UNIVERSITY OF CALIFORNIA

Santa Barbara

Towards an Accessible City:

Empirical Measurement and Modeling of Access to Urban Opportunities for those with Vision Impairments, Using Remote Infrared Audible Signage

A Dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Geography

by

James Robert Marston

Committee in charge:

Professor Reginald G. Golledge, Chair

Professor Richard L. Church

Professor Daniel R. Montello

Dr. William F. Crandall

September 2002

The dissertation of James R. Marston is approved

____
Richard Church

____
Daniel Montello

____
William Crandall

____
Reginald Golledge, Committee Chair

September 2002

Towards an Accessible City:

Empirical Measurement and Modeling

of Access to Urban Opportunities

for those with Vision Impairments,

Using Remote Infrared Audible Signage

by

James Robert Marston

ACKNOWLEDGEMENTS

Many people helped me on my way to this goal. I appreciate and acknowledge them.

- The blind people who made these experiments possible, took part in some difficult tasks, and shared their personal fears, concerns, and difficulties.
- Dr. Williams and the Deicke Low Vision Center in Wheaton, IL and Don Davea form the Illinois Department of Rehabilitation for helping me confront a visual disability.
- Esther Acha, Stella-Nell Akoni, and the staff of the California Department of Rehabilitation for providing adaptive technologies and accomadations.
- My advisor, Dr. Reginald Golledge, for his support, wisdom, and guidance. His accomplishments are an inspiration that those with disability “can-do.”
- Dr. Bill Crandall provided much needed information and tireless assistance for the project and along with Theresa Postello and Linda Myers provided assistance at the San Francisco site that made this experiment possible.
- Dr.’s Dan Montello and Rick Church for their guidance with this research..
- Bill Norrington for his massive efforts to proof and edit this document.
- Susan Baumgart for her photography and beautiful illustrations.
- Mark Grosch for his technical support on document preparation.
- The Department of Geography for the opportunity to study and do research.
- The many friends who encouraged me during this journey.
- California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation; and the United States Department of Transportation, Federal Highway Administration, for partial funding support.
- University of California Transportation Center for partial funding of this research and dissertation.

Curriculum Vitae

JAMES ROBERT MARSTON

September 2002
Email: marstonj@geog.ucsb.edu

EDUCATION

1994 - 2002	Ph.D. candidate in Geography University of California, Santa Barbara, CA
1992 - 1994	M.A. in Geography University of Illinois at Chicago Thesis: "Implications of the Number of Workers per Household on Travel Behavior."
1992	B.A. in Sociology, History minor University of Illinois at Chicago

EMPLOYMENT

Academic-Graduate Teaching Assistant

University of California, Santa Barbara

Winter 2002	Geog 5	Human Geography
Winter 2000	Geog 5	Human Geography
Fall 1998	Geog 146	Transportation Systems
Winter 1998	Geog 5	Human Geography
Fall 1997	Geog 108	Urban Geography
Spring 1997	Geog 5	Human Geography
Winter 1997	Geog 5	Human Geography
Fall 1996	Geog 117b	Research Methods
Winter 1996	Geog 5	Human Geography
Fall 1995	Geog 108	Urban Geography
Fall 1994	Geog 5	Human Geography

University of Illinois at Chicago

Spring 1994	Geog 483	Quantitative methods I
	Geog 481	Geographic Information Systems
Fall 1993	Geog 482	Quantitative methods II
	Geog 481	Geographic Information Systems
Spring 1993	Geog 150	Physical Geography
	Geog 151	Urban Geography
	Geog 210	Astronomy

RESEARCH AND GRANTS

2001 -2006	Research funded by Department of Education for *Wayfinding Technologies for People with Visual Impairment: Research and Development of an Integrated Platform*
2000 - 2001	Research Unit on Spatial Cognition and Choice/MIT *Individuals' Spatial Abilities and Behavior in Transportation Networks* NSF grant #9986475
1999 – 2000	Research Unit on Spatial Cognition and Choice *Off-Route Strategies in Non Visual Navigation* NSF grant #SBR9818545
1998 - 2000	Research Unit on Spatial Cognition and Choice University of California Transportation Center *Towards an Accessible City: Removing Functional Barriers for the Blind and Vision Impaired: A Case for Auditory Signs* UCTC Grant # 65V430
1997 - 1998	Research Unit on Spatial Cognition and Choice *Towards an Accessible City: Removing Functional Barriers to Independent Travel for Blind and Vision Impaired Residents and Visitors* California Partners for Advanced Transit and Highways (PATH) #MOU343
1996 - 1997	Research Unit on Spatial Cognition and Choice *Assistive Devices and Services for the Disabled* PATH Grant #MOU276
1994 - 1995	Research Unit on Spatial Cognition and Choice *The Mass Transit Needs of a Non-Driving Disabled Population* PATH Grant #MOU 157
1993 - 1994	Federal Highway Administration Study of NPTS Data Travel Behavior of Multiworker Households, HPM-40

SERVICE

2002-	Equity Funding Subcommittee of the UCSB ADA Committee
2001	Assistant Organizer, "COSIT '01", Fifth International Conference on Spatial Information Theory, Morro Bay, CA
2001-	Consultant to the Wayfinding Foundation, a non-profit group advocating for blind accessibility, Baton Rouge, LA
2001	Chair, Geography of Exclusion Session, 2001 AAG Meeting, New York
2000-	Project Director, Remote Infrared Audible Signage, UCSB
2000-	Advisor to Associated Students Commission on Disability Access (CODA)
1998-	Member of the Access Subcommittee of the ADA Committee
1998-00	Member of DACA, The Disability Advisory Committee on Access for the City of Santa Barbara, CA
1997-	Graduate Student Association Representative to the UCSB ADA Committee
1996-97	Disability Liaison with the UCSB Ombuds Office
1995-97	Founding Board Member of The UCSB Disability Awareness And Advocacy Coalition (DAAC), A Student Led Organization

AWARDS, HONORS, AND FELLOWSHIPS

2001	"Graduate Dissertation Fellowship," University of California Transportation Center
2001	"Excellence in Research" Award, UCSB Department of Geography
2001	"Graduate Excellence Award for Co-Curricular Activity" nominee UCSB Office of Student Life
2001	"Accessibility Achievement Award" from the Commission on Disability Access (CODA) University of California at Santa Barbara
2001	"Most Creative Program" and "Outstanding Group Achievement," UCSB Office of Student Life. 2 awards for Disability Commission that I advised and help form
1995	"Excellence in Teaching" nominee, Graduate Student Association
1994-2001	Graduate Fellowship and Tuition Support Department of Geography UCSB
1992-1994	Graduate Tuition Support / Summer Stipend University of Illinois at Chicago

PUBLICATIONS

* = Peer reviewed

*Church, R. L., Marston, J. R., (in press) Measuring Accessibility for People with a Disability, Geographical Analysis.

Marston, J .R., & Golledge, R. G. (2000) Towards an Accessible City: Removing Functional Barriers to Independent travel for Blind and Vision Impaired: A Case for Auditory Signs. Final Report, University of California Berkeley: University of California Transportation Center, Grant # UCTC 65V430, June.

Golledge, R. G., & Marston, J. R. (1999) Towards an Accessible City: Removing Functional Barriers to Independent travel for Blind and Vision Impaired Residents and Visitors. Final Report, University of California PATH Research Project, UCB-ITS-PDR-99-33, September.

Okunuki, K., Church, R., & Marston, J (1999) A Study on a System for Guiding of the Optimal Route with a Hybrid Network and Grid Data Structure. In Papers and Proceedings of the Geographic Information Systems Association Japan, 8, 135-138 (Japanese).

Golledge, R. G., Marston, J. R., & Costanzo, C. M. (1999) Assistive Devices and Services for the Disabled: Continuation Proposal. Final Report to the University of California Richmond Field Station PATH Division in fulfillment of Grant (MOU343) (65A0013), June.

Golledge, R. G., Marston, J. R., & Costanzo, C. M. (1998) Assistive Devices and Services for the Disabled: Auditory Signage and the Accessible City for Blind and Vision Impaired Traveler. California PATH Working Paper, UCB-ITS-PWP-98-18, Report for MOU 276, August.

Marston, J. R., & Golledge, R. G. (1998) Improving Transit Access for the Blind and Vision Impaired, Intellimotion, Research Updates in Intelligent Transportation Systems, Transit Research Issue, Vol. 7, No. 2, pp 4-11.

Marston, J. R., & Golledge, R. G. (1998). Removing functional barriers: Public transit and the blind and vision impaired, Proceedings of the 1997 Society for Disability Studies, 10th Annual Meeting, Minneapolis, MN.

Golledge, R. G., Marston, J. R., & Costanzo, C. M. (1998) Assistive Devices and Services for the Disabled. Final Report. University of California Achievement Field Station PATH Division Grant #MOU 276, February.

* Golledge, R. G., Marston, J. R., & Costanzo, C. M. (1997). Attitudes of visually impaired persons toward the use of public transportation. Journal of Visual Impairment & Blindness, 91(5), 446-459.

* Marston, J. R., Golledge, R. G., & Costanzo, C. M. (1997). Investigating travel behavior of nondriving blind and vision impaired people: The role of public transit. The Professional Geographer, 49(2), 235-245.

Golledge, R. G., Marston, J. R., & Costanzo, C. M. (1996). The impact of information access on transit behavior of blind or vision impaired people. Research Conference Proceedings: Spatial Technologies, Geographic Information and the City (Technical Report 96-10): National Center for Geographic Information and Analysis (NCGIA).

Golledge, R. G., Costanzo, M. C., & Marston, J. R. (1996). Public transit use by non-driving disabled persons: The case of the blind and vision impaired (California PATH Working Paper UCB-ITS-PWP-96-1): Partners for Advanced Transit and Highways (PATH).

Golledge, R. G., Costanzo, C. M., & Marston, J. R. (1995). The mass transit needs of a non-driving disabled population (Final Report MOU167): University of California Richmond Field Station PATH Division.

Marston, J. R., Walsh, J., Wertimier, K., & Yang, L. (1994, June 17). Complex trip chains and their effect on transit ridership. Paper presented at the Metropolitan Conference on Public Transportation Research Proceedings at the University of Illinois at Chicago, Chicago, IL.

Soot, S., Sen, A., Marston, J. R., & Thakuriah, P. (1994). Multiworker household travel demand (Demographic Special Reports HPM-40). Washington, DC: Office of Highway Management.

PRESENTATIONS

Marston, J. R., (2001, September 16) Equal Access to Urban Opportunities: Measurement and Mitigation of Travel Barriers for People with Restrictive Vision. Paper presented at the Association of Pacific Coast Geographers (APCG) 64th Annual Meeting in Santa Barbara, California.

Marston, J. R., & Golledge, R.G. (2001, March 20), Empirical Measurement of Barriers to Public Transit for the Vision-Impaired and the use of Remote Infrared Auditory Signage for Mitigation. Paper presented at CSUN 16th Annual International Conference, “Technology and Persons with Disabilities,” Los Angeles, CA.

Marston, J. R., & Golledge, R.G. (2001, March 3) Equal Access or Transit Subsidies, what does the ADA mandate? Limits to transit choice and activities (unequal access) and monetary trade-offs for equal access reported by the vision impaired. Paper presented at the Association of American Geographers (AAG) 97th Annual Meeting in New York, New York.

Marston, J. R. (2001, Jan 3) Transit way finding and orientation for visually impaired. Paper presented (by Billie Bentzen) at the TRB Human Factors Workshop, Can You Catch the Bus? Pedestrian Access to Transit Stops, Washington, D.C.

Marston, J .R., & Golledge, R. G. (2000, August 16) Towards an Accessible City: Removing Functional Barriers to Independent travel for Blind and Vision Impaired: A Case for Auditory Signs. Invited Paper, U.S. Access Board Public Rights of Way Access Advisory Committee, Meeting 4, San Francisco, California.

Marston, J. R., & Golledge, R.G. (2000, April 6) Constricted Space and the Blind Traveler: Reduced Expectations and Limits to Travel and Activity Behavior. Paper presented at the Association of American Geographers (AAG) 96th Annual Meeting in Pittsburgh, Pennsylvania.

Marston, J. R., & Golledge, R. G (1999, May 30) Equal Access to Transit? Blind Transit User's Evaluations of Remote Infrared Signage Systems, Paper presented at the Society for Disability Studies 12th Annual Meeting in Washington, D.C.

Marston, J., & Golledge, R. G. (1999, March 26). Learning spatial configurations using auditory cues: The use of a remote infrared signage system in an urban transit environment. Paper presented at the 95th Annual Meeting of the Association of American Geographers, Honolulu, HI.

Marston, J. R., & Golledge, R. G. (1998, June 4) Toward an Accessible City: The Use of Auditory Signage for the Vision and Print Handicapped. Paper presented at the Society for Disability Studies 11th Annual Meeting in Oakland, California

Marston, J. R., (1998, March 26) An Objective Measure to Identify Problematic Access Routes, Invited Paper Presented to the University of California at Santa Barbara ADA Advisory Committee

Marston, J. R., & Golledge, R.G. (1998, March 26) Exploring terra incognita: Removing functional barriers for the blind traveler using auditory signs. Paper presented at the Association of American Geographers (AAG) 94th Annual Meeting in Boston, Massachusetts.

Golledge, R. G., Marston, J. R., & Costanzo, C. M. (1998, February). Assistive Devices and Services for the Disabled: Auditory Signage and the Accessible City for Blind and Vision Impaired Travelers. Paper presented (by R. Golledge) at the University of California Richmond Field Station PATH Division in fulfillment of Grant (MOU276) Berkeley, CA.

Golledge, R. G., & Marston, J. R., (1997, October 28) Emerging Technologies for Making Cities Accessible to Disabled Persons: The Case of the Blind or Vision Impaired, Paper presented (by R. Golledge) at Bureau of Transportation Statistics Seminar, Emerging Technologies for Making Cities Accessible to Disabled Persons, Washington, D.C.

Golledge, R. G., & Marston, J. R., (1997, August 9) Talking Signs and the Accessible City, Paper presented (by R. Golledge) at PATH Conference, Richmond Field Station, Berkeley, CA.

Golledge, R. G., & Marston, J. R., (1997, July 30 - August 19) Talking Signs and the Accessible City. Paper presented (by R. Golledge) at Australian Housing and Urban Research Institute, Melbourne, Australia, at the Queensland University of Technology in Brisbane, and at GISCO in Adelaide.

Marston, J. R., & Golledge, R. G. (1997, May 23). Removing functional barriers: Public transit and the blind and vision impaired. Paper presented at the 10th Annual Meeting of the Society for Disability Studies, Minneapolis, MN.

Marston, J. R., Golledge, R. G., & Costanzo, C.M. (1997, April 2) Travel Behavior and Transit use by the Blind and Vision Impaired. Paper presented at the Association of American Geographers (AAG) 93rd Annual Meeting in Fort Worth, Texas.

