISS. Procedurally the first task was to install ten TS ® transmitters in the Santa Barbara MTD bus terminal. These were located at the two entrances, (pointing both inside and outside), male and female bathrooms, two information windows, one change machine, and a pay phone. Twenty-seven blind and vision impaired subjects were required to travel from the suburban location of the Santa Barbara Braille Institute to the downtown terminal and perform a selection of tasks. The first task was to leave the suburban location of the Braille Institute and find the appropriate bus stop along the frontal street. They then had to identify the bus by an auditory message and ride it to the terminal. At the terminal they undertook the following tasks:

(i) Disembark and find the entrance to the terminal from the disembarkation area.
(ii) Learn the layout of particular amenities within the terminal.
(iii) Start at a bus located in the disembarkation area, walk to and through the terminal into the frontal street and find the departure place for express buses.
(iv) Return to the terminal, navigate through it, explore the disembarkation area to find a specific bus, and return to the Braille Institute.

All these tasks, including the initial task of finding the bus stop near the Braille Institute, were done with and without the use of the auditory signage. Subjects were randomly mixed as to whether they did the auditory signage task first or the non-auditory signage task first.

Participants

Twenty-seven subjects were used in our experiments. Fifteen of these came from the Santa Barbara Braille Institute and twelve from other sources. There were nineteen males and eight females. Average age was fifty-one; average education level was some college experience; the average age when they became blind was twenty-five; the average length of blindness was twenty-six years. Many different types of diseases or accidents were reported as the primary cause of blindness. There were twelve who had zero vision, eight had a little light recognition capability, and seven could see some large objects. All were legally blind which is defined as a visual acuity of 20/200 or less or a field of vision less than twenty degrees. All but one subject used a long cane for the test; that subject used a guide dog, and two others reported using a guide dog as their normal method of navigation. The average rating of their assessment of the value of the Orientation and Mobility training they had received was 4.67 on a 5.0 scale (with 5.0 being "very helpful"). The group averaged making twelve trips a week. Ten subjects reported taking fewer weekly trips since becoming blind; four reported the same number of trips before and after blindness; and the remaining subjects were not able to provide comparative information. When asked to report the number of motorized travel trips using different transport modes, the average response showed fifty-seven percent of trips made by private car, nineteen percent by bus, seven percent by taxi or mini-cab, and eighteen percent by easy-lift vans. The average number of trips by regular bus each week was two. On average 1.8 trips were made by easy-lift vans, 5.4 trips were made by private auto, and 0.7 trips per week by taxi; 3.7 trips per week were made as pedestrians. Our participants reported learning a new route from once to several times a month. All subjects admitted to anxiety when faced with the task of traveling in a new environment.

Procedures:

Part I

Prior to meeting subjects at the Santa Barbara Braille Institute, a background information questionnaire was completed by phone. In addition to information about type and onset of blindness and demographic information, data was collected about their amount of Orientation and Mobility training and their self-reported feelings about independent travel and spatial skills. Participants were also queried about their use of fixed route and door-to-door van services, their attitude towards different types of transit and modes of transportation, and about difficulties, fears and anxieties they experienced when using a fixed route system. Finally, participants were asked if these problems could be reduced, would they use more fixed route services? These same questions were repeated after all the experimental tasks had been completed including the use of TS ®.

Part II: Specific tasks

Participants were trained for about ten minutes at the Braille Institute in using TS ® receivers and transmitters. The TS ® transmitter was moved to varying locations around the grounds and subjects were trained to find the transmitter's location, and walk up to it. After participants had become familiar with the use of the receiver, then two transmitters were placed at forty-five, ninety, and one hundred eighty degree angles apart so that they could experience spatial differentiation from the signs and begin to experience how direction could be estimated by accessing the cone of transmittal.

After the training period the first task began. Participants were walked to the street corner nearest to the Braille Institute, guided across the street, and asked to find the bus stop pole located approximately 80 feet away. This task was done with and without the help of auditory signage. Next they were asked to detect and board the Number Three bus for a ride from that location to the MTD terminal in downtown Santa Barbara. Two TS® transmitters were placed in the bus: one was located at the door and transmitted at 90° to the side of the buses so that the entrance could be detected, and one was placed in the destination window at the front of the bus so that distant identification of the bus number and destination was facilitated. During the trip participants were told about the bus unloading area of the MTD terminal. They learned the names of the locations to which they would have to navigate so that during the actual tasks confidence could be expressed in the act of learning the location not just learning the labels. Upon arrival at the terminal, subjects were required to exit the bus and to find the door that gave entrance to the terminal (Figure 1). After this had been completed, subjects were led around the terminal twice to visit the locations of places whose name they had just learned. They were then asked to recreate the path they had followed. During this trip they started at the back door and visited in a zigzag fashion, the change machine, telephone, men's and women's bathrooms, and two information booths, as well as finding the main front door. After the final test in the terminal, participants were taken to the bus circle to simulate making a transfer. The final task involved walking from a bus to the terminal, navigating through it, exiting the front door to Chapala Street, turning in the correct direction and finding a bus stop sign for express buses on the street (about 120 feet away). Participants then returned by themselves, walked through the terminal and exited into the boarding area where they simulated finding the correct bus for the return to the Braille Institute.

The population was split into two groups, each group containing combinations of totally blind, those with some light perception, and those who were able to see some object shapes. The total group was split in half, with one group first doing all the tasks using auditory signage and the other group first doing the task without auditory signage.

After two walking trials inside the terminal, subjects consecutively undertook the sets of walking tasks with and without TS ®. They were also required to do the layout learning task and to provide some indication of the spatial information about distance, direction and location of amenities within the terminal. For example, subjects were asked to list the features they had visited in the terminal in the correct clockwise direction after they had visited them in a zigzag fashion. They were then asked to estimate the interpoint distances between all pairs of six designated locations within the terminal. They were also asked to point in the direction of each of these facilities using the two doors in turn as an origin. Directional measures were obtained by reading a compass held by the participant and pointed at the designated amenity location. Finally, after two transfer tasks had been completed, the pre-task survey was administered again and stress, anxiety, and confidence scales were again administered in a post use evaluation of an auditory signage environment.