Golledge, R. G., Marston, J. R., & Costanzo, C.M. (1997, January) Use of Mass Transit by Non-driving Disabled People. Invited talk presented (by R. Golledge) at the University of California at Davis

Golledge, R. G., Marston, J. R., & Costanzo, C.M. (1996, Nov) Activity Patterns and Transit Use by a Blind or Vision Impaired Population. Paper presented (by R. Golledge) at the Regional Science Association International 43rd Annual North American Meeting

Golledge, R. G., Marston, J. R., & Costanzo, C.M., (1996, Sept) The Impact of Information Access on Travel Behavior of Blind and Vision Impaired People. Paper presented (by R. Golledge) at the Spatial Technologies, Geographic Information, and the City, an NCGIA sponsored research Conference, Baltimore, MD

Golledge, R. G., Marston, J. R., & Costanzo, C.M., (1996, Sept) The Use of Public Transit by a Disabled Population: The case of the Blind and Vision Impaired. Paper presented (by R. Golledge) at the Geography Department, George Mason University, Washington, DC.

Golledge, R. G., Marston, J. R., & Costanzo, C.M., (1996, April) Assistive Technologies to Assist the Mass Transit Needs of Blind or Vision Impaired People: Talking Signs and Verbal Landmarks. Paper presented (by R. Golledge) at University of Melbourne, Australia.

Golledge, R. G., Costanzo, C. M., & Marston, J. R. (1995, October 29-November 1). Why don't disabled people use public transit? Paper presented (by J. Marston) at INFORMS (Institute for Operations Research and the Management Sciences), New Orleans, LA.

ABSTRACT

Towards an Accessible City: Empirical Measurement and Modeling
of Access to Urban Opportunities for those with Vision Impairments,
Using Remote Infrared Audible Signage

by

James Robert Marston

This paper examines the problems of defining and measuring access for blind travelers in an urban transit environment. Current accessibility measures do little to account for individual differences or the barriers faced by people with restricted mobility. Independent access to transit and activities in the urban environment are often denied or restricted for those with vision impairments. Their freedom of movement is not blocked by physical obstacles, but by information, signs, and spatial knowledge that are hard to access without vision. In this sense, services and facilities are considered inaccessible if people with limited or no vision lack the information necessary to adequately use them.

Thirty legally blind people made five simulated transfers to different transit modes at a transportation terminal to identify specific barriers to successful travel. Regular blind mobility methods were tested against a Remote Infrared Audible Signage

(RIAS) condition to determine if the devices offered a suitable replacement for typical visual cues and information needed for efficient travel and use of transit. The difficulties of accessing various transit locations and performing necessary tasks were measured, in both conditions, and the extra time penalties were compared and modeled showing the travel constraints of vision loss and the efficacy of using RIAS to increase access. RIAS provided superior travel times, increased independence, and decreased error production.

A survey examined differences reported by blind travelers before and after exposure to RIAS. Many wayfinding tasks faced by transit users were shown to be quite difficult with normal navigation skills and aids, but presented little or no difficulty when using RIAS. High resistance to make mode transfers, especially in new environments, was reported. Inaccessible transit caused "non-trips" and also reduced travel and activity participation. RIAS revealed a *hidden demand* to travel more often, with greater safety, independence, and efficiency. These additional audible cues were perceived as enabling the users to access many more types of activities, such as education, employment, recreational, and entertainment. High monetary benefits were placed on the ability to travel independently and to gain access to urban opportunities, including increased income from employment.

KEYWORDS: Accessibility, ADA, Audible Sign, Blind Navigation, Disability, Infrared, Location based information, Orientation & Mobility, Transit.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1. Problem Statement

1.1. Importance of Research

Visitors to a foreign city know all too well the loss of independent travel when confronted with signage in an unfamiliar language. Street corners cannot be identified, people cannot tell where the buses that pass them are going, transit stations and mode changes are confusing, public buildings are hard to negotiate, and even finding the proper washroom can present a problem. Imagine a world without signs. One would not know where trains and busses went, know where to find an information booth, or understand the cues necessary for navigating a city or even a building. Consider then the trials of blind travelers. Besides seeing no signs to inform their orientation and information needs, they do not even see what the world around them looks like.

Information, which aids accessibility, is the key to increased public transit usage for the blind(Golledge & Marston, 1999; Golledge, Marston, & Costanzo, 1997; Marston, Golledge, & Costanzo, 1997). For people who are blind of have low vision (hereafter, “people who are blind”), this often translates into an ability to find appropriate locations where facilities can be boarded or locations where information about routes or frequency of travel can be obtained. For the general population, signs readily accessed by vision provide this information, if they are of good quality, effectively placed, and contain accurate and concise information. These signs include indicators of bus stops, terminal entrances, or printed schedules, which are experienced first-hand and up close by the potential user. Information about vehicles is carried in the form of numbers, routes, or destinations indicated at the front, rear, and sides of vehicles. The latter can be observed at some distance if vision is acute enough. Vision is the premier sensory modality for travel and navigation, and, in the absence of vision, inferior cues must be used. This research examines how vision-impaired people can overcome functional barriers caused by lack of vision and examines how to make a city more accessible to this population. The specific bottlenecks and barriers to travel faced in the pursuit of urban opportunities for the vision-impaired are examined in this dissertation.

1.1.1. An Accessible City

A major change in urban form has taken place in the last half of the 20th Century. The decentralization of cities has meant that not only do people move further away from the urban center but also that many jobs have followed into less dense areas which are under-served by transit. This has left the urban poor, minorities, and other people who do not drive a car at a clear disadvantage. Those that work find that they must make long and arduous reverse commutes using transit, often having to make several transfers or mode changes. Information about these transfers can be hard to find in an easy manner, and, for the blind and vision-impaired, it is often difficult to incorporate this information and integrate it into an acceptable travel plan.

Funding and support for public transit lags far behind the resources committed to the automobile and its infrastructure. Less attention has been paid to making it more attractive, easier to use, or safer. In many areas, transit riders are treated as "second-class" citizens, and their continued patronage is assumed because they have no alternative and are "transit dependent." Making transit more user-friendly may help increase ridership, which in turn helps make cities more accessible. One view that has been expressed is that "public transportation is all about anxiety, uncertainty, and waiting - usually in uncomfortable and often unsafe areas" (Hepworth & Ducatel, 1992, p. 139). What can be done to make transit more attractive? "The goal of Intelligent Transportation Systems (ITS) technology applied to public transportation is to generate and utilize information to mitigate these negative aspects as well as to increase productivity of public transportation systems, so that ridership will increase, thereby reducing automobile travel and congestion while supporting desired urban forms" (Hodge & Morrill, 1996, p.729). However, this **information** is not readily accessible to some people and that is the main research problem.

1.1.2. Problem Rationale

The processes involved in mobility and orientation are still imperfectly understood in terms of what knowledge is required and how it should be presented to pedestrians.

Moreover, the wealth of information available through visual cues, signs and maps is denied to visually impaired or blind travelers. They are unable to read print on signs, to make sense of a series of numbers and letters that designate routes and schedules, or perhaps cannot even locate where suitably accessible information (Braille or verbal information) is available. Although the Americans With Disabilities Act of 1990 has provided the legal incentives for improvement in transportation systems and vehicles for access by different disabled populations, most of the activity to date has involved retrofitting sidewalks, buildings, and vehicles to allow easy access by those who use wheelchairs or have other ambulatory disabilities. Recently, there has been some attention paid to determining the types of changes that could materially assist other disabled groups, including the blind and vision-impaired, in the context of helping them find their way or move about complex environments (Bentzen, Crandall, & Myers, 1999; Bentzen & Mitchell, 1995; Bentzen, Myers, & Crandall, 1995; Brabyn, 1985; Crandall, Bentzen, & Myers, 1996; Crandall, Bentzen, Rosen, & Mitchell, 1994; Crandall, Bentzen, & Meyers, 1998; Crandall, Bentzen, & Myers, 1995, 1999; Crandall, Bentzen, Myers, & Mitchell, 1995; Crandall, Brabyn, Bentzen, & Myers, 1999; Crandall & Geary, 1993; Golledge, 1993; Golledge, Blades, Kitchin, & Jacobson, 1999; Golledge, Costanzo, & Marston, 1995, 1996; Golledge, Kitchin, Blades, & Jacobson, 2001; Golledge, Klatzky, & Loomis, 1996; Golledge, Loomis, & Klatzky, 1997; Golledge, Loomis, Klatzky, Flury, & Yang, 1991; Golledge & Marston, 1999; Golledge, Marston, & Costanzo, 1996; Golledge, et al., 1997;

Marston & Golledge, 1998a, 1998b; Marston & Golledge, 2000; Marston, et al., 1997).

The 1990 Census showed that disabled people make far fewer trips than the rest of the population, and Marston, et al. (1997) showed that vision-impaired subjects reported limited trip taking and activities. Nationwide, less than half of all disabled travelers use public transportation (Corn & Sacks, 1994). Clark-Carter, Heyes, & Howarth, (1986) reported that at least 30 percent of persons with vision impairment or blindness make no independent trips outside the home. Since legally blind people do not drive, this also has a negative impact on their access to work and limits their activity choices. Recent research (Golledge et al., 1995; Golledge & Marston, 1999; Golledge et al., 1997; Marston & Golledge, 1998a, 1998b; Marston & Golledge, 2000; Marston et al., 1997) into why people who are blind or vision-impaired do not use public transit has shown that perhaps the most important thing that is lacking for this group is access to information.

Less than one third of working age blind and vision-impaired people are employed (Kirchner, Schmeidler, & Todorov, 1999). Marston & Golledge (2000), and Marston et al. (1997) suggest that this is in no small part due to the lack of appropriate transportation facilities. These include public transit and other means to allow an individual to go from home-base to a work destination in a timely manner. They further report that even those with access to public transit of one form or another have continuous and ongoing difficulty in gaining information about schedules, timeliness of transit modes, and difficulties when changing modes in mid-trip. They report problems in finding the appropriate stop on a public street or near a major terminal where a vehicle halts for embarkation and disembarkation. Golledge et al. (1997) found that, for their blind and vision-impaired subjects, 70 percent said that finding where to board a bus was “somewhat difficult” or even harder. Most of the participants (85%) agreed that it was ”difficult”, “often difficult”, or “always difficult” to find pick-up points for transfers, and 89 percent said it was always or often difficult to find a transfer point when crossing a street. With these facts in mind, researchers have begun to pay more attention to the problem of getting appropriate information (that is often displayed on signs accessible by vision) to these vision deficit populations. It is believed that these obstacles reduce transit use and lead to restrictions on access to urban opportunities and self-sufficient lifestyles.

In addition to the problems faced by the blind traveler when confronted with printed information, such as schedules and vehicle identification, they also face several other problems, especially in new environments. Without vision, the ability to gain suitable and sufficient information about the environment and its spatial arrangements, to enable a person to independently understand and navigate unfamiliar areas, is restricted. This research looks at the difficulty in getting the following types of information when navigating without sight.

- **Specific Information and Positive Identification at Locations:** Even when a blind person finds a location, such as a door, bus stop, or counter, it might be difficult to be positive of its identification.

- **Spatial Information Accessed From a Distance:** Without vision, a person usually has to actively search for locations along walls and open spaces until the location is within the area of the body or the cane's reach. Therefore, a blind person can be totally unaware of an important location that is only several feet away. Spatial layouts cannot be viewed randomly, in their entirety, as with vision, but must be learned in a physically active, deliberate, and sequential search.

- **Directional Cues to Distant Locations:** It can be difficult to walk directly to locations without having to follow a learned path. With the exception of some other sensory input (sounds, air currents, heat, or perhaps light perception), there are no available directional cues to walk directly to a distant target, such as directly crossing a large lobby to reach a location.

- **Self-orientation and Location:** Without vision, it is quite possible to lose track of where one is in a space and even which way one is facing. Blind people might need to walk to a wall, familiar location, or curb to orient their position.

- **Integrated model of the space:** Without vision and easy access to distal cues, it can be quite difficult to build a "view" or mental image of a space that contains the spatial relationship between locations. This map-like image allows people to explore spaces with greater efficiency, without having to adhere to learned routes.

These missing cues are of utmost importance to travelers. People can get "lost" or disoriented when they make a wrong choice at a decision point (go straight or turn). Each of these decision points is an *independent* event and the probability of success (or failure) for each event is multiplied as the number of decision points increases. If a very skilled blind traveler made only one mistake in every 100 attempts, there would be a cumulative probability (>50%) of making an incorrect choice after 69 decision choices. If a traveler made only five mistakes in every 100 attempts, there would be a cumulative probability of making an incorrect choice after 14 decision, and if a person made a wrong choice 10 times out of 100 choices, it is more likely than not that an incorrect decisions occurs after only 7 choices. In addition, without a way to "view" the world, it can be much more difficult for a person with severe vision loss to recover from these types of errors. For all travelers, the ability to access cues (with vision or other accessible cues) to determine where one is located in a space, by positive identification of a landmark or signs, allows a person to "snap-back" their imagined position to the "real-world" position. These problems of acquiring spatial knowledge for successful navigation in the absence of full vision are investigated in this paper, and possible mitigation is researched through the use of location-based audible signage. This research addresses the very practical need for more understanding of the role of vision in locomotion and wayfinding.

1.2. Research Questions and Objectives

Electronic travel aids (ETA) have been developed to extend the very limited preview range of the long cane or guide dog used by many who lack vision. Some of these aids do not adequately provide the missing environmental cues, because the role of vision in navigation, and how to substitute for it, is not well understood. (Brabyn, 1985) raised the following questions. What are the essential components of information needed for orientation? What spatial cues does a sighted person rely on for maintaining a safe course through the environment? How can environmental cues be coded and transmitted to a person without vision? .

Most blind people receive some type of Orientation and Mobility (O&M) instruction. What is also needed is the means to access knowledge that gives information helpful in the spatial task of orientation or wayfinding. The standard travel aids for the blind assist in mobility, and they work as barrier or obstacle avoiding aids. However, they are not very useful for gaining environmental knowledge (orientation) that allows for exploring new routes and environments or making shortcuts. A *GPS* and *GIS* based Personal Guidance System (Loomis, Golledge, & Klatzky, 1998), developed at the University of California, Santa Barbara, can transmit spatial information to assist in orientation, making it a big advancement over aids that only help with mobility. Research on the ability of vision-impaired people to use complex spatial locational and relational information is required to better understand the role of vision and how to provide this information to the blind (Golledge, 1993).

To date, there is little understanding of the **functional** barriers that discourage travel and access to the urban environment for those who lack vision. **Structural** barriers that limit access for people who use wheelchairs have been widely studied and are much simpler to define and identify. They include, for example, curbs, stairs, steep inclines, and heavy doors. Mitigation costs can be estimated with little problem, based on decades of engineering and public works experience. For these structural barriers, one can easily compare the path of travel for the general public against those routes required for a person using a wheelchair in order to determine the “penalties” imposed on these users (Church & Marston, in press; Okunuki, Church, & Marston, 1998).