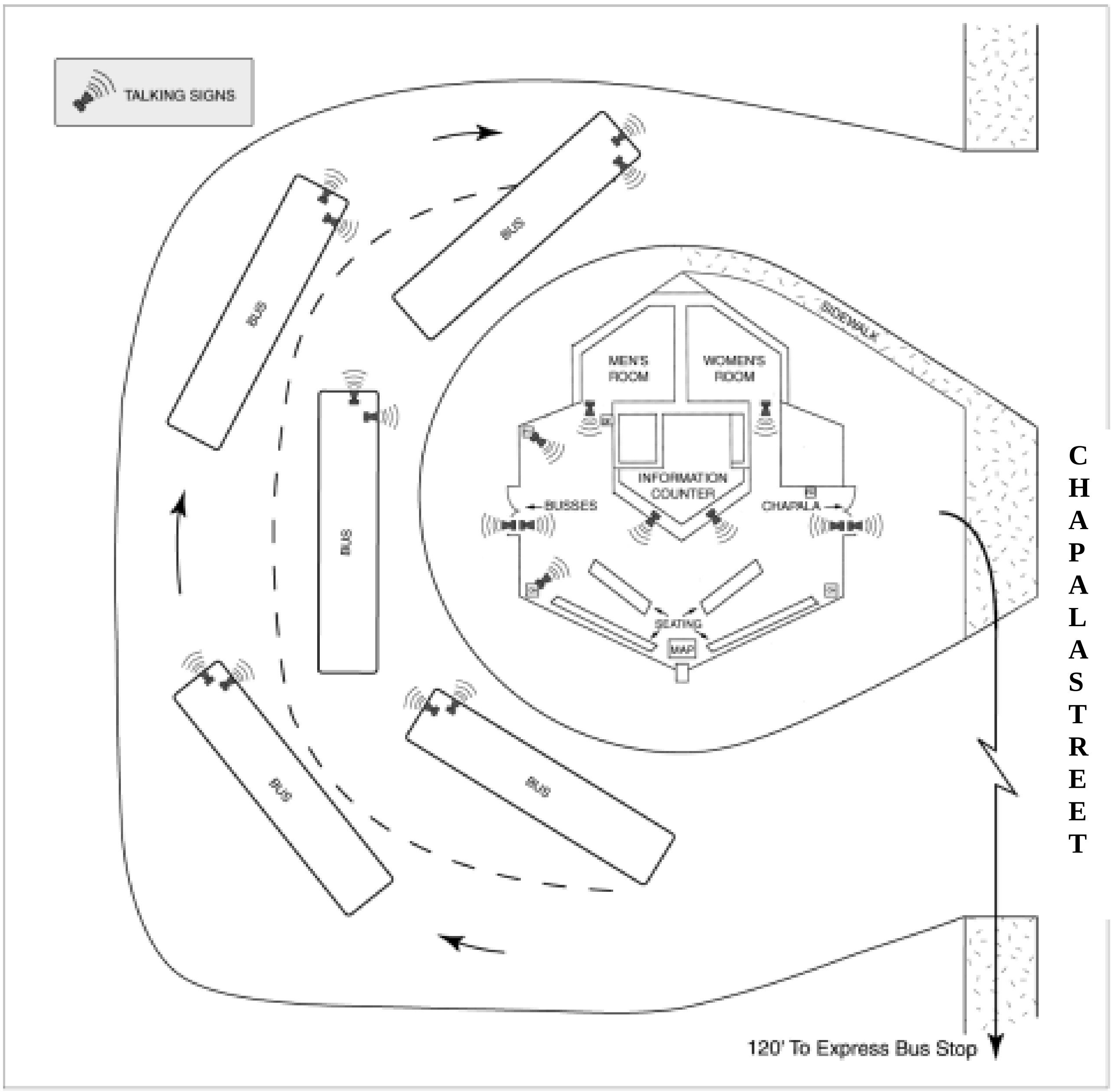


Fig 1: Santa Barbara Transit Terminal

Results

For each of the tasks that involve the use of auditory signage, the principal variable collected was response time (RT). For all tasks, performance errors (e.g. location errors) were collected. For example, the number of violations of the clockwise sequencing of amenity locations was recorded as error as was the number of missed locations: the absolute difference between real and designated distances and directions among points in the terminal were also collected and used as indicators of error. Responses to survey questions were generally recorded in terms of scale scores ranging from 1 to 5. In this section we report the results in parallel form for trials with and without the auditory signage technology. In a later section we examine responses to the pre- and post-test questionnaires.

The first task involved walking eighty feet to find and identify a suburban bus stop pole. Participants conducted two trials, and were split into two groups such that one group used auditory signage in the first trial and the second group used auditory signage on the second trial. For the group as a whole, walking without TS® averaged 107 secs.; when TS® were used, average time for the whole group dropped to 32 secs. (significant difference at $p<0.0014$). For the group that did not use TS® on the first trial their average time was 114 seconds. On the second trial, when using auditory signage the average time was 31 seconds. They reduced their time on average by 83 seconds over the two trials and this was significant at $P<.008$. However, some of this reduced time must be attributed to learning after the first trial. During the no auditory signage trials performances, seven of the twenty-seven participants (approximately twenty-five percent) missed the bus stop pole completely, even when given a maximum of 300 seconds to find the pole. In every trial when auditory signage was used, no participant failed to find the object of the search and response times were significantly different (T-test provide $P<0.0014$) (Table I). For the group that used TS® on the first trial, average time was 35 secs. When no- TS® were used on the second trial, RT was on average, 99 secs. (significant difference of $p<0.04$)When the participant group were broken down first by whether or not they used auditory signage or no auditory signage on the first trial and were grouped according to whether they were totally blind, could see some light, or perceive some shape, the relevant significant values for each group were: when TS® was used on the first trial $P<0.09$; $P<0.19$; $P<0.31$; when no-TS® was used on the first trial $P<0.06$; $P<0.18$; and $P<0.16$ respectively. Most probably the small n-sizes (5,4,3 and 7,4,4 respectively for each of the different groups), may account for these non-significant p-values.

The second task was undertaken at the bus terminal, which is a centrally located building surrounded by a semicircular bus disembarkation area (see Figure 1). The disembarkation area has two lanes and depending on the amount of traffic buses can occupy quite different locations at each successive disembarkation time. A particular bus can park short of, next to, or beyond the door to the main terminal. These problems make it difficult to find the door to the terminal on any particular trial, because one's orientation is confused upon exiting the bus. Nevertheless, upon arrival at the terminal we recorded response times for individuals based on the time taken to find the terminal door.

Table I.

80' Walk to Bus Stop

Subjects by Vision Type – 1st Trial Condition

		RT TS	RT NTS	Difference with TS
TOTAL BLIND	NTS FIRST	38	59	21
TOTAL BLIND	NTS FIRST	36	54	18
TOTAL BLIND	NTS FIRST	42	300	258
TOTAL BLIND	NTS FIRST	31	31	0
TOTAL BLIND	NTS FIRST	19	39	20
TOTAL BLIND	NTS FIRST	37	40	3
TOTAL BLIND	NTS FIRST	37	300	263
TOTAL BLIND	TS FIRST	35	31	-4
TOTAL BLIND	TS FIRST	65	300	235
TOTAL BLIND	TS FIRST	47	300	253
TOTAL BLIND	TS FIRST	37	35	-2
TOTAL BLIND	TS FIRST	14	24	10
SEE SOME LIGHT	NTS FIRST	N/A	N/A	
SEE SOME LIGHT	NTS FIRST	35	300	265
SEE SOME LIGHT	NTS FIRST	24	40	16
SEE SOME LIGHT	NTS FIRST	24	41	17
SEE SOME LIGHT	TS FIRST	27	35	8
SEE SOME LIGHT	TS FIRST	23	300	277
SEE SOME LIGHT	TS FIRST	34	28	-6
SEE SOME LIGHT	TS FIRST	25	27	2
SEE SOME OBJECTS	NTS FIRST	23	23	0
SEE SOME OBJECTS	NTS FIRST	20	47	27
SEE SOME OBJECTS	NTS FIRST	42	300	258
SEE SOME OBJECTS	NTS FIRST	19	24	5
SEE SOME OBJECTS	TS FIRST	37	32	-5
SEE SOME OBJECTS	TS FIRST	33	29	-4
SEE SOME OBJECTS	TS FIRST	39	43	4
Average		32	107	75
Total Blind Average		37	126	90
Some Light Perception Average		27	110	83
See Some Objects Average		30	71	41
T-Test Total Blind			0.01	
T-Test Some Light			0.07	
T-Test See Some Objects			0.15	
T=Test All			0.0014	

The average time taken after disembarking to find the terminal door without the use of auditory signage was 54 seconds; the average time using auditory signage was 19 seconds. A significant difference (P<0.0075) resulted (Table II). Given the uncertainty as to where a given bus would stop with respect to the terminal door, subjects were allowed to ask anyone except the researcher for help – but few did.

Again, the participant group was split into those who first accessed the door using auditory signage and those who had no such help. Without the use of auditory signage, two subjects were unable to find the terminal door within the given time period of 300 seconds. Again, the subjects were required to undertake two trials. When they used no auditory signage on their first trial their average time was 58 seconds. Time for the second trial when auditory signage was used was 20 seconds. The time reduction because of the use of TS ® was 38 seconds between the two trials (significant at P<0.02). But again, this difference can be mediated somewhat by the learning effects. When subjects used auditory signage for their first trial, their average time was 18 seconds. The time for the second trial without auditory signage was 49 seconds. Thus, in this case, their performance time was increased by 31 seconds, a difference that was significant only at P<0.098. Again, when broken into the two subsets with Group A using auditory signage first and Group B having no auditory signage first, and differentiating between totally blind, some light perception, and some shape discrimination, the resulting statistics are: P<0.148; P<0.193; and P<0.180 for those using TS ® first; and P<0.09; P<0.13; and P<0.06 respectively for the group using no auditory signage first. Here there are obvious learning effects reinforced by the use of auditory signage which allow a second trial even without the use of auditory signage to have significantly reduced performance times (Table II).