However, identifying specific problems that reduce access for the blind is not simply the difference between sighted and blind travel route efficiency and effort. Because of fears about personal safety, concerns about uncertainty, and obstacles in the environment, blind travel will probably always have extra effort factored into it. The major research objective addressed here is to determine the effects on accessibility when vision-impaired people use their regular method as opposed to using auditory spatial cues. A spatial information aid, Remote Infrared Audible Signage (RIAS) known as Talking Signs® (TS) was used in this experiment. This dissertation reports on an experiment that tested if blind and vision-impaired people can perform travel tasks more efficiently, in less time, and with fewer errors when auditory directional and identification cues are provided, and, if this is the case, will they be able to:

- Perform transit tasks with less difficulty and restriction?
- Gain access to more activity space and travel more often?
- Positively influence affective states (such as feelings of independence, comfort, assurance, and safety) during the overall travel experience that are usually negatively affected by the lack of visual cues in the physical world?

In other words, given auditory signage assistance, can they travel through transit space with more efficiency, can they have a higher quality of access to the opportunities of urban life through more efficient travel, and will they feel more confident and enjoy the task of travel? These research questions are addressed in this experiment, and the penalties that vision loss creates in accessing urban opportunities are determined by comparing blind individuals' RIAS performance to that when using regular methods of guidance. With the use of auditory signage, skilled vision-impaired travelers can be used to determine some of the barriers to independent travel, to provide information to gauge the impact of vision loss on accessibility, and, perhaps, to determine if additional environmental cues can help mitigate these barriers to independent travel for those lacking vision. This research report is designed to provide needed information to regulators, transportation designers, and technologists as to the specific problems experienced by visually impaired travelers and to specific solutions to these problems.

The secondary objectives of this research are to determine how:

- Specific locations and tasks cause difficulty in travel and transit use.
- The difficulties and barriers to access negatively affect spatial knowledge acquisition and trip and activity behavior.
- The restrictions on independence and access negatively affect the quality of life and mental state of this population, adding uncertainty to travel.

1.3. Experimental Hypotheses

Hypothesis 1: Experiment data will show that, for those with limited vision, specific locations and tasks cause difficulty when using transit. The use of auditory signage will mitigate much of the difficulty.

Hypothesis 2: Difficulties of transit tasks will affect travel activity and behavior and reduce trips and accessibility. Subjects will estimate they would make more trips and access more places if RIAS was installed.

Hypothesis 3: Travel and access limitations negatively impacts the quality of life for those with vision loss. When using RIAS, subjects will report a wide range of positive influences on their quality of life.

Hypothesis 4: The field test data and subject's observations, ratings, and opinions will demonstrate a wide variety of benefits that accrue to the user of RIAS.

1.4. Structure of Dissertation

The structure of this paper follows the hypotheses listed above. Chapter 1 explains the experiment proposal and design, subject recruitment and training, and ends with preliminary data on the subjects. Chapter 2 sets the stage and includes a literature review. Chapter 3 examines specific tasks and locations that restrict travel for those with vision impairments and reports data on the performance of the subjects in the test environment. Chapter 4 examines how these tasks and locations have a negative affect on trip making and activity choice and how access is limited by these problems. Chapter 5 details how overall quality of life is reduced by vision loss and how spatial information from auditory cues can help this population lead a more satisfying life. Chapter 6 summarizes the various benefits attributed to increased access to information and the transit and urban environment. Monetary benefits and "willingness to pay" data are then examined. Chapter 7 discusses the overall implications of the study in terms of making environments more accessible for people with vision disabilities. Also discussed are the contributions made by this study to spatial and geographic theory related to human navigation, an evaluation of the experimental design and methodology used in the study, and suggestions for future research that may arise as RIAS technology is enhanced in the future.

1.5. Experiment Design

1.5.1. Choosing the Experiment Location

After several years of testing auditory signage in controlled and small environments, it was highly desirable to test the system in a much larger urban transit environment with "real world" simulations and tasks. The robust environment that was available at the San Francisco Caltrain station was chosen. It provided the ability to test blind subjects transferring between four different transit modes in an area that had 51 Talking Signs(R) transmitters. This rich environment was a superb place to conduct much needed research and a very broad range of questions and tasks were designed to take full advantage of the opportunity.

It is quite difficult to get a group of blind travelers together at the same site for testing and it can also be quite expensive and time-consuming. While trying to limit subject fatigue and stress, attempts were made to elicit the most information from the experiment by asking many relevant questions and performing many complex field tasks.

1.5.2. San Francisco Caltrain Experiment Site

The San Francisco Caltrain station environment offered a unique opportunity to test RIAS in a realistic urban multi-modal setting. The train station takes up the entire block face along 4th Street. Across one intersecting street (King Street) is the Municipal Railway Muni "N" Judah line Light Rail station. On the other intersecting street (Townsend Street) outside the train station is a cabstand and across 4th Street are several bus shelters. Figure 1.1 shows a diagram of the area used in this experiment and all Talking Signs® installations. Figure 1.2 shows a blowup of the 4th and King Street intersection installations. Table 1.1 lists the exact verbal message heard at each of the RIAS transmitter locations.

Figure 1.1 Talking Signs® Installation at Caltrain Station

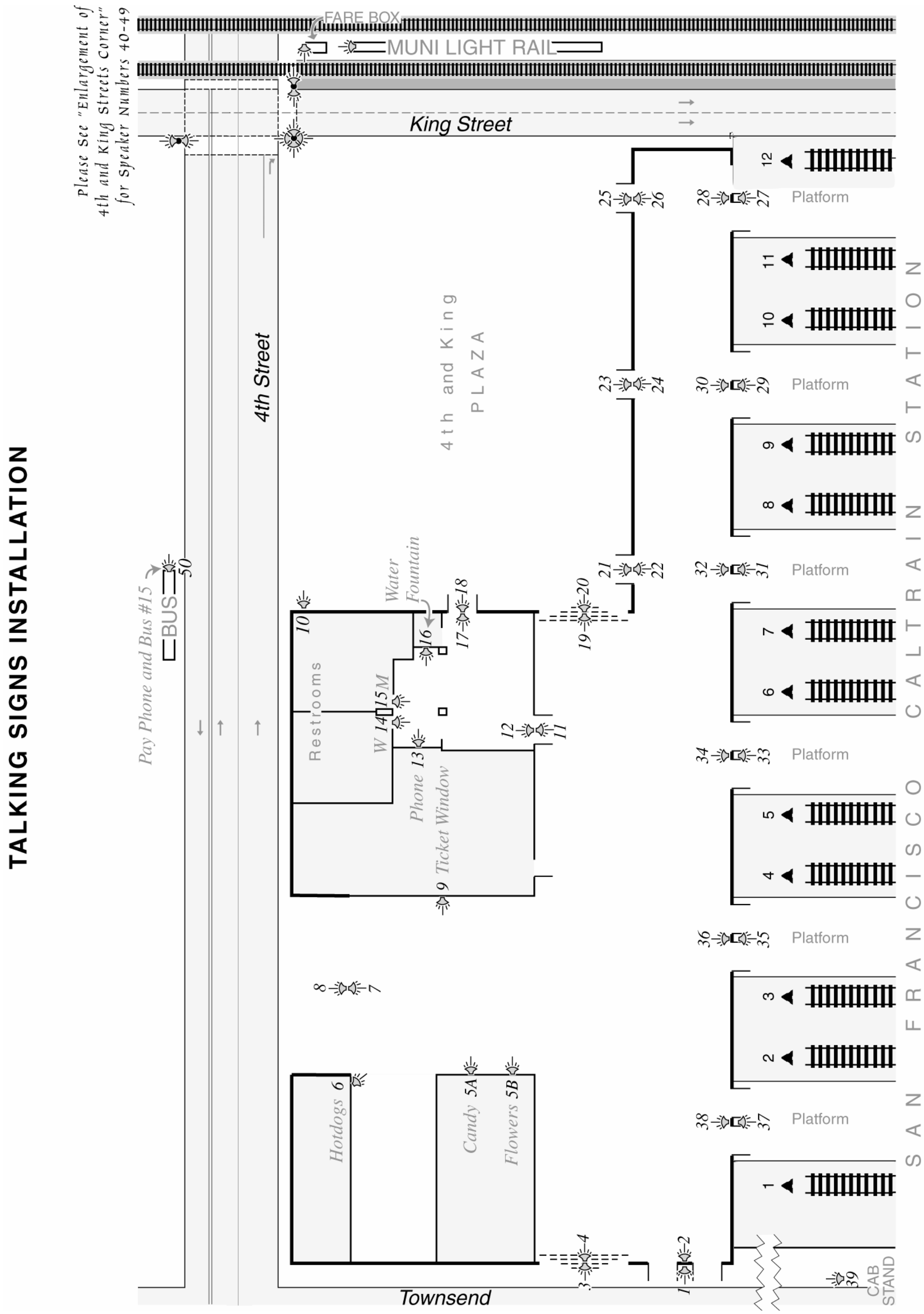


Figure 1.2 Street Corner Detail

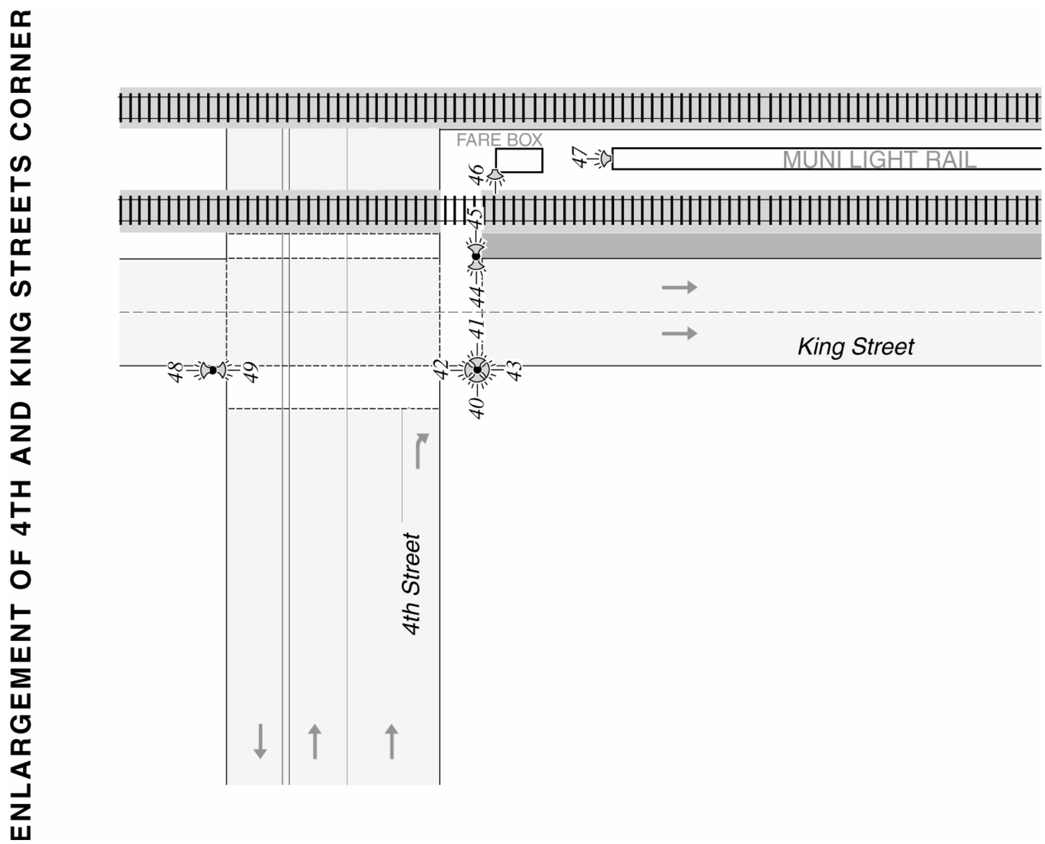


Table 1.1 Legend for Figure 1.1 and Figure 1.2.

San Francisco Caltrain Station and Surrounding Environment Verbatim Talking Signs® Message and Location Legend
01 Townsend Street Entrance to Caltrain Station
02 Exit to Townsend Street
03 Townsend Street Entrance to Caltrain Station
04 Exit to Townsend Street
05A Newspapers, Magazines, Snacks, and Candy
05B Flowers and Drinks
06 Refreshments, Coffee, Hot Dogs, and Doughnuts
07 Exit to Fourth Street
08 Fourth Street Entrance to Caltrain Station
09 Tickets and Information
10 Caltrain Ticket Machine and instructions
11 Waiting Room, Restrooms, Public Phones, Drinking Fountain
12 Exit to Station
13 Public Phones
14 Women's Restroom
15 Men's Restroom
16 Drinking Fountain
17 Exit to Fourth and King Plaza
18 Caltrain Waiting Room, Restrooms, Public Phones, Drinking Fountain
19 Exit to Fourth and King Street Plaza
20 Fourth and King Street Plaza Entrance to Caltrain Station
21 Plaza Entrance to Train Platforms
22 Exit to Fourth and King Street Plaza
23 Plaza Entrance to Train Platforms
24 Exit to Fourth and King Street Plaza
25 Plaza Entrance to Train Platforms
26 Exit to Fourth and King Street Plaza
27 Exit to Station
28 Platform Eleven (on the Right) and Platform Twelve (on the Left)
29 Exit to Station
30 Platform Nine (on the Right) and Platform Ten (on the Left)
31 Exit to Station

San Francisco Caltrain Station and Surrounding Environment Verbatim Talking Signs® Message and Location Legend
32 Platform Seven (on the Right) and Platform Eight (on the Left)
33 Exit to Station
34 Platform Five (on the Right) and Platform Six (on the Left)
35 Exit to Station
36 Platform Three (on the Right) and Platform Four (on the Left)
37 Exit to Station
38 Platform One (on the Right) and Platform Two (on the Left)
39 Passenger Pickup and Drop off, Taxi stand
40 Traveling east on 700 block of 4th St. toward King Street. For Muni Light Rail Raised Platform cross 2 south bound lanes of King Street. Push button to activate pedestrian signal.
41 Walk Sign King Street. Wait King Street
42 Walk sign 4th street. Wait 4th Street
43 Traveling north on 100 block of King Street toward 4th St. Muni bus shelter for #15 and 91 owl on north side of 4th Street. Push button to activate pedestrian signal
44 Walk Sign King Street. Wait King Street
45 Traveling west on 800 block of 4th St. toward King Street. Caltrain station on west side of King Street. Push button to activate pedestrian signal.
46 Fare machine for Muni "N" Judah line
47 Ramp up to Muni platform
48 Traveling south on 200 block of King Street toward 4th Street. Caltrain Station on south side of 4th Street. Push button to activate pedestrian signal
49 Walk sign 4th Street. Wait 4th Street
50 Pay phone and bus shelter for Muni bus line #15

1.5.3. Outline of Tasks

Making transit transfers and mode changes can be difficult barriers for many people with vision restrictions and for those with other print-reading disabilities. The tasks in the field experiment determined if blind people would be able to use Talking Signs® to safely and easily move from one form of transit to another and to efficiently find and use amenities and cross streets with much less effort and time than when attempting these mode changes with their regular method of travel. Hypothesis 1 is tested in these field tasks where 30 vision-impaired people make five different mode transfers, making realistic stops along the way for various amenities and ticketing or fare-paying tasks. Altogether, subjects traveled five different routes to simulate making five transfers using four different forms of transportation (a detailed description of each route and intermediate stops, along with subject's performance, is given in Section 3.1). Travel time, errors, and requests for assistance during the experimental trials were recorded. Because of unforeseen construction barriers and time constraints, the principal researcher acted as a sighted guide and walked the subjects to several locations where no measurements were taken.