In the next task subjects were led into the terminal and walked around, visiting the eight locations at which TS ® transmitters had been placed. Again, the groups were split into non-auditory signage and auditory signage conditions on the first trial. In the non-auditory signage condition they were led around using sighted guide technique (i.e. holding the experimenter's arm). In the auditory signage condition they were led around and asked to scan the room with the receiver which allowed them to pick up cues from other amenity locations. After two guided trips they were asked to retrace the path. They stopped at each point and the segment times were collected. If they failed to find the target within 180 seconds they were led to it. The average time for the condition without TS ® was 177 seconds and for the trials using auditory signage 113 seconds. A significant difference (P<0.037) resulted (Table III).

For participants without auditory signage on the first trial the average time was 215 seconds; their time for the second trial using auditory signage was 105 seconds. Travel time was reduced by 110 seconds over the two trials which was a difference significant at P<0.04. When participants used auditory signage on their first trial their average time was 123 seconds; the time for the second trial without auditory signage was 130 seconds. The absolute difference in performance time was only 7 seconds, not a statistically significant difference. However, this did appear to show that using auditory signage helped the participants learn the locations and when they had to perform the task without the auditory aid, they had considerable success in correctly finding such locations.

Table II

From Bus to Terminal Door

Subjects by Vision Type – 1st Trial Condition

		RT TS	RT NTS	Difference with TS
TOTAL BLIND	NTS FIRST	25	63	38
TOTAL BLIND	NTS FIRST	21	58	37
TOTAL BLIND	NTS FIRST	34	32	-2
TOTAL BLIND	NTS FIRST	12	18	6
TOTAL BLIND	NTS FIRST	9	11	2
TOTAL BLIND	NTS FIRST	28	21	-7
TOTAL BLIND	NTS FIRST	20	21	1
TOTAL BLIND	TS FIRST	24	300	276
TOTAL BLIND	TS FIRST	22	36	14
TOTAL BLIND	TS FIRST	17	29	12
TOTAL BLIND	TS FIRST	22	19	-3
TOTAL BLIND	TS FIRST	8	28	20
SEE SOME LIGHT	NTS FIRST	47	300	253
SEE SOME LIGHT	NTS FIRST	27	56	29
SEE SOME LIGHT	NTS FIRST	18	50	32
SEE SOME LIGHT	NTS FIRST	6	18	12
SEE SOME LIGHT	TS FIRST	14	39	25
SEE SOME LIGHT	TS FIRST	27	17	-10
SEE SOME LIGHT	TS FIRST	13	21	8
SEE SOME LIGHT	TS FIRST	15	21	6
SEE SOME OBJECTS	NTS FIRST	20	32	12
SEE SOME OBJECTS	NTS FIRST	10	99	89
SEE SOME OBJECTS	NTS FIRST	7	13	6
SEE SOME OBJECTS	NTS FIRST	13	76	63
SEE SOME OBJECTS	TS FIRST	13	18	5
SEE SOME OBJECTS	TS FIRST	24	45	21
SEE SOME OBJECTS	TS FIRST	18	16	-2
Average		19	54	35
Total Blind Average		20	53	33
Some Light Perception Average		21	65	44
See Some Objects Average		15	43	28
T-Test Total Blind			0.09	
T-Test Some Light			0.09	
T-Test See Some Objects			0.04	
T=Test All			0.0075	

Table III

Walk Around Terminal

Subjects by Vision Type – 1st Trial Condition

		RT TS	RT NTS	Difference with TS
TOTAL BLIND	NTS FIRST	94	108	14
TOTAL BLIND	NTS FIRST	189	459	270
TOTAL BLIND	NTS FIRST	127	570	443
TOTAL BLIND	NTS FIRST	129	915	786
TOTAL BLIND	NTS FIRST	59	76	17
TOTAL BLIND	NTS FIRST	165	150	-15
TOTAL BLIND	NTS FIRST	92	112	20
TOTAL BLIND	TS FIRST	113	102	-11
TOTAL BLIND	TS FIRST	228	446	218
TOTAL BLIND	TS FIRST	115	150	35
TOTAL BLIND	TS FIRST	131	84	-47
TOTAL BLIND	TS FIRST	105	95	-10
SEE SOME LIGHT	NTS FIRST	86	71	3
SEE SOME LIGHT	NTS FIRST	137	156	19
SEE SOME LIGHT	NTS FIRST	96	127	31
SEE SOME LIGHT	NTS FIRST	66	80	14
SEE SOME LIGHT	TS FIRST	114	63	-51
SEE SOME LIGHT	TS FIRST	112	114	2
SEE SOME LIGHT	TS FIRST	66	62	-4
SEE SOME LIGHT	TS FIRST	121	112	-9
SEE SOME OBJECTS	NTS FIRST	77	70	-7
SEE SOME OBJECTS	NTS FIRST	69	99	30
SEE SOME OBJECTS	NTS FIRST	71	83	12
SEE SOME OBJECTS	NTS FIRST	123	149	26
SEE SOME OBJECTS	TS FIRST	117	122	5
SEE SOME OBJECTS	TS FIRST	143	116	-27
SEE SOME OBJECTS	TS FIRST	115	98	-17
Average		113	177	64
Total Blind Average		129	272	143
Some Light Perception Average		100	98	-2
See Some Objects Average		102	105	3
T-Test Total Blind			0.04	
T-Test Some Light			0.43	
T-Test See Some Objects			0.36	
T=Test All			0.037	

Again, breaking the performance down into those who used auditory signage first and those who used no auditory signage first, and noting the performance for each of the blind, some light perception, and some shape groups, the following results of t-tests were obtained: P<0.24; P<0.14; and P<0.15 when TS ® were first used; and P<0.05; P<0.15; and P<0.08 when no TS ® were used on the first trial. Again, there is indication that the use of the auditory signage reduced subjects' time of performance of tasks when such signage was available and provided substantial differences in terms of reduction of travel time when used to guide travel on the second trial.

One of the most difficult tasks agreed to by all actual and potential bus travelers among the blind and vision impaired subjects was that of transferring between buses at a busy terminal. We simulated two transfers – one from the bus circle through the terminal to the front door, then along the frontal street to the express bus stop which was located 120 feet west of the terminal; and second, a return path leaving the express bus stop and walking to the door of the terminal, traveling through it, exiting onto the bus circle loading area, and finding the proper bus. Participants were allowed to ask anyone except the researcher for help but again, few did. The average time for the condition in which no auditory signage was used was 357 seconds; the average time for the condition in which auditory signage was used was 180 seconds. A significant difference (P<0.00005) resulted. For the twenty-seven total subjects across all trials, thirteen locations were missed completely, most of them involving not finding the express bus pole or not finding the correct bus in the departure circle. Again, subjects performed this task twice, once in a TS ® first condition and once in a no-TS ® first condition. When no auditory signage was used on the first trial average time was 323 seconds; an average elapsed time on the second trial when auditory signage was used was 173 seconds. Over the two trials response times were reduced by 150 seconds which was significant at P<.0003. If TS ® were used on the first trial average response time was 190 seconds; average time for the second trial when no auditory signage was used was 400 seconds. The increase of time averaged 210 seconds which was significant at P<0.004. For the two conditions with and without auditory signage on the first trial, and differentiating the population into totally blind, some light, and some shape groups, the results were as follows: P<0.009; P<0.104; and P<0.066 when auditory signage was used on the first trial; and P<0.036; P<0.066; and P<0.040 when no TS® were used on the first trial. Differences in response times across the entire group are given in Table IV.

If we accumulate performance over all four tasks, and differentiate between the three groups (totally blind, some light, and some objects), some interesting results emerge (see Figure 2). Overall, the totally blind had the poorest levels of performance while those who could see some objects had the best performance levels without TS®; using TS® there were only small differences between the groups. Within each group, however, the difference in response times when auditory signage was and was not used was highly significant. The increased time for each of the four tasks across the total group when auditory signage was not used is shown on Figure 2.

Distance and direction tasks

After the walking tasks in the terminal, the participants were required to give interpoint distance estimates among six locations of designated amenity locations. They were given two standard distances, forty-three feet between the front and back doors of the terminal, and thirteen feet between the two information windows. By the time they were asked to do this task, subjects had

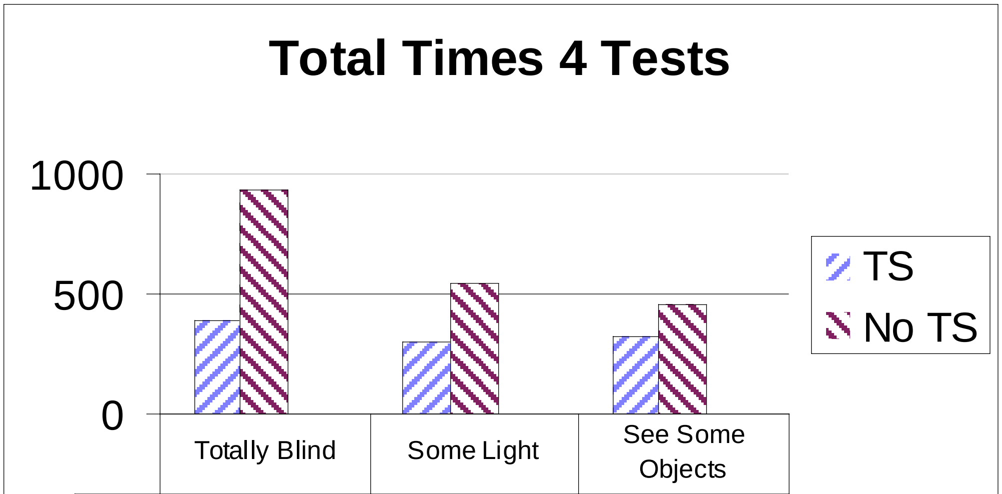
Table IV

Transfers

Subjects by Vision Type – 1st Trial Condition

		RT TS	RT NTS	Difference with TS
TOTAL BLIND	NTS FIRST	181	243	62
TOTAL BLIND	NTS FIRST	254	985	731
TOTAL BLIND	NTS FIRST	303	460	157
TOTAL BLIND	NTS FIRST	185	362	177
TOTAL BLIND	NTS FIRST	154	224	70
TOTAL BLIND	NTS FIRST	196	295	99
TOTAL BLIND	NTS FIRST	148	230	82
TOTAL BLIND	TS FIRST	206	738	532
TOTAL BLIND	TS FIRST	288	601	313
TOTAL BLIND	TS FIRST	191	709	518
TOTAL BLIND	TS FIRST	192	785	593
TOTAL BLIND	TS FIRST	142	178	36
SEE SOME LIGHT	NTS FIRST	145	460	315
SEE SOME LIGHT	NTS FIRST	166	256	90
SEE SOME LIGHT	NTS FIRST	149	255	106
SEE SOME LIGHT	NTS FIRST	121	137	16
SEE SOME LIGHT	TS FIRST	157	158	1
SEE SOME LIGHT	TS FIRST	196	481	285
SEE SOME LIGHT	TS FIRST	127	199	72
SEE SOME LIGHT	TS FIRST	165	211	46
SEE SOME OBJECTS	NTS FIRST	141	165	24
SEE SOME OBJECTS	NTS FIRST	171	303	132
SEE SOME OBJECTS	NTS FIRST	126	282	156
SEE SOME OBJECTS	NTS FIRST	147	183	36
SEE SOME OBJECTS	TS FIRST	189	264	75
SEE SOME OBJECTS	TS FIRST	228	263	35
SEE SOME OBJECTS	TS FIRST	201	218	17
Average		180	357	177
Total Blind Average		203	484	281
Some Light Perception Average		153	270	116
See Some Objects Average		172	240	68
T-Test Total Blind			0.0012	
T-Test Some Light			0.0139	
T-Test See Some Objects			0.0090	
T=Test All			0.00005	

Figure 2



	Totally Blind	Some Light	See Some Objects
TS	389	301	319
No TS	936	543	459
P<	0.000016	0.0014	0.0026

already walked the configuration either 3 or 6 times and it was presumed that their interpoint distance estimates would reflect the spatial properties of the configuration or layout as they had learned it by walking. Examining the signed distance errors in feet for each origin-destination pair shows that only the distances from the back door to the women's bathroom, the phone to the women's bathroom, and the men's room to the women's bathroom, were differently estimated in the TS® first and no-TS® first conditions. Each of these paths was non-linear and required more mental manipulation to calculate Euclidean distances. While there were some considerable variations between the two conditions, there was no clear pattern showing that TS® had facilitated better estimation and recall of interpoint distances among the designated locations used in the terminal exercises. The results also indicate that repeated trials had produced reasonable layout learning whether or not TS® were used.

When examining absolute values of the differences for the estimates when TS®and no- TS® conditions were in force on the first trial, there are no significant differences among the distance estimates (Table VA and VB). However, the distances from the phone to women's bathroom and men's to women's bathroom are not well estimated, because of the non-linear association between them. There are no significant differences in the absolute values of the error means.

No clear results were obtained from direction estimates. It appeared that a significant cause of this was the effect of magnetic disturbance on the compass used in the pointing task. Field experimenters noticed significant differences between the direction pointed at by the subjects and compass readings at that time. The variation was so great that no confidence was placed in the data so collected.

Table V(A)

Absolute Value distance error using TS

	AVG TS	TS 2nd	TS 1st	p<
Phone-Men's	4.2	4.3	4.0	0.83
B door - Change	3.6	3.7	4.2	0.25
B door - Phone	3.6	3.7	3.4	0.80
B door - Men's	6.6	5.7	7.7	0.26
Women's - F door	7.0	6.4	7.7	0.47
Men's-Women's	7.6	8.6	6.4	0.38
Change - Phone	7.3	7.0	7.7	0.74
Change - Men's	8.5	8.4	8.6	0.95
Phone - Women's	9.4	9.9	8.8	0.60
B door - Women's	7.6	7.4	7.8	0.88
Men's - F door	7.0	7.4	6.6	0.75
Change - Women's	9.4	9.3	9.6	0.96
Change - F door	6.4	6.8	5.8	0.77
B door - F door	0.4	0.0	0.8	0.14
Phone - F door	6.8	6.4	7.4	0.80
Average Error	6.4	6.3	6.4	0.93
				No Sig

Table V (B)

Distance Errors: Absolute Value distance error NTS

	AVG NTS	NTS 1st	NTS 2nd	p<
Phone-Men's	4.0	3.5	4.6	0.39
B door - Change	3.8	4.5	3.0	0.38
B door - Phone	3.9	3.5	4.4	0.35
B door - Men's	5.8	5.2	6.6	0.41
Women's - F door	6.4	6.6	6.2	0.85
Men's-Women's	9.9	11.6	7.8	0.12
Change - Phone	7.4	7.3	7.5	0.92
Change - Men's	9.7	10.6	8.7	0.53
Phone - Women's	9.8	11.4	7.7	0.12
B door - Women's	9.1	8.6	9.8	0.61
Men's - F door	8.3	9.4	7.0	0.46
Change - Women's	8.5	9.2	7.6	0.62
Change - F door	6.8	6.4	7.2	0.81
B door - F door	0.4	0.1	0.8	0.38
Phone - F door	7.5	7.3	7.8	0.91
Average Error	6.8	7.0	6.4	0.68
				No Sig

In an attempt to confirm the results from the distance estimation procedure, estimated distances were analyzed using multidimensional scaling. Interpreting the distance as a measure of spatial similarity or proximity, the multidimensional scaling algorithm creates a minimum dimensional configuration of the points used as origins and destinations. If the original configuration is used as the starting configuration, successive iterations in effect distort the original layout to fit each participant's interpoint distance estimates. The index of fit (Stress) consequently can be interpreted as a measure of departure from reality, or an indication of the amount of distortion in the memorized and recalled cognitive configuration of each participant. Since distance estimations were collected after both the TS® and No-TS® trials, a layout matching measure (or index of spatial similarity) can be calculated. In its simplest form this is a difference between the goodness of fit (Stress) statistic for the TS ® first and non- TS ® first conditions. The results are shown on Table VI. Overall, subjects in both TS® and no-TS® conditions were able to reproduce the actual configuration of points with a reasonable degree of success. Seventeen of 26 subjects had stress values less than 0.10 in the TS® condition, while eighteen out of 26 in the No-TS® condition met this criteria, thus producing similar good layout fits. The differences between Stress values per TS® and No-TS®conditions were usually small, indicating that a good understanding of the layout had been achieved.