Subjects were asked classification questions to determine the characteristics of their blindness or vision loss and to reveal information about variables such as age, education, sex, and basic travel skills and abilities. Pre-test interviews gave information on the subjects' travel and activity behavior, and perceived difficulties while using transit and making transfers. Following the experiment with RIAS, the same questions were asked to determine if changes in transit attitude had occurred. Post-test interviews were conducted to measure attitudes and feelings about the possible impact of this technology. Subjects were asked about difficulties of various transit tasks, rated their perceptions as related to the relative benefits of the technology, and data gathered about their spatial understanding of the environment.

Subjects compared their regular method of travel to their experience when using the RIAS, specifically rating street crossings, in-terminal searching and walking tasks, and making transfers in general.

Other post-test questions related to subjects' perceived trip-making behavior and difficulties of travel in environments that would be as fully served by RIAS as the test environment. This provided data to determine if the technology was perceived as improving their ability to use transit, their frequency of using it, and whether it improved their quality of life by encouraging them to take trips that they had previously not taken. Near the end of the post-test interview, questions were asked to evaluate how helpful RIAS was in various locations and if they should be installed there, as well as other evaluations of the system.

Although blind and vision-impaired persons are the primary focus, this technology has much wider appeal for other print-handicapped people.

1.5.4. <u>Question Design</u>

A combination of experimental methods and techniques was used in this research. Pre and post-test interviews were given to all 30 subjects. Many of the questions were the same in both conditions. They consisted of a combination of five-point rating scales for evaluating various perceptions. Numerical data on trips made on various modes and also trips for various activities, as well as subjects' walking and riding times for these activities, were also collected. Other data were collected by subjects, choosing from a list of choices or "filling in the blank" responses. Evaluations of the perceived difference between their regular method of travel and the RIAS travel with regard to street intersections, in-terminal use, making transfers, and the effects on travel behavior were collected, using non-timed, open-ended questions. This combination of question types helped establish *methodological* or *convergent validity* and reduced experimenter bias in the phrasing of questions and responses.

Since many of the same questions were asked before and after the experiment, data were collected on "within subject" variations of the impact of the system and also on "between subjects" variations. The within subject data helps to understand differences for each individual, no matter what their degree of blindness, skills, socio-economic statue, or other characteristics. Using within subject data, more statistical power can be gained with fewer subjects because one assumes that, except for condition, the other variables are identical. Between subject data allows for testing the differences between wide ranges of subjects.

1.5.5. Field Test Design

In order to collect the most naturalistic and "real-life" data possible, a field experiment was conducted at the terminal test site. Subjects were free to ask others for verbal assistance, if needed, and to use whatever techniques were best for them.

Except for the two conditions of using their *regular method* or using *RIAS*, no other variables were manipulated. A time limit of four minutes was put on each walking and search sub-task in order to avoid undue stress and extreme frustration. Subjects were given verbal information as to the locations to be visited and when to start and stop.

The order of the two conditions was manipulated. Fifteen people traveled using their *regular methods* first, no RIAS (*NRIAS*), and then repeated the experiment using *RIAS*. The other 15 subjects used *RIAS* on their first attempt; 10 of these 15 subjects then tried transfer tasks 1 & 2 with their regular method (5 of the 15 did not perform the tasks with their regular method because of time constraints during the study). It is normal for people to have some learning gain on a second trial. Previous experiments (Golledge & Marston, 1999) showed that people that used the *RIAS* for their first trial had travel time and error production quite similar to those who had walked the route first with their *regular method* and then tried the *RIAS*, especially in more complex routes. Since many of the destinations have no readily accessible cues to indicate “you are here,” it is difficult to “learn” a route after only one trial, especially for those with no usable vision. Therefore, means test between the group that used *RIAS* first and those that used it second allowed for between-subject testing of the same condition to determine if any learning effect took place. The learning effect of repeated exposure in the regular method condition was also examined during the first two trials.

With both between and within subject experiment design in both conditions, powerful analysis should be insured, and the following comparison analysis can be made.

Group 1	Group 2
Regular Methods (NRIAS)1st (N=15)	RIAS 1st (N=15)
RIAS 2nd (N=15)	Regular Methods (NRIAS)2nd First two transfer tasks only (N=10)

1.6. Subjects

1.6.1. <u>Subject Recruitment and Procedures</u>

Using a list of potential blind subjects provided by two O&M instructors in San Francisco, telephone contact was made and it was explained that subjects needed to be legally blind and be able to get to the test area themselves (the principal researcher has a vision impairment and could not offer to pick up subjects with a car). Subjects were offered $50 each for their time and effort. If interested, they were immediately assigned to one of the two test order conditions in an alternating fashion. At that time, a phone interview was conducted on the pre-test questionnaire or an appointment was made to interview them later. The phone interview took about 30-45 minutes. At the end of the phone interview, a field test was scheduled and arrangements were made to meet them near the test site. Subjects were asked to meet the experimenter away from the Caltrain test area, either at a bus stop, cab stand, or at the Light Rail station, all of which were nearby. After the field test, subjects were taken away from the test area and offered a drink and a place to sit while the post-test interviews were given and recorded. Subjects were then paid, signed a receipt, and were escorted to their requested mode of transportation for their return trip. Thirty subjects were recruited and they all completed the entire experiment

1.6.2. <u>Subject Classification and Analysis</u>

Five subjects were from the Peninsula Center for the Blind (PCB) and seven were from the Living Skills Center (LSC). Both these groups train living skills for the blind. The LSC is mostly for young blind adults after high school age who want to be independent. PCB also trains older people that become blind or vision-impaired. The rest of the subjects were mostly employed and middle aged adults who were known to the two contact people who provided the subject list. Some worked for the California Department of Rehabilitation, the Lighthouse for the Blind, or the Department of Veterans Affairs. Several subjects were referred by other participants. No one who worked for Smith-Kettlewell Eye Research Institute or had ties to Talking Signs® was used as a subject, although some were used in the pilot testing.

Eleven subjects were female and 19 were male. The average age was 37, ranging from 19 to 67. The average education was midway between having some college and being a college graduate. Five were high school graduates, eleven had some college, seven were college graduates, and seven had advanced degrees. All subjects were legally blind, meaning they had either a corrected vision of 20/200 or less or had a restricted field of vision less than 20 degrees. Sixteen were born blind (congenital blindness) and one was blind at age one. The average amount of time that the 30 subjects had been blind was 29 years. Many pathologies were represented. Subjects reported macular degeneration, retinitis pigmentosa, optic nerve damage, cancer of the eye, retinopathy of prematurity, measles, albinism, cataracts, and glaucoma. A wide range of visual acuity was reported, with 11 subjects having no perception at all and eight more having only light perception. The other 11 subjects reported some type of useful vision; six reported they could see shapes, and five said they could see objects up close. Four subjects could read large print, six could read large print with a magnifier, and 20 could not read print at all. All those who could not read print and two who could (22) reported Braille skills.

The impact of adaptive and assistive technology was quite evident. All but one subject used some type of device to aid in reading. They ranged from a simple magnifier (3) to CCTV, scanners, tapes, computer speech synthesizers, and Braille machines. Three people reported slight hearing loss, though not enough to cause a problem with the auditory output of the RIAS.

1.6.3. Mobility Information and Experience

Four subjects did not use any aid in travel, 20 people used a cane as part of their normal travel, and 6 subjects normally used a guide dog. Some of the dog users used a cane during the experiment. Nineteen subjects reported having had an average of 2.5 years of Orientation and Mobility training on using transit. Twenty-six subjects reported having had Orientation and Mobility training for independent travel skills, with an average training length of 3.7 years.

Twenty-four of the subjects had heard of Talking Signs® before being contacted for the experiment. Eleven had never tried them, and 19 said they had tried them "a few times." No one reported being a regular user.

Fourteen subjects said they had never been to the experiment area, the Caltrain station at 4th and King. Eleven reported being there "a few times," and five said they had been there more often than that.

1.6.4. Distribution of Subject Characteristics across the Two Conditions

Experiments with people having vision loss are confounded by several factors. First, it is hard to recruit large numbers of suitable subjects to conform to more common standards of statistical requirements, and, second, there is a large range of travel-related skills and characteristics of vision among members of this group. The number of subjects in this experiment is actually much larger than many experiments conducted with blind individuals. Even though the subjects were alternately assigned to the two conditions, with the small number of subjects (N=30), the large agreement of subject characteristics added to the validity of the conclusions.

Table 1.2 shows certain variables that could impact the equitable distribution across the two conditions. One subject with rapidly deteriorating vision insisted that he be able to perform the field test while blindfolded. He said it would give him a better idea of how the system would help him in the future, and so, for the field test only, he was treated as a totally blind subject (no useful vision). Significance tests were conducted on the characteristics below, and no significant difference was found between the characteristics of subjects assigned to the two conditions.

Table 1.2 Distribution of Subject Characteristics across the 2 Conditions

Subject Characteristics	Condition 1	Condition 2
	Regular Method	With RIAS
	NRIAS 1st	RIAS 1st
Gender ratio	60% M	67% M
Age	34	39
Congenitally (born) blind	10	7
Age at onset of blindness (non- congenital)	18.8	18.1
Education completed (median)	Some Col.	Some Col.
Years legally blind	28.2	29.3
Subjects, no useful vision	11	9
Subjects, see some shape	2	4
Subjects, see some objects	2	2
Independent travel (mobility rating)	1.9	1.7
General sense of direction (mobility rating)	2.4	1.9
Mobility in new environment (rating)	2.9	2.7
Frequency of learning a new route (rating)	3.7	3.7
Familiarity with Talking Signs® (rating)	1.8	1.5
Familiarity with Caltrain station (rating)	1.5	1.9

1.6.5. <u>Training with Remote Infrared Audible Signage</u>

All subjects received about 10 to 15 minutes of training using Talking Signs®. An explanation was given as to how the transmitter sends a conical beam of light that carries a message that the receiver picks up and speaks to the user (see Section 2.4 for details). They practiced finding the edges of the transmitted cone by moving the receiver and finding where the message finally disappeared at the top, bottom, and both side edges of the cone. A transmitter that was not on the route was used for this purpose, and subjects practiced walking and following the beam to this site three times. Next, each person was taken to another location not on the route and practiced walking toward this transmitter. A portable transmitter was then attached to a light pole away from the route, and they made three more walks to locate the pole. These last two transmitters were close enough that subjects could receive signals from both while standing at a central location. Here they learned how to orient themselves between two signals. The initial explanation and these nine practice walks were the only training each received. Other experiments using non-directional acoustical sounds have required many weeks or months of training to teach auditory localization (Easton & Bentzen, 1999).

1.6.6. <u>Sighted Subjects for Baseline</u>

The major purpose of the experiment was to document how people with vision impairments performed tasks with their regular method and when using location-based infrared transmitted auditory signage. However, some data were obtained from sighted subjects to use as a baseline comparison. Clark-Carter et al. (1986) suggests that the best way to test different navigation aids is to compare walking times. By extension, the walk times of the blind subjects are compared with that of a sighted person to better compare the degree of restriction imposed by the absence of vision. The field experiment at the Caltrain station was based on tasks requiring searching and walking. Baseline walk times were obtained from two sighted subjects. The first subject was a research assistant who had never been to the test site before. He was blindfolded and taken to the start point. Here, the blindfold was removed, and he performed the field tasks. Walk times, requests for help, and errors were recorded. Since it was his first exposure to the environment, several errors were made, as was expected. His times represented a first-time sighted user (FTSU). To obtain a baseline of error-free walk times, the principal researcher, who was very familiar with the environment, walked the route. His times represented a familiar sighted user (FSU). The FTSU was younger and taller and his walk times were often a few seconds faster than the FSU, but since he was unfamiliar with the area, he did not always walk a direct path and a few times were much longer, so that the total time for the FSU were less than for the FTSU. APPENDIX 1 shows the times for these two sighted users.

The effect of vision loss on transfer making behavior was studied by asking a series of questions about perceived behavior when making a decision to transfer. In order to compare those responses, 30 sighted people were interviewed. On the daily public transit ride to and from the experiment site, the principal investigator looked for sighted people of the same sex and general age range as that day's test subjects, who were then asked if they were regular users of transit, and, if so, were told of the experiment. They were asked the same six questions that were asked of the blind test subjects about transfer making behavior. This group represented sighted users (SU).

2. Background

2.1. Self–Reported Transit Task Difficulty

To focus this research, it is important to first look at what vision-impaired people say about their activity and travel in order to understand if some type of impedance to access exists, and, if so, if it can be mitigated through increased spatial knowledge delivered by a location-based auditory modality.

Data collected from two different experiments relating to difficulties that blind and vision-impaired people face when using transit validate our research interests and procedures. A previous experiment was conducted with 27 vision-impaired subjects in the mid-size town of Santa Barbara, California. The only forms of public transit in the city are a bus system, some paratransit, and cab service. That study produced data about subjects' perception of using transit (Golledge & Marston, 1999). They rated the difficulty of performing specific transit tasks and some of those data are compiled for the following table.

Table 2.1 Transit Task Difficulty (Santa Barbara)

Golledge & Marston, 1999)

Rating scores based on values of "Extremely difficult (1), Very difficult (2), Difficult (3), Somewhat difficult (4), Not at all difficult (5)"

"How Difficult Are These Transit Tasks?"	Rating
Finding the proper bus stop	2.4
Finding my way around the main terminal	2.5
Finding the proper bus among those at the terminal	2.6
Transferring from one bus to another at the main terminal	2.6
Transferring to another bus on the line	2.8
Having to cross busy streets	3.1
Finding and boarding the proper bus	3.2

All tasks we rated between the range of "Very Difficult" to "Difficult". Finding a bus stop was rated as the hardest with a rating of 2.4, closer to "very difficult" than to "difficult." Navigating around a terminal was rated mid-way between "very difficult" and "difficult."

Finding and transferring buses at a busy terminal were rated almost as difficult as the first two tasks. Transferring buses on the route was not as difficult as at a terminal. Crossing a street and finding and boarding the proper bus was rated close to "difficult."

A larger and more intensive interview was conducted during this reported research in San Francisco, a much larger city with many forms of public transit.

Table 2.2 shows a wide range of 20 transit tasks listed in the order of the difficulty reported by 30 subjects in the present study. The same rating scale was used as in the first table. These data are discussed later in much more detail (see Section 3.2, User Rated Difficulty of Transit Tasks).