Pre and Post test Interviews

Spatial Anxiety: To better understand why the blind travel less often and avoid transit when possible, we asked in-depth questions about various situations and specific areas that this group encounters in everyday activity. Stress and anxiety were measured using scales developed by Lawton (1994), and were collected in pre- and post-experimental conditions.

Lawton's scale used a four-point evaluation procedure. Subjects rated a variety of situations as either "extremely anxious", "very anxious", "somewhat anxious", or "not at all anxious". Responses were assigned a rank of 1-4 respectively. Table VII shows the average ranking for the six questions that make up Lawton's Anxiety Scale. These types of questions lead to an understanding of what situations cause problems for the blind traveler. Reported anxiety was approximately one whole category less when they considered a TS® installation in these situations. With TS®, their answers were skewed toward "not at all anxious." The range of anxiety was much smaller between situations, showing that TS® appeared not only to reduce anxiety but also to reduce it more for the situations that were ranked as the most anxiety producing. TS® installations were rated as causing little anxiety in these normally difficult situations.

Perceived Difficulty: It is widely known that the blind and vision impaired have difficulties and stress when traveling and when using transit but little is known about which specific tasks produce these feelings. Understanding which parts of transit use cause difficulty and stress can lead to understanding of how and where to address these concerns. Table VIII indicates that use of TS® reduced perceived difficulty of tasks on average by two categories of difficulty.

Table VI

Actual distances vs. Subjects estimated interpoint distances:

Multidimensional Scaling Results

			MDS stress		
		Actual Distances:	Stress = 0.00		
		Estimation:	Stress		Difference
SUBJECT	Vision		w/ TS	w/out TS	NTS-TS
N-1	20/400		0.04	0.12	0.08
N-2	AB		0.02	0.11	0.09
N-7	Total		0.15	0.12	-0.03
N-8	TB		0.05	0.07	0.02
N-9	TB		0.32	0.29	-0.03
N-10	20/400		0.06	0.08	0.02
N-11	AB 2%		0.11	0.09	-0.02
N-12	?		0.02	0.02	0
N-14	TB		0.24	0.18	-0.06
N-15	TB		0.04	0.09	0.05
N-16	TB		0.23	0.2	-0.03
N-17	TB		0.02	0.07	0.05
N-18	20/300		0.03	0.06	0.03
N-19	?		0.05	0.1	0.05
N-20	20/400		0.06	0.05	-0.01
T-2	20/400		0.11	0.04	-0.07
T-7	20/700		0.18	0.08	-0.1
T-8			0.04	0.05	0.01
T-11	AB		0.18	0.11	-0.07
T-12	20/300		0.08	0.04	-0.04
T-13	TB		0.04	0.1	0.06
T-16	TB		0.08	0.03	-0.05
T-17	TB		0.09	0.08	-0.01
T-18	20/400		0.24	0.43	0.19
T-19	10 & 15degree		0.05	0.05	0
T-20	TB		0.03	0.08	0.05
* One subject stress could not be calculated					
		AVG	0.10	0.11	0.01
		AVG NTS 1st	0.10	0.11	0.01
		AVG TS 1st	0.10	0.10	0.00
		T-Test by condition	0.87	0.76	0.51
		T-Test TS-NTS	0.39		
		T-Test NTS 1st	0.32		
		T-Test TS 1st	0.47		

Table VII: Anxiety Measures

Statement	Pre-test before TS	Post-test with TS	Improved score
Leaving a store that I have been to for the first time and deciding which way to turn to get to a destination makes me:	3.19	3.78	0.59
Finding my way out of a complex arrangement of offices that I have visited for the first time makes me:	2.70	3.70	1.00
Finding my way around an unfamiliar mall makes me:	2.67	3.59	0.93
Finding my way to an appointment in an area of town with which I am not familiar makes me:	2.69	3.56	0.87
Trying a new route that I think will be a shortcut without the benefit of a map makes me:	2.41	3.48	1.07
Finding my way back to a familiar area after realizing I have made a wrong turn and become lost makes me:	2.37	3.56	1.19

Table VIII: Estimated Task Difficulty

	Pre-test: W/O TS	Post-test: With TS	Improvement with TS
Finding the proper bus stop	2.44	4.81	2.37
Finding and boarding the proper bus	3.19	4.85	1.66
Having to cross busy streets	3.11		
Transferring to another bus on the line	2.78	4.70	1.92
Finding my way around the main terminal	2.52	4.78	2.26
Finding the proper bus among those at the terminal	2.56	4.74	2.18
Transferring from one bus to another at the main terminal	2.63	4.70	2.07

(Note: Subjects rated the degree of difficulty of various tasks while using transit. Before they tried TS® the average rating was between very difficult and difficult. After using TS® the ratings changed to between not very difficult and not at all difficult. Overall, difficulty dropped by over 2 categories.)

When relating perceived difficulty to the specific task of using transit, and employing a 5 point scale (extremely difficult [1] - not at all difficult [5]), we asked: how difficult were these situations when using transit in an UNKNOWN AREA or when planning a trip? Table VIII shows that on average these tasks were rated as being "difficult" for blind travelers. Finding the proper bus and crossing busy streets were rated the least difficult; transferring buses on the line was a more difficult task; transferring buses at the terminal and finding the proper bus at the terminal were rated even more difficult; finding one's way around an unfamiliar bus terminal was judged the next most difficult; and the most difficult task was finding a bus stop. At most bus stops there is no way for a blind person to find or identify the pole unless there are other possible cues such as benches or shelters. There are few of these in the Santa Barbara area. We asked the same questions after the subjects had used TS® in the experiment and actually encountered each task situations. We did not test TS® at a street crossing so we did not ask them to rate the difficulty of that task when using the TS® system.

When using TS®, the results were quite powerful. The difficulty ranking dropped by approximately two full categories. All six tasks were rated very close to "not at all difficult" with the vast majority of the subjects using that rating. The two most difficult tasks showed that TS® reduced difficulty by about 2.5 categories, thus changing perceived difficulty so much that it appears that the installation of this type of system would give blind travelers almost the same ease of travel as is available to the sighted public.

Perceived Stress: The question asked was: Using a 5 point scale (extremely stressful [1] - not at all stressful [5]) how stressful are these situations when using transit in an UNKNOWN AREA or when planning a trip? Table IX shows that on average these tasks were rated as being "stressful" for all the blind travelers. Finding the proper bus was rated the least "stressful" as it is always possible to ask the driver for information. Transferring buses on the line and crossing busy streets were rated a little more than "stressful." Finding a bus stop, transferring buses at the terminal, finding a bus at the terminal and finding one's way around the terminal were all rated between "stressful" and "very stressful." It is interesting to note that these four tasks were rated as more stressful than crossing a busy street. We believe that the sighted public would think that crossing a street was much more stressful than these other tasks. This research shows that many transit tasks are actually more stressful than crossing a busy street.

We asked the same questions after the subjects had used TS® in the experiment and actually encountered these situations. The results were also powerful. The stress ranking dropped by approximately 2 full categories. All six tasks were rated very close to "not at all stressful" with the majority of the subjects giving these tasks that rating.