In order for the reader to fully appreciate the challenge faced by those persons with visual impairments seeking independent travel, this author challenges the sighted reader to consider how easy these tasks are with vision and then try to imagine what they would be like without sight. These two tables, which show how difficult these tasks are, highlight the important nature of this research. Again, the ratings fall between “Very Difficult” and “Difficult”. With this degree of difficulty, independent travel in a safe and timely manner is denied to many vision-impaired people. Hence, for this group, the city needs to be made more accessible.

Table 2.2 Transit Task Difficulty (San Francisco)

Rating scores based on values of "Extremely difficult (1), Very difficult (2), Difficult (3), Somewhat difficult (4), Not at all difficult (5)"

"How Difficult are these Transit Tasks?"	Rating
Finding the proper boarding gate at a train station when there are many doors or gates to various platforms.	2.0
Having the same access and ease of use of transit and public buildings as enjoyed by the general public is?	2.3
Transferring buses at a busy terminal.	2.3
Finding information or ticket windows, services and amenities such as phones and bathrooms in a new building or terminal.	2.3
Finding a bus stop.	2.3
Knowing which buses stop at a bus stop.	2.3
Finding my way around an unfamiliar train or bus terminal.	2.4
Finding out which Muni routes are served by a platform.	2.5
Transferring from a train or bus terminal to another mode of transit (light rail or bus) one block away.	2.5
Leaving a station and finding a taxi stand on the street.	2.5
Getting enough suitable information about an unfamiliar transit terminal or building so that you could make an unaided trip.	2.6
Finding the proper bus.	2.6
Knowing what street corner I am at when in an unfamiliar area.	2.7
Transferring to another bus on the line.	2.8
Realizing I am lost while traveling and don't know which street corner I am at.	2.8
Getting enough suitable information about transit boarding locations on an unfamiliar transit route so that you could make an unaided trip.	2.9
Finding the entrance and the platform for a street level Muni platform	2.9
Finding which side of the platform to wait at for the proper train.	2.9
Finding the door to a train at an unfamiliar platform.	3.2
Crossing a busy street in an unfamiliar area.	3.2

2.2. Navigation and Wayfinding Without Sight

Independent travel without vision (Bateman, Langford, & Rasbash, 1999) is full of fear, anxiety, uncertainty, and disorientation. Indeed, space itself seems transformed. Golledge, (1993, p. 64) says that, in spatial interaction, "effort is magnified many times when one is disabled." He goes on to say that "Gutters become chasms, sidewalks and streets become treacherous paths, stairs may become impossible cliffs, distinctive size, shapes or colors may lose their significance, layouts become a maze, maps, and models may be uninterpretable. Space can become widely distorted either by incomplete knowledge (for the blind) or laboriously transformed (as in the case of the wheelchair user). Who better to examine the nature of the distorted spaces in which these populations must endure than the geographer? As spatially aware professionals, geographers should have the best tools for understanding the transformations between objective reality and the realities in which persons with disability live and interact."

There are a wide range of investigative techniques and professional viewpoints that are used to examine the nature and effects of vision loss, and the geographer, or spatial scientist, can add to that body of knowledge by disciplined analysis of the use of space and spatial interaction exhibited by those individuals. This current research uses a spatial and travel behavior approach to study this group.

The Americans with Disabilities Act is very explicit in terms of requiring equal access to urban opportunities such as transit and public buildings for disabled populations. For example, Section 302 (b)(1)(A)(ii*) Participation in Unequal Benefit*, states: "it shall be discriminatory to afford an individual or class of individuals, on the basis of a disability or disabilities of such individual or class, directly, or through contractual, licensing, or other arrangements, with the opportunity to participate in or benefit from a good, service, facility, privilege, advantage, or accommodation that is not equal to that afforded to other individuals" (Commerce Clearing House Editorial Staff, 1990, p.154). This establishes the right of disabled citizens to equal opportunity or equal access to services such as public transit. This is a laudable goal, but "equal access" is hard to define or even to achieve. While "equal access" is referred to in this document, what is discussed are barriers to wayfinding and travel and how to **increase access** for visually impaired people to enable them to have more opportunities through more efficient, safe and successful interactions in the built environment.

In order to assess the degree of access afforded vision-impaired people, a previous survey was conducted of activity behavior and travel needs of fifty-five blind bus users. They were also interviewed about what was needed to increase transit use. Information about which bus was arriving, where they were en route to, where to get off, where bus stops were, how to cross streets to transfer between busses, and finding their way around the terminal were what they reported needing most (Golledge et al., 1995).

The Americans with Disabilities Act mandates that all people are entitled to equal access to public transit and buildings. Curb cuts for wheelchair users, ramps, and bus lifts have removed many of the **structural** barriers to equal access. The use of location-based auditory signs can remove some **functional** barriers that the blind and vision-impaired encounter because they cannot read signs or pick up visual environmental cues (Marston & Golledge, 1998a). If a person cannot find a bus stop, read a bus name or number, locate transfer locations, find the correct train platform, or find stairs and elevators in a building, they do not have equal opportunities to use those facilities. Locations marked with Braille are helpful, but do not help blind people find their way to those places.

People who are blind are often taught routes in real environments to get from point A to point B. Although this type of instruction is called Orientation and Mobility training, most of it is mobility training only and is limited to the immediate surroundings of the body. Canes and dog guides are used to avoid obstacles and dangerous places, but orientation to the environment and spatial understanding in unfamiliar areas usually means asking people for help and information. If people are not nearby or do not know the area, this can be very frustrating and time consuming, not to mention the loss of independence, possible safety concerns, and the loss of self-esteem that may ensue. The combination of the many restrictions and the various concerns of visually impaired travelers affects their access to urban opportunities. The research reported here is concerned with identifying these impedances to accessibility and determining how to measure them, which would also enable measurement of any mitigation technique that might affect accessibility for this sub-set of the population.

2.3. Measuring Accessibility

The urban landscape and our interactions within it are rapidly changing due to forces like suburbanization, transportation and telecommunication technologies, economic and global restructuring, and the life stages and cycles of the people within. These interactions are widely studied, and Pirie (1979, p. 299) states "there can scarcely be a book or paper on urban and regional affairs that does not allude to the notion of accessibility."

2.3.1. Definitions

Hanson, (1995, p. 4) defines accessibility as "the number of opportunities, also called activity sites, available within a certain distance or travel time." Ingram (1971) says that accessibility is an inherent characteristic of place and is operationalized in terms of overcoming some form of friction. There are three dimensions to these definitions. First, a distance or spatial interaction among locations (activity sites);

second, a transportation system or network that links these locations; and, third, the desire and means or ability (financially, physically, and temporally) to visit these sites and overcome the spatial separation (an impedance function).

The study of the extent and strength of human interaction with the environment is a central concern within the study of Human Geography. These measures can be used to address planning and policy decisions (Talen, 1995, 1996). Accessibility is also a common focus for geographic study of fields ranging from social equity to urban form, and from transportation to economic growth. Although central to this research, accessibility is often a misunderstood and poorly measured construct and it seems that every sector of this field has its own definitions and methods for discovering this interrelationship and process. This is true, because finding an operational concept of accessibility is very difficult and quite complex. Gould (1969, p. 64) summed up these problems well with his statement that accessibility "is a slippery notion…one of those common terms that everyone uses until faced with the problem of defining and measuring it."

Traditional measures treated accessibility as strictly a physical or spatial construct. They were usually based on distance between origins and destinations. Later, other surrogates for travel efforts were used, such as network modeling showing travel times or costs. All these models of spatial separation and interaction are based on physical networks or topology and might be considered as revealing a potential accessibility within that system. They ignored constraints of time or constraints on the activities. They most certainly ignored other social and individual constraints that might hinder the ability to connect with different activities.

2.3.2. <u>Conventional Physical Measures</u>

2.3.2.1. Distance measures

Relative measures of accessibility (Ingram, 1971) are expressed by distance or travel time between two points. The further away the points are, the less accessible they are. The measure is usually symmetric if the connection between the two places is not unidirectional. Physical distance, time, or some measure of cost can be used to measure the degree of spatial separation. Integral measures determine the relationships between one point and all others in the study area. This is like the attraction model in store location theory. Unlike the relative measure, it is not reflexive (the accessibility of a store to all homes is not the same in the other direction). It can also be used to show which points have the highest or lowest degree of accessibility to the entire set of opportunities. This can be used to determine social equity in the case of planning agendas (Talen, 1995).

2.3.2.2. Gravity-based measures

The *gravity measure* is, so far, the most popular of accessibility measures. It is based on network distances combined with a measure of opportunity or attractiveness at the other nodes (Hanson, 1995). The distance or effort that needs to be overcome reduces the number of opportunities or attractions at a particular node. This gives a measure of the relative accessibility of that location. An impedance function is used to define the effort needed to overcome distance or effort. The most widely used impedance functions are the inverse power function, a negative exponential function, or a modified Gaussian function. A major problem with this seemingly straightforward approach is that, as urban structures, opportunities, and people's desires and abilities change, the distance decay or impedance function also changes. To be successful, these functions need to be fine-tuned for each new study to reflect the true impedance at that point in time and space. Another problem here is that zonal centroids are used, and so the models assume that all individuals are gathered at the centroid and enjoy the same accessibility, although they may perceive the set of alternatives quite differently (Ben-Akiva & Lerman, 1979). Also, any change in intra-zonal access, like local roads or shuttle service, will not be reflected. Pirie (1979) says that zonal accessibility measures not only neglect the distribution of activity sites within the zone but also assume that all individuals within the zone have the same set of opportunities.

2.3.2.3. Cumulative-opportunity measures

If the impedance function from the gravity model can be made to exclude opportunities beyond a set distance, this leads to another type of measure of accessibility, *cumulative opportunity measures*. These are based on how many opportunities are available within a certain distance, travel time, or cost (Wachs &

Kumagai, 1973). They do not discount measures of opportunity over this restricted distance, because all sites within the distance are rated as equally accessible. For those with a car this is not such a shortcoming as for those who are on foot.

2.3.2.4. Problems with traditional measures

Traditional measures treat attractions, such as zonal employment possibilities, equally for all members in a designated zone. In fact, job skills and job vacancies may mean that no one in the zone can be employed there. Also, with these measures it is incorrectly assumed that all trips originate from the home location. They ignore the many trips that originate from the work location (such as noon errands and child-care), other anchor points, and the abundance of multi-linked trips (Golledge & Stimson, 1997). These complex linkages of multi-stop trips present major problems for these types of models. Although helpful, these models appear to be more a measure of mobility around a network. They are perhaps best for modeling the transportation network and looking for ways to model traffic flow and future improvements. Although accessibility is central to human activity and movement, standard transportation analysis such as travel demand modeling and methods like Intelligent Transportation Systems (ITS) actually ignore accessibility and, instead, focus on increasing system throughput. Zonal models are highly efficient computationally, and the data are available from many sources, usually already in digital format.

Aristotle reminded us to examine problems at the scale of detail that they admit to us; this research problem needs to be examined on the individual or disaggregate level. More than measures of physical mobility or distance are needed—it is also necessary to examine accessibility from a behavioral perspective. These methods (the aggregate, zonal, network distance, time, or cost models), fail to answer the most important question “what about the people?"

2.3.3. Time Geography and Constraints

The seminal work by Hägerstrand (1970), "What about people in regional science," brought human actors to the forefront of physical measures of accessibility. His work led to the realization that it was necessary to address accessibility from an individual and behavioral perspective. One of his major concepts was his theoretical framework of *constraint*s, which influence “how paths are channeled or dammed up” (p. 11). This framework is applicable to all people but is especially pertinent when analyzing the activity space and travel behavior of different disabled groups. Hägerstrand points out that the “set of potentially possible actions is severally restricted” by these constraints that are “imposed by physiological and physical needs” (p. 11) as well as other types of decisions, both public and private. Daily, we face societal constraints on our time and travel that restrict our freedom to interact in the environment, and Hägerstrand identifies three classes of constraints: *capacity, coupling,* and *authority.* Marston et al. (1997) consider how these constraints can affect people with limited vision. *Capacity constraints* limit human activity because of biological (like sleeping and eating) and physical conditions (ambulatory problems or restricted vision). The lack of *tools*, such as a car or ability to use transit, affect the travel time or distance which one can travel (based on the total time budgeted or available.). Lack of access to tools or materials are then also capacity constraints that limit activities. *Coupling constraints* are those arrangements of time and duration where people have to meet up with other people or tools, (such as rides), to perform activities, or to form *bundles* of consumption, social interaction, and production (Pred, 1977). These couplings or bundles occur when people have to arrange their schedule to match that of another. For example, using transit requires meeting the vehicle and being dependent on its arrival time. A work schedule might involve having to meet clients or superiors within a small time window or leaving at a specified hour, regardless of the transportation available. *Authority constraints* refer to social and economic barriers and all the laws and rules of a structured society. These constraints limit freedom of movement and activity participation, or the freedom to "choose activity bundles" (Pred, 1977, p. 638). Indeed, these three types of constraints form a system of barriers that prevent certain movements or the ability to move freely (Hägerstrand, 1975).

Scheduling of activities is spatially constrained but also highly dependent on available time, desire, means, and individual preferences and abilities. By increasing the resolution to this level of observation and analysis one can find not only the potential accessibility of a system or network, but also a revealed and realized accessibility of individuals, households, and groups. Space-time constraints and individual time budgets determine an individual's accessibility. It does not matter how many opportunities are located at some distance to an individual, but how many of these are within reach of the individual's capacity and situation (Dyck, 1989). The *zone* or *census tract* models give one only averages to work with. With the use of *space-time prisms* (Lenntorp, 1976), one can use potential path space to determine individual accessibility to the environment. No longer tied to zonal averages, one can better understand accessibility for different groups like the elderly, children, non-drivers, families, empty-nesters, single people, and disadvantaged or disabled people.

Behavioral research finally freed us from the tyranny of the rational "economic man" who had perfect knowledge and worked to maximize opportunities. From the work of Golledge and others (e.g., Golledge, 1967; Wolpert, 1965; Amedeo & Golledge, 1975), it is known that people "satisfice" rather than optimize and do not possess perfect knowledge of all available opportunities (opportunity sets) (Golledge, Kwan, & Gärling, 1994). As work with the vision-impaired has shown, lack of information about the environment is the most limiting factor in independent travel and access to urban opportunities (Marston et al., 1997). Add to this the anxieties, difficulties, and stress, along with slower walking and search times, and it is no wonder that blind people make fewer trips. For example, it is quite probable that a blind person and a sighted person who lived next door to each other would have completely different access to urban opportunities, but these differences would never be measurable with any of the traditional, physical, and network based systems.

Time Geography was not considered a network accessibility measure at first, probably due to the problems of scaling the concepts into workable aggregate units. Advances in GIS and spatial modeling now allow researchers like Kwan (1998a, 1998b, 1999) and Miller (1991, 1999) to use Hägerstrand's concepts to better understand the individual nature of accessibility. Their research has shown that the problems of efficient computation and geo-coding of individual origins and destinations no longer pose a constraint on the examination of accessibility at its necessary scale of study—that of the individual. These time-space approaches will bring research much closer to Weibull’s definition of accessibility as a measure of an individual’s freedom to participate in activities in the environment (Weibull, 1980).

This new use of Time Geography allows one to look at both structures and functions of the environment. Instead of a measure of potential accessibility, it is now possible to determine revealed or realized accessibility for different groups of people. Because scheduling of activities is not only spatially constrained but also time dependent, research in *human* geography demands that people should be the scale of interest for the understanding of spatial interactions.

With time-space prisms, one can also examine gender issues of equality, as researched by Kwan (1999). She examines issues of space-time constraints such as those imposed by work schedules, child-care obligations, and coupling one's schedule to friends, children, and those in authority, such as stores or services that are only open certain hours. This author would have liked to use this kind of research to analyze the accessibility of blind people; but simply comparing blind travel patterns to a group of sighted people would have revealed little more than what is already known—i.e., that the majority of people who are blind have a very restricted activity space and hence less accessibility than people who are sighted. There was also no way to test blind people's actual travel behavior through diaries, with and without new technical travel aids, as no urban area is so equipped.

In this experiment, both objective field data (such as travel times and errors) as well as subjective data (including estimates, opinions, and affective states) were collected and analyzed. The accessibility measurements used traditional models with a behavioral approach. It is easy to see how the lack of a driver's license, having to rely on transit or other people for travel, along with the lack of vision to inform people about the environment and the lack of information needed to perceive it quickly and correctly add many constraints to life, travel, and accessibility for a blind person.

2.4. Remote Infrared Auditory Signage (RIAS)

Auditory cues are often used to replace some of the environmental information that is not available to people without sight. Various technologies might be used in the future to provide location-based auditory cues. Cameras or digital devices (like bar code readers) might be used from a distance to read signs and speak their message, giving information and directional cues. Global Positioning Systems (GPS) based devices might be used to transmit a directional auditory beacon that appears to come from a location.

This research looks at a current technical device—Remote Infrared Audible Signage (RIAS)—that can eliminate the reliance on existing auditory cues in the environment that is often masked and indistinct and supplement them. Using RIAS, messages are structured and distinct, delivered in a natural spoken language, give landmark names and spatial direction information, and do not produce unwanted noise pollution. These auditory labels can substitute for visual cues unavailable to the blind traveler and should increase the ease of travel and the acquisition and accuracy of spatial knowledge. It is hypothesized that these benefits will increase the availability of urban opportunities and, therefore, increase the accessibility of the vision-impaired.

Remote Infrared Audible Signage technology (e.g., Talking Signs®) was originally developed in 1979 at the Smith-Kettlewell Eye Research Institute in San Francisco

(Loughborough, 1979). The technology has been under continual development and evaluation at Smith-Kettlewell's Rehabilitation Engineering Research Center on Blindness and Low Vision (part of the National Institute on Disability and Rehabilitation Research [NIDRR]). Talking Signs® (TS) have found commercial deployment in numerous locations in the US and other countries. In San Francisco, Talking Signs® have been installed in various public and government buildings (City Hall, Courthouse, Main Library), streetcar, subway, and commuter rail platforms, bus stops, non-profit organizations, banks, sidewalk intersections, and even at outside public toilets. They are installed at other cities in California (Berkeley, Freemont, and Santa Barbara) and in other sites across the country. Talking Signs® are installed in various countries in Europe, such as Finland, Italy, and Scotland. Major commitments have been made in Japan; where thousands of transmitters have been installed at street intersections, transit terminals, museums, schools, and other locations (Talking Signs Inc., 2000, 2002).

Audible signage can give freedom and independence to the blind and vision-impaired, the developmentally disabled, the dyslexic, and other print-handicapped individuals, not to mention people who don't read the local language. The particular audible signage system tested in this experiment consists of an infrared transmitter that sends a directional signal to a hand held receiver that plays the transmitter's audio message through a speaker or an earphone. The receiver thus gives orientation and location information to the user. The range of the signal and the duration of the message can be adjusted to suit environmental needs. With it, one can identify street corners, bus identification numbers and routes, the location of bus stops, information kiosks, building entrances and exits, and public facilities such as drinking fountains, washrooms, phones, and elevators. In fact, any location (including those commonly identified with a written sign) can be identified with an auditory sign. These devices have the potential to give blind and vision-impaired people access to the information that the sighted take for granted. They can travel independently, shop, and visit buildings such as government offices, transit centers and rail platforms, libraries, malls, hotels, and other large spaces, which are normally confusing to the blind traveler. For more technical details on the electronics of the system see Crandall, et al. (1994, 1998), Crandall, Bentzen, & Myers (1995), and Crandall & Geary (1993).

Figure 2.1 shows the receiver used in the present experiment. It shows the sensor that receives the infrared signal, the speaker, "on" pushbutton, and a breakaway neck strap. (Power and volume switch and earphone jack not labeled). It is lightweight and easy to carry in the hand. An infrared beam transmits the message imbedded in the sign to this hand-held receiver, which is heard through the receiver's speaker.

Figure 2.1 The RIAS Receiver

Figure 2.2 shows the appearance of the transmitter cover used at the test site. Various designs can be used; this one is a 4” square, a truncated pyramid covering the light-emitting diodes. It is usually mounted at approximately seven feet above the floor to avoid interference from people and other objects.

Figure 2.2 Transmitter Cover and Placement

Figure 2.3 shows how the transmitter above a doorway to a building gives an identifying signal whose message names the building. The signal is homed in on to give the user a direct path to the labeled location.

Figure 2.3 Directional Beam from Transmitter to Receiver

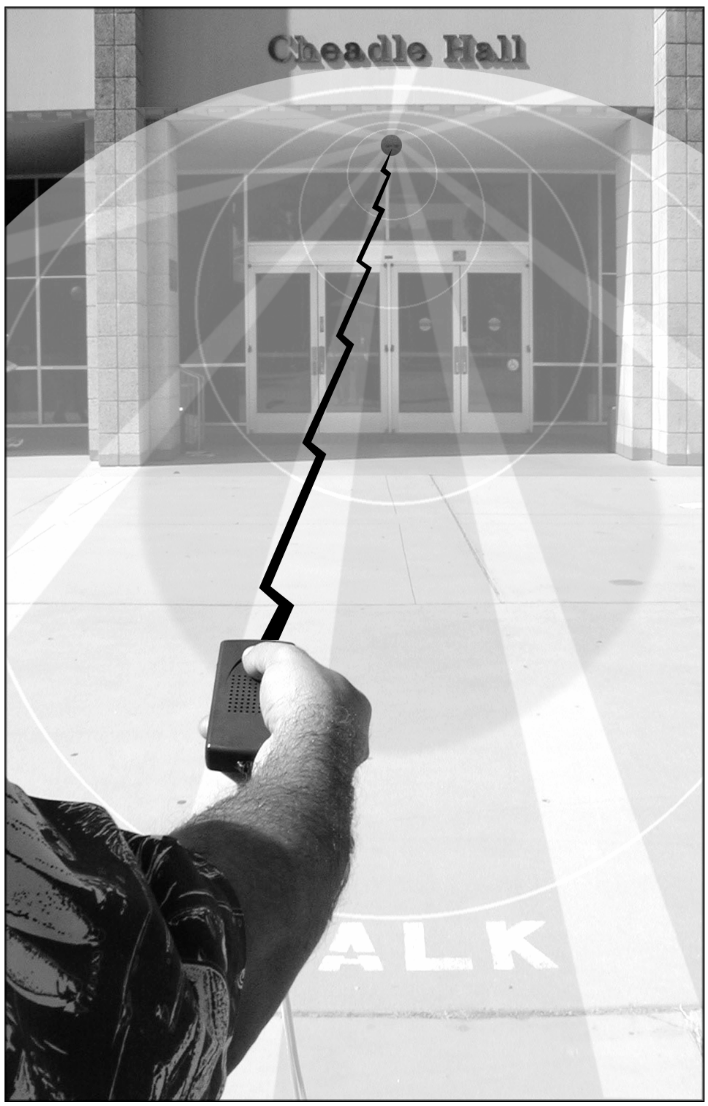
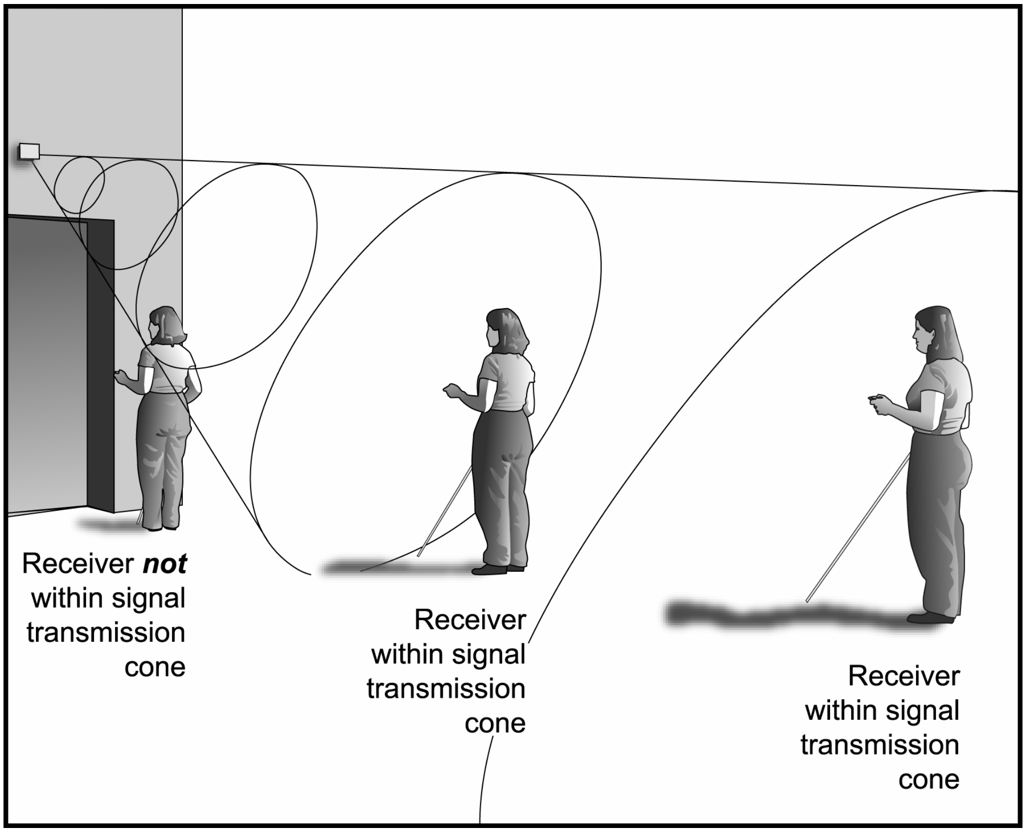


Figure 2.4 shows how the light beam forms a 51-degree cone and covers more area the further away it shines. At a far distance, the user scans the area with the receiver and intercepts the beam. This causes the receiver to “speak” the verbal message imbedded in the sign. Keeping that beam aligned with the receiver’s sensors gives a direct path to the beam’s origin. As long as the message is heard, users know they are going directly to the correct location. As one approaches the transmitter location, the conical beam becomes smaller, until, up close, the user would have to point the receiver up to find the exact location. This allows users to know when they are “almost there.” It must be understood that this is a simplified drawing. The conical shape comes from each diode, and there are, in this model, 18 such diodes. Therefore, these diodes can be arrayed to fan out, so that, in the case of a building entrance, the beam could actually cover a 180 degree area so that, no matter from which direction one is approaching, the beam would take you directly to the source. An interior corner would require a maximum of a 90-degrees spread, and a bus stop pole or public phone in a plaza could have a complete 360-degree range. The actual coverage of the beam, in both direction and intensity, is individually adjusted to fit the environment and situation.

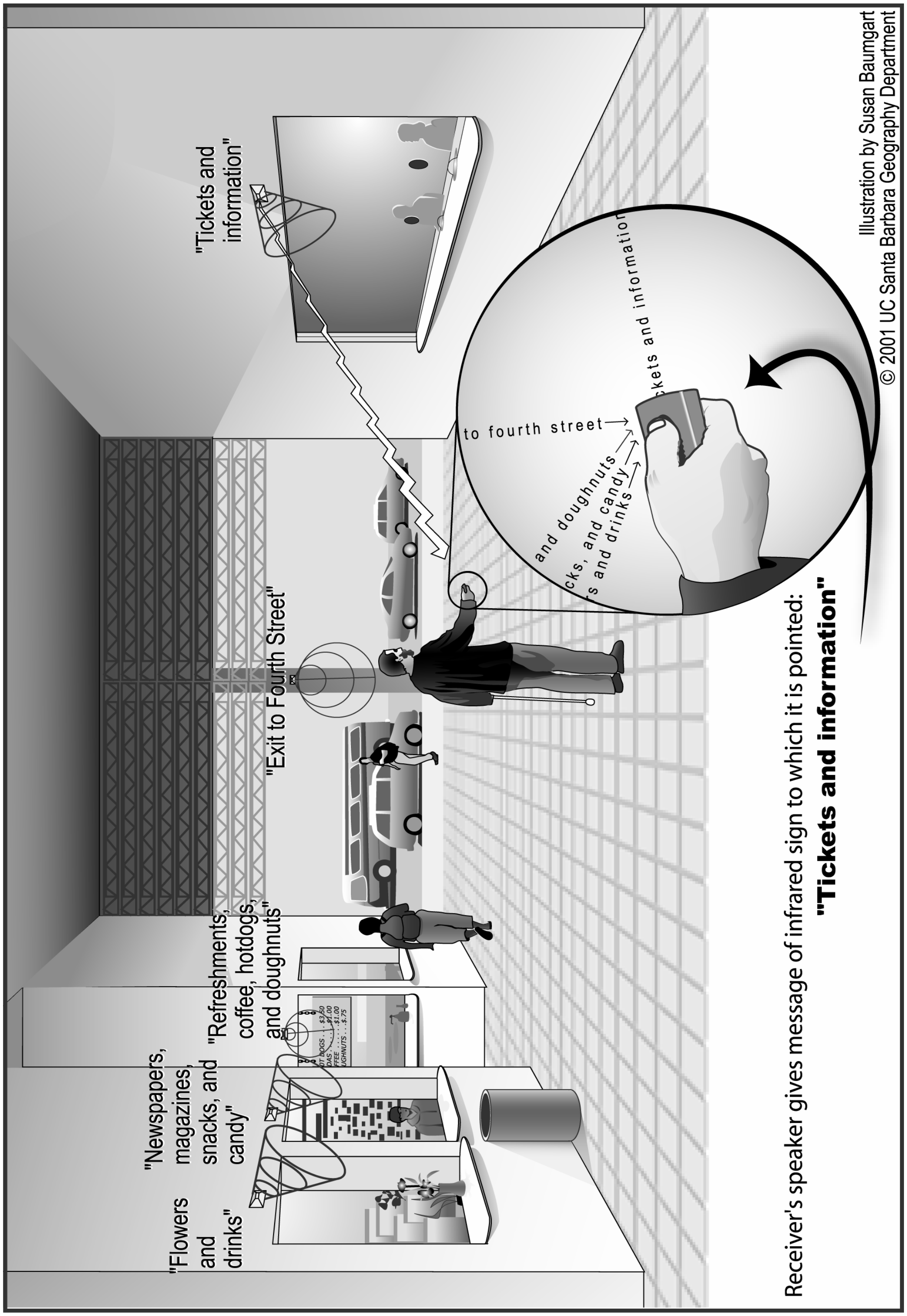
Figure 2.4 Cone Shaped Infrared Light Beam from Transmitter



A person with a RIAS receiver can thus enter a new environment, such as a transit terminal, and, by scanning around with the hand; identify different locations from a distance and also know the direction to that location. This alone is a great help to independent travel, but even more can be gained from such a system.