The next question asked: If TS® were widely located in the Santa Barbara area, would you use transit more often? Our pre-test questions asked if they would use transit more often if it could be made “easier and less stressful.” After using TS®, we asked them specifically if TS® were installed at bus stops, on buses and at terminals, would that prompt them to use transit more often? The results were nearly identical, showing that TS® did meet their expectations of what

Table IX: Pre and Post Test Stress Estimates

	Pre-test: W/O TS	Post-test: With TS	Improvement with TS
Finding the proper bus stop	2.81	4.74	1.93
Finding and boarding the proper bus	3.00	4.67	1.67
Having to cross busy streets	2.85		
Transferring to another bus on the line	2.89	4.63	1.74
Finding my way around the main terminal	2.70	4.67	1.97
Finding the proper bus among those at the terminal	2.70	4.74	2.04
Transferring from one bus to another at the main terminal	2.81	4.70	1.89

was implied by "easier and less stressful." The overall results show an average answer of about 1.3, meaning they lean toward the "strongly agree" category.

Other information sought in the post-test included queries as to what difference RISS made when using transit, and what behavioral changes RISS produced from the subject's normal mode of operation for using transit services, (Table X).

Table X: Support for TS® installations

	Ratings
TS in the MTD terminal are very helpful	1.15
The TS in the terminal should be made permanent	1.11
I would like TS installed on all buses	1.07
I would like TS installed at bus stops	1.07
I would like TS installed at street crossings that tell what street I am at and which direction I am facing.	1.22
I would like TS installed at crosswalk to keep me in the walkway and tell me the WALK/DON'T WALK signal.	1.30
TS on retail and other buildings would help me navigate and let me know what shopping or activities were available	1.11

Open-ended Questions

To better understand problems facing blind travelers and how a RISS could mediate those problems we asked 5 unstructured, open-ended questions regarding the use of TS®. Subjects had no restriction on how many opinions they could express and all answers were recorded. The responses were categorized for each question. Four Ph.D. students in Human Geography were asked to sort the answers by category. Later some changes were made to facilitate final categorization. The statements were then parsed and each statement was put into a category. If the answers were not unanimous, the four students discussed the classification until agreement was reached.

During the field experiments, the first question was asked after the subjects had walked 80’ to find a bus stop pole. Twenty-six subjects were asked what was different about finding a pole using a RISS compared with their regular method. Two of the categories of answers dealt with the properties of a RISS. Fifteen statements were made indicating that the system gave them a direction to follow, such as “gives direction” or “points like a beam.” Another 15 statements mentioned that a RISS gave positive identification, such as “tells you when at bus stop” or “knew it was a bus stop.” Other answers dealt with positive changes to their normal travel experience. Thirteen statements were made about easier or more efficient travel such as “easier”, “more simple” and “no guesswork.” Another 14 statements were made about the confidence and assurance that the system gave them. Some typical statements were “comfortable and reassuring”, “more sure of where you are” and “TS ® gives confidence.” Eight people made statements that they “didn’t have to ask” for help. These were put in a final category. In all, 26 subjects made 62 statements about how TS® was different from their regular method. All statements were positive about their experience with the system.

These statements also shed light on problems and fears of blind travelers. Since 15 statements were made about TS® giving direction and another 15 were made about getting positive identification, we can see that the blind traveler is well aware that the lack of directional cues and positive identification of locations cause problems. Thirteen statements were made about the RISS being more efficient or easier, another indication that unaided blind navigation is filled with extra effort. Confidence and assurance were mentioned in 14 statements. Without aided navigation, therefore, there is strong doubt and fear. Five people mentioned they “did not have to ask” which can lead us to an understanding that having to ask people for help is something that is on the minds of the blind traveler. All these statements illustrate some of the problems and concerns facing the blind and vision impaired when attempting to travel independently.

When asked about problems of finding and boarding the proper bus, fourteen people made statements about the RISS giving them the proper identification of the bus. Some answers were “tells which bus it is and where it goes” and “didn’t have to flag and stop all buses.” Another 10 statements dealt with the positive information about where to board the bus. A transmitter next to the door guides the user directly to the opening without having to search along the side of the bus. Some examples of this type of statement were “knew exactly were door is” and “didn’t have to feel for bus and door.”

Other statements had more to do with positive changes in the travel experience. Almost all subjects, 23, mentioned specifically that they didn’t have to ask for help or information. Another 6 used the word or made statements about how the system gave them independence such as “this time I was independent” or “didn’t have to rely on anyone else.” Eighteen statements were made about the system being easier and quicker than their regular method, such as “saves time when many buses in line” or “easier because you know for sure.” Three statements were put in the “safe and secure” category, such as “don’t have to get up close” or “more positive and secure.”

Three statements were made about there being less stress when using the system, such as "not nervous."

These statements show us that without a sighted guide or a RISS, blind travelers face many problems finding and boarding the proper bus. Their responses showed that they had major problems with getting a positive identification of the bus and with finding the door location. They almost unanimously voiced their displeasure with having to ask for help and information and in being dependant on others. By rating TS® as easier and quicker than their regular method, they let us know how time-consuming and difficult this task is without assistance. They also showed that fear, stress and issues of safety were present in their regular method of travel.

Post experiment opinions

At the conclusion of the experiment, after the subjects had used TS® for many different transit tasks, we asked specific questions about their opinion of the system in different settings, which is reported elsewhere. The last questions asked of our 27 subjects were three open-ended, unstructured questions. All responses were recorded, no limit was put on the number of observations they made. The first of these queried whether, if TS® were installed all around town, how would this affect your travel? Twenty-five statements were made that they would travel more, using that phrase or statements like "would take more trips" or "would travel to new places." Another 17 made comments that were categorized as "easier and faster travel." They used those words or made comments like "saves lots of time and trouble" and "wouldn't get lost." Fifteen statements were made that they would be more independent or not need help from others. Another 5 people specifically said they wouldn't have to ask for help. Eighteen statements were made about the system giving them an improved mental state or less anxiety. Some typical comments were ''more relaxed", ''more spontaneous" and "not nervous.'' Ten statements were made using the terms safety or security. Another 8 statements were made saying the subject would feel more confident or have more assurance.

All 98 statements about how TS® would affect their travel were regarded as positive to the effects the system would have on travel by blind and vision impaired people. It appears that the use of TS® would give blind people the independence, and confidence, to travel more often, travel easier and faster and with less mental stress and fear.

The next question asked where would participants like to see TS ® installed? This question showed the value of open-ended questions, as some responses were given that the researchers had not considered. One blind subject who rides in cars a lot wanted to see them installed at expressway interchanges so he would know where he was during a trip. Another thought they would be helpful to announce sidewalk grade and width changes. Another mentioned he would like to see them on cruise ships so that he could explore without having a sighted guide. Structured questions designed by a researcher might have missed some of these types of locations.

The types of places that were suggested were broken down into nine categories. Twelve suggestions were put into the "everywhere" category, 6 people used that term and others said things such as "all over" and "worldwide." Nine suggestions were placed in a category "Multipurpose / large public areas." These included statements like "downtowns" or a "campus." Subjects mentioned 23 locations that were large or public buildings, including museums and libraries. Some suggestions were specific like "convention centers" while many mentioned government or public buildings. The most mentioned location (29) was that of retail stores. These included mention of places such as malls, shopping centers and grocery stores. Recreational locations such as parks, amusement parks, theaters and entertainment areas were suggested 23 times. Locations that provide services like banks, hotels, medical offices and restaurants were mentioned 23 times. Suggestions to put TS® at street corners and intersection were made 16 times. Transit, including buses, airports and transit stations was mentioned 23 times. Seven peoples suggested using TS ® to label amenities or provide information such as restrooms, public phones, building directories and information kiosks.

Finally, we asked, "What is your overall opinion of TS®?" The last question allowed subjects to express their overall opinion of TS® after they had used them during the experiment. There were 93 opinions expressed. Two were somewhat negative, one did not like holding the receiver in the hand and the other suggested the ergonomics could be improved. There were 34 responses which we categorized as "superlatives." These included such strong support for the system as "fantastic", "great idea for the blind", "wonderful" and "terrific." Another 12 people expressed a desire to see them installed immediately. These included such statements as "tremendous need", "should be universally installed" and "should be done on a large scale." The enhanced travel that a RISS gives to the blind traveler was mentioned 18 times. These statements included opinions like "best thing yet for blind orientation", "encourages spontaneous and more travel", "opens up possibilities for blind" and "great for unfamiliar places." "Independence" or "not relying on others" was mentioned 12 times by the subjects. Four people specifically mentioned the increased safety they felt when using the system. A more positive mental state or less stress was mentioned 11 times. Some of these opinions were "uncertainties would not stop me anymore", "TS® would help me feel reconnected to the outside world", "much more secure and comfortable", "help me re-establish a new life", and "lowers stress level."