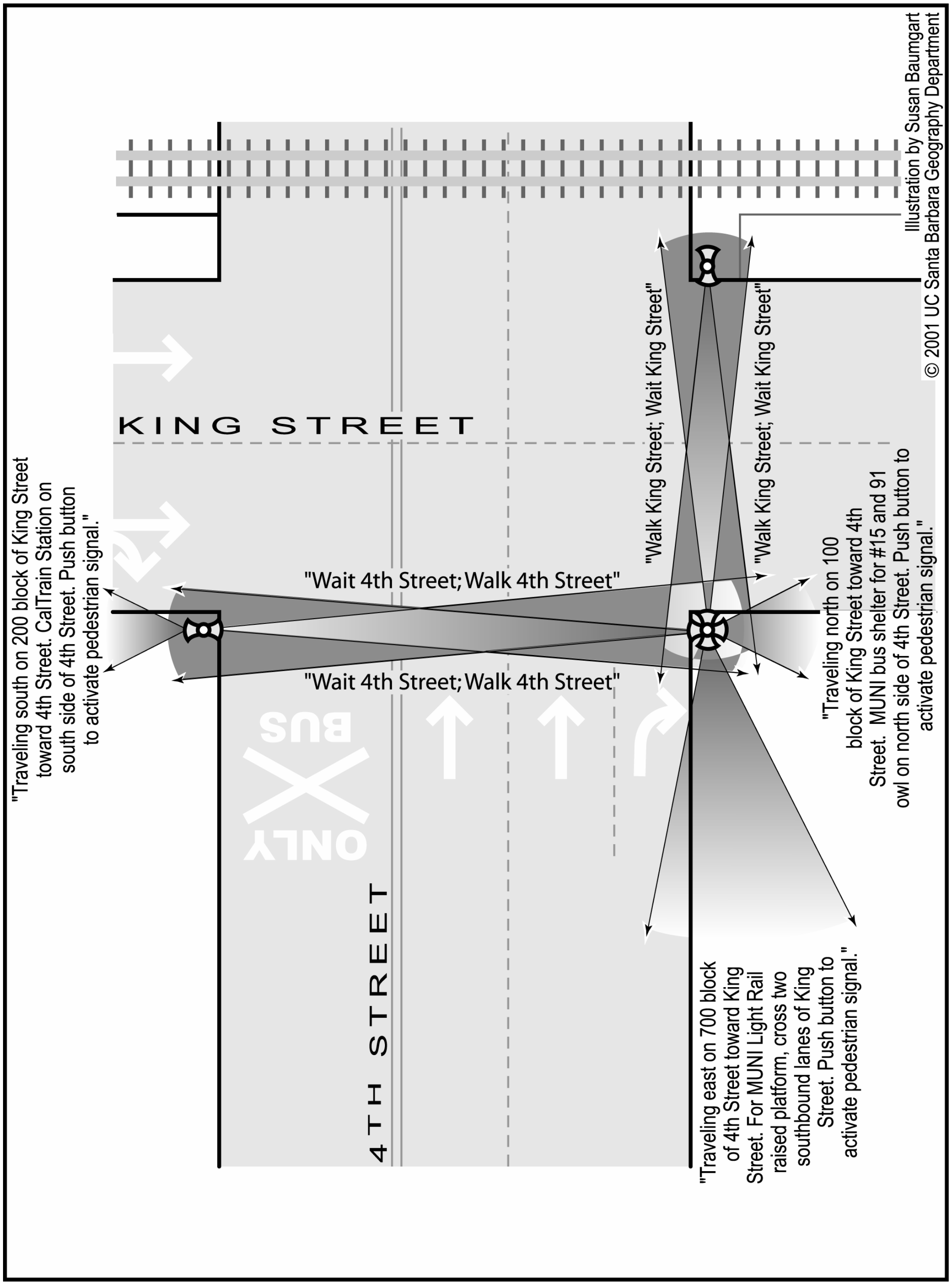
For example, Figure 2.5 shows an installation at a train terminal. Typically, when blind people are in an environment like this, they would have to find their way to a wall and start to learn the locations of amenities along that wall and then check out other walls. This is a very time-consuming activity, but this is how most blind people learn a new environment. Whenever blind people become disoriented in an open space, they might have to return to a wall and try to figure out where they are and the relationship to the other locations around them. As the diagram shows, the person using RIAS can stand in the middle of an open space and pick up the direction and identity of distant, multiple locations, all without moving around the environment. Instead of having to walk to each of the locations many times to learn their spatial relationships to each other, RIAS users have almost instantaneous feedback from the objects, akin to using vision, and can place those relationships directly into their cognitive map. In this illustration, the person can find the ticket window, the exit to 4th Street, and three different concession stands. Although it is not shown, this person would also be able to scan to the rear of the building and find out that the doors to track #3 and #4 are directly opposite the exit. This ability to gain almost instant knowledge of an area is far superior to anything yet developed and holds great promise for the blind to increase their access to environments.

Figure 2.5 Transit Terminal Installation



RIAS can also be used to identify street intersections, traffic flow, and signal information. Unlike auditory traffic signals, which merely provide an auditory signal of a certain duration during which time it is “safe” to cross a street, Talking Signs® go well beyond the concept of a simple indicator. They are, in effect, an information system. The Remote Infrared Audible Signage equivalent of an auditory traffic signal (see Figure 2.6) transmits a wide beam with the name of the two streets, the address number of the block, and the direction the receiver (person) is facing. It can also give information about nearby places of interest and inform if there is a push button available to change the pedestrian signal. The narrow beam gives a distinct WALK or WAIT signal for the pedestrian traffic in the direction the traveler is facing, as well as defining the width of a safe passage corridor for crossing a street.

Figure 2.6 Typical Street Information and Coverage with RIAS



2.5. Previous Research on Auditory Signage

2.5.1. <u>Early Indoor and Outdoor Evaluations</u>

Early field experiments with auditory signage, as a supplement to tactile signage, were concerned with determining how well it worked and which design yielded the best performance. The American Council of the Blind sponsored a comparative evaluation of two technologies, Verbal Landmarks (VL) and Talking Signs® (TS), at their 1993 conventional hotel. VL is an inductive loop system that broadcasts an omni directional signal that gives instructions, whereas TS labels locations and gives a directional signal to that location. The use of convention participants as subjects resulted in a good cross-section of the blind population (Bentzen & Mitchell, 1995). Bentzen designed an experiment to evaluate the two systems in a non-laboratory setting. Subjects were evaluated on three routes of different complexity. Significantly more users of VL, compared to TS, reached incorrect destinations, gave up on routes, or required assistance. Talking Signs® exhibited overwhelming performance advantages over Verbal Landmark in both travel time and travel distance. Subjects using Talking Signs® were significantly less likely to become frustrated and unable to independently complete the route than was the case with participants who used Verbal Landmarks.

Post-test surveys and rating questions were conducted to gather subjective data from the participants. Verbal Landmarks were rated as decreasing ease and speed of travel while Talking Signs® were considered to increase speed of travel and ease of use. In addition, Talking Signs® were rated significantly higher in user desirability for installation, ease of message comprehension, and ease of use.

An evaluation of Talking Signs® in a campus environment was conducted at San Francisco State University (Crandall et al., 1994). Sixteen blind subjects navigated six routes twice. Significantly more routes were successfully completed using Talking Signs® than with only verbal instructions. The efficacy of Talking Signs® was noted with 94% of the subjects agreeing that they would want to carry a receiver in both familiar and unfamiliar areas. Subjective responses on evaluation questions showed that the majority "strongly agreed" that the system was easy to use, that it was easy to learn to scan, and that the messages were easy to pick up and easy to understand. Furthermore, 62% "strongly agreed" that, once they got a signal, it was easy to follow it to the destination.

2.5.2. <u>Transit Terminal</u>

The campus experiment raised the question of how the level of training was related to the ease of use, learning to scan, ease of picking up messages, and following signs to destinations. Training requirements for effective and safe use of Talking Signs® were evaluated at San Francisco's Powell Station (Crandall, Bentzen, Myers et al., 1995; Crandall, Brabyn et al., 1999; Bentzen et al., 1999). They wanted to determine the minimum amount of training required for a person to effectively and safely use

Talking Signs®, whether by hands-on experience or by instruction. A group of 36 visually impaired people used the Talking Signs® system as an aid to navigation through this complex subway station in downtown San Francisco. Subjects were divided into three groups, each group matched for familiarity with the station, use of transit modes, type of regular aid used, and degree of vision and mobility skills. Each group received a different amount of training on the proper use of the RIAS system.

Each group was tested for one hour on their ability to travel routes of increasing complexity in the station. Subjects were not allowed to request information or assistance. A full 97% of subjects were able to complete at least two easy routes, and 67% succeeded in traveling some medium and hard routes in the one-hour time allotted. The group that had no personal instructions was not as successful as the other groups, but the amount of training did not significantly affect route completion.

2.5.3. <u>Finding Bus Stops and Buses</u>

Locating bus stops and choosing from a group of buses have long been problems for blind transit users (Crandall et al., 1996; Bentzen et al., 1999). Crandall and associates conducted a test to determine the efficacy of Talking Signs® in these two situations. Eighteen blind subjects were tested regarding finding and correctly identifying three types of bus stops. Bus stops were fitted with tactile signs and TS. When trying to find a bus stop that was at a single pole, no subjects found it with their regular method. With TS, 15/18 subjects found the sign. The other two bus stops were shelters, one at the curb line and one at the building line. Significant improvements were also noted in finding the shelter by the curb. The results for finding the shelter at the building line were about equal. Mean times to find the correct bus stop were also quicker but highly variable and not significantly different for the two shelters. Dog users reported that finding bus stop poles with their dog was very hard, because the dog tried to steer them away from obstacles.

In their other experiment, three stationary buses were lined up in a row, and subjects were asked to find the correct bus. It appears that the design of this experiment resulted in no significant difference being found between subjects using TS and subjects' regular methods. A researcher was always there to act as the bus driver to answer questions, there were no pedestrians or other obstacles in the way, and the buses were not approaching and leaving as in a normal situation. Therefore, subjects were able to walk directly along the curb to approach each bus and always got a correct and prompt answer when they asked the "bus driver."

However, their answers to post-test questions revealed a very strong preference for the TS system. Nine questions were asked about the ease of use, understanding of messages, and their desire to use the system. Between 93% and 100% either agreed or strongly agreed in a favorable way with these nine questions. Subjective data from focus groups also were highly favorable towards the use of TS to label bus stops and buses. Subjects often mentioned problems in asking and receiving appropriate help and feeling safe while in this vulnerable situation. Talking Signs® were seen as a way to be more independent and to not have to rely on others for help.

2.5.4. <u>Intersections and Street Crossings</u>

Crossing streets and getting suitable information about an intersection are difficult, sometimes impossible, tasks for the blind. Bentzen et al. (1999), Crandall, Bentzen, & Myers (1999), and Crandall, Brabyn et al. (1999) evaluated 20 blind subjects making street crossings at four complex signalized crossings in downtown San Francisco. Without TS, subjects requested assistance in locating the crosswalk and requested assistance completing the crossing 19% of the time; participants requested assistance about knowing when the Walk interval began on 22.5% of crossings; and started their walk during the Don't Walk or Wait signal 17% of the time.

Talking Signs® information included the timing of the Walk interval, the shape of the intersection, the angle of the crosswalk, the nature of the traffic control system, and spatial information about the street names, block number, and direction of travel. This additional information made crossings more successful and more independent. With Talking Signs, no participant requested assistance locating the crosswalk and also in completing the crossing on only one trial (3%), respectively; no participants asked when the Walk signal started; and just one crossing was started in an unsafe condition (when the Walk signal was not present).

Unsafe street crossings cause much anxiety for blind travelers, many of whom do not venture beyond familiar areas, thus restricting their range of travel and activities. The presence of a researcher at these "independent" crossings probably made subjects feel safer and led to fewer requests for assistance then would normally have been the case while traveling independently using their regular methods. Use of the Talking Signs® system at intersections should vastly increase safety at these dangerous spots. The information about the timing of the Walk interval can give assurance to vision-impaired pedestrians, as it does to the sighted, that they have the right of way at a cross walk. It is also important to begin the crossing at the earliest appropriate moment in order to allow adequate time for completing the street crossing.

Taken together, these studies point to further research in the efficacy of TS in larger and more complex situations as well as to gather much more subjective data on the impact that this system had on people's lives, their travel behavior, and their activity choice.

2.6. Previous UCSB Experiments With Auditory Signage

The research reported in this dissertation is the latest of four research projects carried out at UC Santa Barbara, all investigating problems of transit use by those with vision impairments. The work on the first three projects was performed as part of the California PATH Program of the University of California and the latest project was partially funded by the University of California Transportation Center. The Principal Investigator was Dr. Reginald Golledge from the UCSB Department of Geography and the Research Unit on Spatial Cognition and Choice. The first project consisted of interviews with 55 vision-impaired subjects from the Santa Barbara area.

2.6.1. Santa Barbara Interview of Transit Use and Opinions

The purpose of these interviews was to gather data on transit use, frustrations, opinions, and improvement suggestions from a group of vision-impaired subjects (Golledge et al., 1995; Golledge, 1996; Golledge et al., 1997; Marston et al., 1997). These data were needed in order to frame more specific future studies. The subjects reported a high degree of frustration when using transit, and the most important finding was that access to more information was what was needed to reduce transit-related difficulties and increase transit use. The subjects also reported a need for more information about schedules, bus numbers, routes, and locations of bus stops and terminal amenities. They thought that auditory messages would help them cross streets in order to make transfers and would also help if installed on buses and in terminals. There were many elderly people in the survey who did not make many trips, and there were also 10 subjects who had access to a household car. People with access to a household car had a much harsher view of transit use. Their estimates on how long they wait for transit were much higher than those of subjects who had no car to rely on and who used transit more often. Those who had no household car reported longer wait times for a ride (from friends or others) than in waiting for transit. These findings led us to investigate the use of auditory signage (Talking Signs®) to determine if it would provide sufficient information needed to increase path following accuracy, decrease walking and search times, and make finding a bus easier in actual field test conditions.