DISCUSSION

The results of our various testing procedures were highly supportive of our hypotheses relating to the positive impact of auditory signage on location, path following, terminal use, and transit transfer activities. In all cases, participants showed dramatic decreases in travel or response time as a result of using auditory signage (Figure 3). From the task of finding a suburban bus stop pole to finding the correct bus in a designated multiple bus parking area adjacent to the main terminal, response times were reduced significantly when TS® were used, many times by a factor of four or five. In addition, in all of the tasks, some subjects without the use of auditory signage, were unable to complete the task successfully within the given time period. This means they would not have been able to identify, catch, or use a bus in a timely way. The problems of finding local stops, identifying the correct bus, disembarking and finding a terminal, navigating the terminal, and transferring to other buses, all were performed easily and quickly with the auditory signage. Figure 4 shows the substantial differences in perceived degrees of difficulty and stress for each differently sighted group from before to after using RISS. When using

Figure 3

Decreases of Time After Using TS®

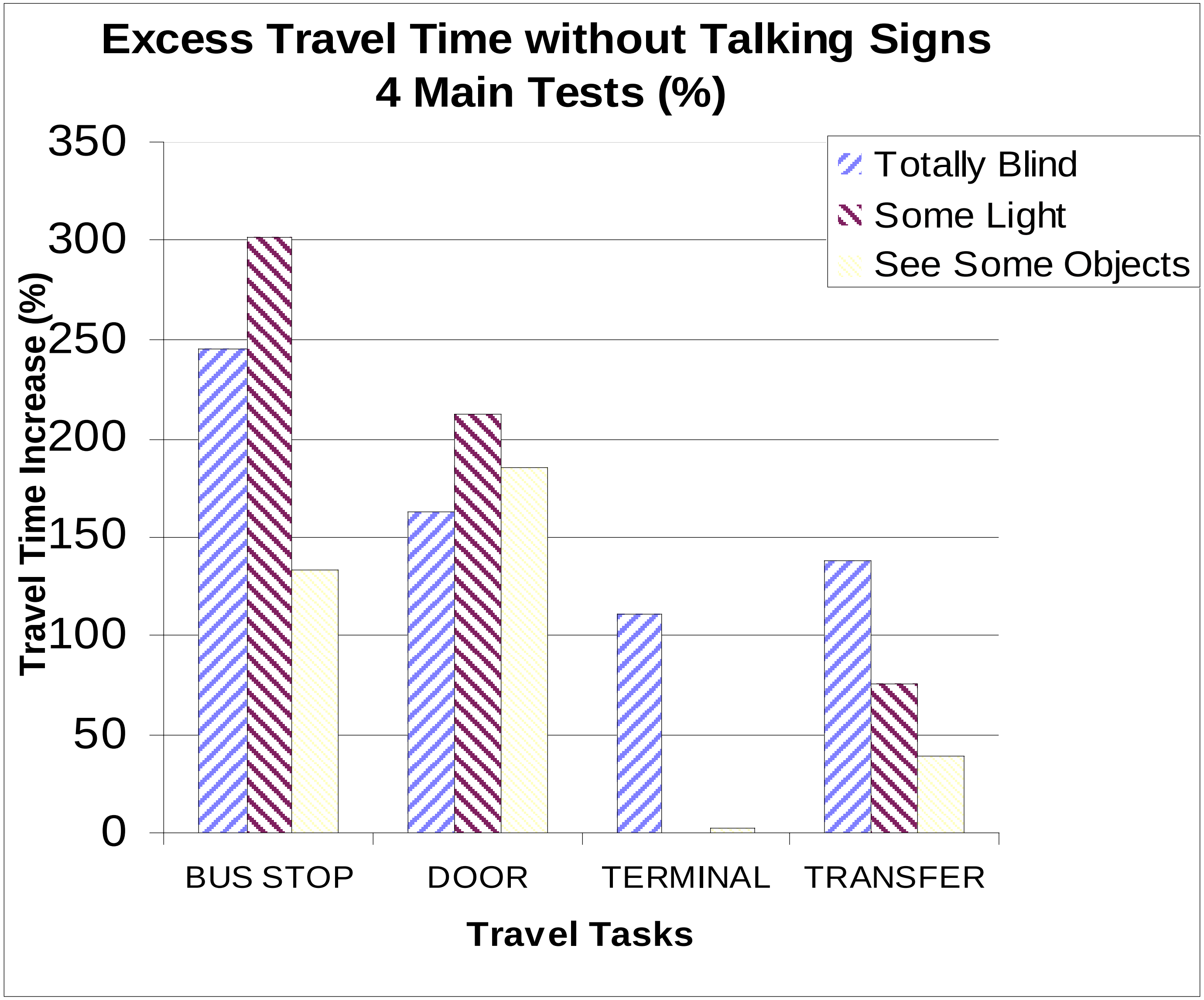
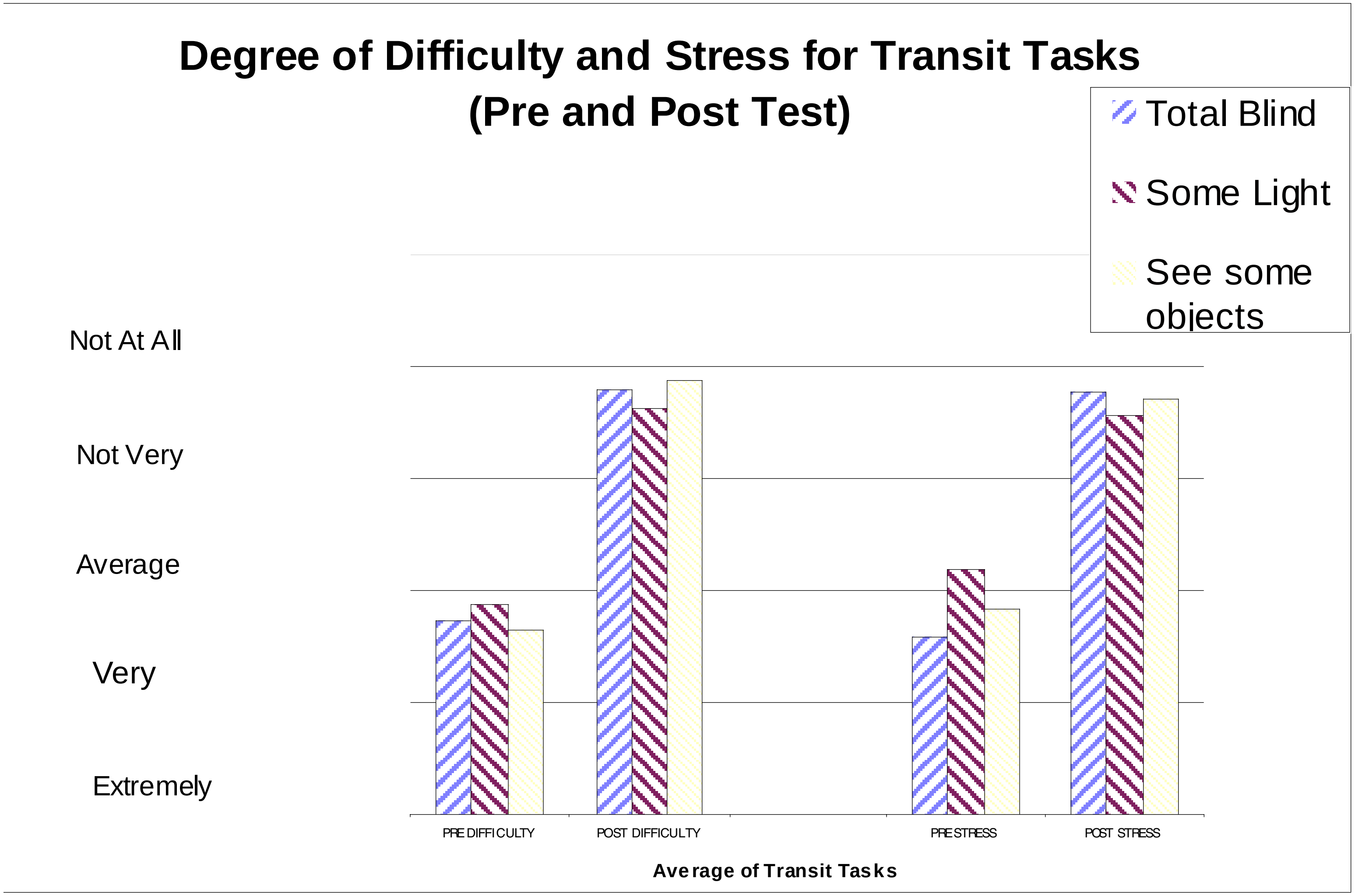


Figure 4

Differences in Perceived Stress and Difficulty for Each Group Before and After Using TS®



conventional mobility aids and without the use of auditory signage all these tasks proved very difficult, with some of them not being able to be performed. To this extent, therefore, it can be claimed that significant benefits accrue to potential users if auditory signage transmitters were installed and potential travelers had access to appropriate receivers. We asked subjects after the experiment to rate their opinion of TS® installations. The scale went from strongly agree to strongly disagree. The results indicate strong support for the widespread installation of auditory signage. Further questions showed that most participants felt that that installation of Remote Auditory Signage at key locations throughout the city would help them feel that the 1990 ADA legislation would really help them engage in more activities; we presumed this would increase their quality of life.

The statements from the final open-ended questions, show that blind transit users do not enjoy equal access to transit as mandated by the ADA of 1990. Until these problems are mitigated, the blind user is still left far from the general public in terms of access to public transportation. This research appears to show that a RISS like TS® has the ability to overcome these problems and give equal access as mandated.

Subjects disagreed strongly that the ADA was currently meeting their access needs (Table XI). They strongly agreed that the use of TS® would grant them more equal access. Responses to other questions indicated that they also strongly agreed that they would favor a citywide TS® installation. Overall, the ratings show how strongly subject felt about the usefulness of TS® and the desire to see it in use.

Table XI: TS® as an ADA Compliant Measure

I feel that I can get information and then find, access and use public buildings and transportation and that I enjoy the same access to buildings and transit given to the general public.	4.54
If TS were installed on public buildings and transportation, I would have the same access given to the general public.	1.31

Comments about the positive benefits of TS® also accentuate the current problems facing the blind traveler and what is needed to ensure equal access for this population. *By stating that they would travel more if the system was installed, they let us know that they are aware that they travel less than they desire, and that they do not make trips because there are too many obstacles to overcome*. The responses show us that they are aware that travel without assistance is both slow and difficult. Many comments were made that TS® would make them independent and they would not have to ask others for help. These remarks indicate that the current infrastructure makes them feel dependent on others. Their other comments also show that there is a high degree of mental stress, anxiety and fear and that safety and security concerns affect their freedom to use the urban and transit environment. City planners, transit agencies and access coordinators should heed these statements as to the problems that prevent blind or vision impaired people from enjoying equal access to transit and the urban environment. Regardless of whether we timed their travel, noted errors, asked closed-ended or open-ended questions the results show strongly that the blind or vision impaired are denied access to many parts of the world and that a RISS can provide a substantial increase to their access and use of transit, public and private buildings and other amenities that the general public takes for granted.

None of the suggestions for locating TS® in a real environment were for small scale or familiar places such as at home or in their immediate environment. The suggestions show the extent to which blind or vision impaired people have difficulty using the rest of the urban environment and its services. Their agreement on large areas such as malls, public buildings, stores and offices allows us to understand how difficult these areas can be to reach and to use. The wide range of areas mentioned should impress on planners and government agencies the current difficulties encountered by blind users and how important it is to improve access to this part of the population.

The opinions expressed about TS® also help to highlight the access problems faced by blind travelers. The RISS simply gives directional cues and identification information about the location. With 34 superlative opinions expressed like “terrific” and “great help” it is easy to see how much information is missing in their sightless world. Twelve people expressed the desire to see it installed, again showing the absence of these cues in their normal travel. They implied that their vision impairments restrict their travel, makes them feel dependant on others and feel unsafe while traveling. Their comments also inform us of the stress, difficulty and other negative mental states that occur while trying to access the urban environment.

Our qualitative data strongly support the installation of a RISS in many urban locations. The subjects’ responses show how little access they actually enjoy in these types of situations. For those subjects who were sightless from birth, or from an early age, this system gave them their first true understanding of how the sighted are able to better access the environment, receiving visual cues as to direction and identification of objects.

These qualitative data are also highly supported by our findings about reduced travel times in the experiment and also by the findings that subjects got lost without the system and never missed a target using TS®. This study, therefore, shows clearly the value of using auditory signage to provide a sufficient set of information to allow non-transit users to effectively and efficiently begin to use a transit system. While the open-ended questions showed a considerable and positive change in attitude toward the use of RISS, the results of the distance and direction estimation tasks and the cognitive mapping tasks, also showed some interesting results. For example, in the distance estimation tasks, people were told of standard distances of forty-three feet between the front and back door of the terminal. Estimates of that distance varied from 35’ to 50’. Nevertheless, distance estimates were, on the whole, reasonably well estimated. Directional estimates were found to be marred by electromagnetic interference from the local environment which at times threw compass readings of the pointing directions off by a considerable margin. In the MDS analysis, the configurations produced from distance estimates in the no auditory signage condition and distance estimates from the auditory signage condition were not significantly different. Both conditions (with and without TS®) produced reasonable layout configurations, showing that the relative positions of terminal features had been learned. When thinking of the reasons for any lack of differentiation between TS® and no-TS® conditions, however, one must realize that very little is known about people's ability to auditorially localize. Considerable research has shown that using sound can produce reasonably accurate direction estimates from individuals but that it contributes little understanding to the distance away of the sound source. Our results tend to confirm that much more work needs to be done in understanding the psychophysics of auditory localization before we can determine the extend to which people's cognitive maps may be enhanced by the use of auditory signage. This appears to be a valid area for future research and can be undertaken by both field and laboratory experiments using different forms of auditory signage (e.g. real, digitized, and virtual sounds).

The two most stressful tasks showed that auditory signage reduced stress by fully 2 categories. It also reduced stress so much that it appears that the installation of this type of system would give blind travelers almost the same ease of travel as is available to the sighted public.

Conclusion

Experiments conducted in this project using auditory messages transmitted by Remote Infrared Signage Systems have provided information on the value of the systems in terms of reduced anxiety and increased confidence levels for undertaking different spatial tasks. These reductions in "cost" and increases in "favorable attitudes" towards using public transit, are direct and positive benefits that would accrue to populations of blind or vision impaired travelers as well as to others who have high levels of spatial anxiety and low levels of wayfinding ability. The tasks remaining are to attempt to build a model that can help solve the problem of identifying the most effective distribution of the RISS in terms of both numbers and locations of the devices. Currently, a RISS transmitter obtained from Talking Signs® Inc. of Baton Rouge (LA), costs $750 for standalone transmitters and $1000 for those installed and connected to a centralized control system. Receivers cost $265. For each bus, a complete retrofit would cost approximately $2000 per bus, while the cost would drop to $1000 if the bus included "next stop announcement" or "talking bus device" as would be the case with the next generation of buses purchased. A small transit system like that in Santa Barbara (67 buses used on 24 routes, with a small downtown terminal), could have its buses and terminal equipped with TS® at a cost of about $150,000. This could be doubled if we add in the cost of a reasonable set of transmitters located throughout the downtown and suburban areas. Equipping selected suburban and downtown bus stops with TS® could require a further study to define a reasonable set of locations. In total, this seems a small price to pay for dramatically impacting the lives and behaviors of the thousands of print handicapped people in the local area. Perhaps what is needed next is a carefully designed cost-benefit analysis to clarify this question.

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