2.6.2. Path Following and Finding a Bus

This experiment consisted of two field experiments to test the effectiveness of Talking Signs® (Golledge, Marston, & Costanzo, 1998a & b; Marston & Golledge, 1998a). Several path-following tests were conducted, using a square or rectangle shaped path, and then a field test was conducted where subjects tried to identify a specific bus among a group at a busy bus stop. Subjects consisted of 10 legally blind subjects from the local blind community and 10 sighted students. All subjects performed the tasks blindfolded, thus giving the opportunity to regard the 10 blindfolded sighted subjects as newly blinded subjects who, unlike the blind users, had no previous experience in blind wayfinding and navigation. These sighted students also had no formal Orientation & Mobility training, during which people with vision restrictions had received many hours of training to help them follow routes, either using a long cane or a guide dog.

The first experiment was set in an open field with 4 stanchions set either in a 60’ x 60’ square or a 30’ x 60’ rectangle. Subjects were led around the shape three times and then were asked to follow the path on their own, twice in a forward direction and then once in the reverse order. Without Talking Signs®, the 10 blindfolded sighted subjects only found 14 of 120 stanchions. The vision-impaired subjects did better, finding 35 out of 120 attempts, although 15 of those 35 successes were accomplished by just two subjects who used echolocation to identify the targets. When using the RIAS technology, all 20 subjects found all the stanchions in a timely fashion. This test provided strong evidence that, with just a few minutes of training, RIAS could increase speed and accuracy in locating objects and in successful completion of a path of travel.

The second field test was conducted at the UCSB bus circle, where three or four buses at a time might be waiting. Finding bus stops, and, especially, identifying the proper bus when many are present, has always been a difficult task for people with vision restrictions. With limited or no vision, people are forced to approach each bus that they hear, find the door, and then ask the driver or others for the route or bus number. This task can lead to missed connections and, often, unkind remarks from irate drivers or passengers.

The bus identification experiment started with two practice walks from the West side of the bus circle to the boarding area, subjects walked halfway around the circle and crossed two service roads. The same two groups of nine (there was one no-show) blindfolded sighted people and 10 blindfolded people with vision restrictions were used. All subjects tried the walk and bus identification task three times, first using Talking Signs®, then with their regular method, and then again with TS. All of the people with vision restrictions were able to find the proper bus after walking around the loop when using TS during both trials. Without the system, 8 of 10 were able to find the proper bus in a timely manner. Of the subjects who were sighted and blindfolded, without the system they were only able to find the bus two of nine times. When using the RIAS, they found the bus five out of nine times on the first trial and seven out of nine times on a second trial. Those who missed the bus using the system still got to the proper area but not in time to catch the bus. The elapsed times for the trip for both groups were higher without the system than with RIAS. The strong results of this experiment gave us motivation to test this system in more complex environments. Post-test evaluations and comments from the subjects were very positive about the usefulness of these devices, and many people expressed a desire to have them installed; respondents also mentioned that they appreciated the fact that they did not have to ask for help. Some of those comments led us to design more situations and questions for further exploration.

2.6.3. <u>Santa Barbara MTD Bus Terminal Experiment</u>

The previous experiment used four temporary RIAS transmitters in two different field tests. Based on the positive results and acceptance of the system by the blind subjects, the next step was to test the system in a more extensive and “real world” environment. Ten transmitters were permanently installed at the Santa Barbara, CA Metropolitan Transit District (MTD) bus terminal. Using several more temporary installations, a round trip route by bus from the local Braille Institute to the main terminal and back was designed (Golledge & Marston, 1999). Twenty-seven people with visual impairments, recruited through the Braille Institute and other agencies, were used. Subjects found bus stops, identified the proper bus on the street and in the bus staging area, found the location of amenities in the terminal, and simulated making several transfers between buses. More independence was given to the subjects in this experiment. That is, they were allowed to search and walk to locations without first being led to them several times. This was much more akin to what happens when people with vision restrictions have to perform typical wayfinding tasks. For example, subjects were told a bus stop was 120 feet away, and, with no further instructions or a practice walk, they searched for it on their own. When they arrived by bus at the station, they searched for the terminal entrance without directions or practice.

Dynamic spatial relationships are a constant source of problems even for the best blind traveler, who might master many spatially static environments. Fixed locations and routes can be learned by rote practice, but an ever-changing configuration of buses at a bus terminal staging area cannot be learned and poses much uncertainty for blind travelers. This experimental design gave much more data on how the lack of sight affects the ability to complete travel and how the use of RIAS could overcome the lack of visual cues. For example, while leaving the station in order to find the proper bus for the return trip, those with little or no sight had to ask for help from strangers or find a bus by walking toward a sound or shape, locating the door, and then asking the driver to identify the bus. If this was not the proper bus, they were usually "pointed" in the right direction to try again. When using RIAS, they could scan the area, pick up the proper bus transmitter, and walk directly to the bus door. The response times in finding proper locations were highly significant for the RIAS condition. Subjects located two bus stops, found the terminal entrance, and located buses in much less time, with fewer mistakes, and without having to ask for help as often.

Some tests of spatial knowledge acquisition of various amenities in the terminal were also conducted. The area was often very crowded, and subjects were first led around the area three times before they tried it on their own. A *pointing task* and an *inter-point* distance estimation task were used to record their estimation of the location of different amenities in the terminal. Multidimensional scaling was used to determine if there was a significant difference between the two conditions; a person's *regular method*, and when using *RIAS*. No significant differences were found in those two tasks. The pointing task was confounded by magnetic interference when using the compass to record direction. The terminal was quite small, and it appeared that subjects learned the area so well with the three guided walks that their previous walk through the area overshadowed any benefit of using RIAS in that location.

Based on the user comments that were obtained in the previous experiment, many more questions were asked after the test was concluded. Data were recorded on subjects' opinions of the usefulness of the system at various locations, their overall opinion of the system, and where they would like to see them installed. The answers were very positive regarding the usefulness of the system. Respondents mentioned many places they would like to see them installed and also had praise for the system in general. In order to learn more about how difficult travel without sight could be, a series of questions was asked about the stress and difficulty of various transit tasks, such as finding a bus on a street or in a busy terminal, transferring buses, crossing streets, and finding a bus stop. These questions were asked before the test in order to establish a baseline for subjects' current practices and then asked again after they had used the system. These results were highly significant. Subject ratings were recorded on a five-point Likert scale, and, in many cases the ratings were a full two or more points better after they used the RIAS. Many of the subjects used an agency door-to-door van service, which picked up and dropped off a large group of people. Subjects were asked if they would switch to the fixed route bus system if it was made more accessible and easier to use. Most subjects said they would rather use the local bus routes, however, several people said they did not mind the long van ride, that they spent the time talking with other riders. This attitude toward the value of time prompted further inquiry into how vision-impaired travelers viewed saving time by making transfers or staying on a less direct bus. These discussions with travelers suggested including further investigations into transfer-making decisions in the next experiment.

That experiment was, until then, the most comprehensive study on RIAS, combining real world travel and wayfinding, terminal and amenity search, user input on transit and transfer difficulties, and opinions of the RIAS system. It proved overwhelmingly that RIAS made travel and bus use easier and quicker. Subjects unanimously stated that they did not have to ask for help when using the system, and they felt more independent. These findings prompted the design of a further experiment with even less spatial information and path training provided to subjects.

2.6.4. Findings from Previous Work that Warrant More Research

To highlight what led to the desire to conduct an even larger experiment, using more modes of transit in a larger, more urban environment, four sections of the Santa Barbara MTD experiment are summarized.

2.6.4.1. Finding A Bus Stop

Subjects were asked to explain the difference between RIAS and their regular methods of navigation when finding an unfamiliar bus stop. APPENDIX 2 lists all subject's comments; a few are listed here as examples.

- “lost without it, points like an arrow, gives direction, simple”
- “info available, definite direction, knew it could be found, more sure of where you are, comfortable and reassuring, know where I am, like a person saying "Here is the stop"
- “just follow beam, no worry about drift, confident of direction, so you only think about safety, confident”
- “know it's there, didn't have to ask or look all over, gives assurance”

Twenty-six subjects gave 62 responses to this question; these were parsed and categorized as follows.

Table 2.3 Bus Stop, User Response Categories

“What is different from your regular method when using Talking Signs® at a bus stop?”

Category	26 subjects
Gives direction	15
Gives positive identification	15
Confidence, assurance	14
More efficient, easier travel	13
Don’t have to ask	5

2.6.4.2. Finding the Proper Bus

A RIAS transmitter mounted on a bus sends out a signal that can reach over 100 feet. This signal can contain the bus name, number, direction or other route information so that users know in advance which bus is coming and allows time to reach the boarding area and flag the proper bus, with complete and positive knowledge about which bus is approaching, where it goes, and the location of the entry door. Figure 2.7 shows a bus equipped with the RIAS transmitter mounted on the front.

Figure 2.7 Using RIAS to Identify an Approaching Bus

Source: R, G. Golledge (2001) Reproduced with permission of the author.

Subjects were asked to explain the difference between RIAS and their regular methods of navigation when finding and boarding the proper bus. APPENDIX 3 lists all subjects' comments, a few are listed here as examples.

- "know where bus goes without having to ask, half the battle is figuring out where the bus goes"
- "with regular method I have to feel for bus and door and then ask people or driver, not so with TS"
- "knew it was #3 bus, otherwise would have had to ask, knew exactly where door was, knew bus was coming down street"
- "more positive and secure, confidence, don't have to ask, don't need to flag and stop all buses"
- "ID's bus, gives exact location of door, typically I inquire, this time I was independent"

Twenty-six subjects gave 89 responses to this question; these were parsed and categorized as follows.

Table 2.4 Finding and Boarding Proper Bus, User Response Categories

"What is different when using Talking Signs® to find the proper bus?"

Category	26 subjects
Don't have to ask	23
Easier, quicker	18
Positive identification of bus	14
Boarding location (door) information	10
Independent	8
Safe and secure	3
Less stress	3

2.6.4.3. User Ratings of Talking Signs®

At the end of the MTD terminal experiment, subjects were asked to rate their approval of various installation locations for the system. They were also asked how the system would affect their travel if it was installed on transit and at various locations. These tables are sorted with the highest ratings first. "Strongly agree" = 1, "Agree"= 2, through "strongly disagree" = 5. All responses were quite positive.

Table 2.5 User Opinion of RIAS: Specific Locations and Travel Behavior

User Opinion about Talking Signs® Installations	Ratings
I would like TS installed on all buses	1.1
I would like TS installed at bus stops	1.1
The TS in the terminal should be made permanent	1.1
TS on retail and other buildings would help me navigate and let me know what shopping or activities were available	1.1
TS in the MTD terminal are very helpful	1.2
I would like TS installed at street crossings that tell what street I am at and which direction I am facing.	1.2
I would like TS installed at crosswalk to keep me in the walkway and tell me the WALK/DON'T WALK signal.	1.3

User Opinion about Talking Signs® and Travel Behavior	Ratings
I would be more independent using TS	1.2
I would feel safer when I traveled	1.2
I could be more spontaneous when planning trips	1.2
I would take more trips	1.3

These very positive responses to the value of RIAS at bus stops and identifying the proper bus demanded more investigation into how this system would help in other transit environments. The equally strong ratings about the efficacy of RIAS at various locations led to the examination of other specific types of locations beyond that of a bus terminal and in a more varied environment. The strong opinions that RIAS would positively affect travel behavior led to a desire to test these sentiments in more empirical and robust experiments. More information was needed to determine what people thought about their current trip-making behavior and what could be done to make it more equal to the general public.

A pre and post-test question was asked that attempted to reveal the feelings of these vision-impaired subjects on their overall attitude toward equal access, as it is now and how it would be if RIAS was installed throughout the environment. The results were so strong that they also demanded more research investigating why access was so limited and also to find what specific locations caused these problems and what mitigating effects the addition of environmental cues, such as location identity and direction, had on increasing access to urban opportunities. The following two questions were asked with a five-point scale, ranging from 1= "strongly agree" to 5 = "strongly disagree."

Table 2.6 ADA Compliance Measures, Pre and Post Talking Signs®

	Rating
Pre-test: 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.	4.5
Post-Test: If TS were installed on public buildings and transportation, I would have the same access given to the general public.	1.3

These two questions revealed that people with vision impairment do not think that they are getting the equal access that was mandated for them in 1990, and that they feel like a system that gives environmental cues would greatly help them to achieve this elusive goal of social equity and access. Furthermore, in the survey, they also voiced a strong support for citywide RIAS installations and legislation to make installation mandatory.

To better understand the problems of blind navigation, and building on past work, there appeared to be a need to collect more data on making transfers, about which locations were the most difficult, and where the use of RIAS could have the most benefit. Subjects had mentioned many times how difficult using transit was, and this inspired a decision to ask further specific questions to determine how vision loss restricts independent travel and if RIAS could provide more access to urban opportunities and increase access to jobs, other activities, and travel. There appeared to be a need to collect more empirical data about the problems of transit use and transferring between different transit modes. More knowledge was also desired about how travel without vision affects trip-making behavior, limitations on activity space, and participation. Little is known about restrictions and barriers to making transfers and how people with little or no vision perceive these barriers. There is a need for data about how this group reacts to these barriers and if they have a different internal resistance to distance or change. There is a need to understand if the *distance decay* function is different for this group than that exhibited by the general public. Previous research on RIAS has either tested the efficacy of RIAS by itself or studied success when using the system compared to users' regular methods. There is also a need to test the efficacy of the system using a comparison to the walking speed of a sighted person. Clark-Carter et al. (1986) point out that, when testing different aids for persons who are blind, in addition to measuring errors and wrong turns, researchers must realize that the speed of the subjects reflects their ability to use an aid to increase travel skills. By comparing the walking and search times of blind subjects using their regular methods or RIAS to a standard baseline derived from a sighted person, time penalties and their mitigation with a new aid can be clearly identified. This method also allows for a broader understanding of which locations present the biggest problems to independent travel and which locations are more easily accessed without sight. To be serious about understanding and then improving travel for people who are blind, researchers must be able to identify which locations cause the most problems for the blind and what aids or instruction can best be used to increase travel, independence, and quality of life for this group.

Thus, the design of this research experiment evolved over many years of prior research into the needs and travel restriction of people with limited vision. Starting with a comprehensive interview schedule to determine attitudes and needs, experiments progressed next to very controlled situations and then proceeded to the first "real world" experiments. The empirical data, plus the comments from subjects, led to the design of the present, much more comprehensive field test.

There has been criticism in certain academic circles that disability research is not representative of disabled people's experiences and knowledge. For example, Kitchin (2000) found such a lack of representation in his research with disabled people, and he stresses that research needs to be "carefully selected, presented in a way that is unambiguous, has a clear connection between theory and the lives of disabled people, and needs to be acted upon" (Kitchin, 2000, p. 29). Kitchin also states that disabled subjects are concerned that much research is ineffectual in transferring research results to real world improvements in their lives by helping to dismantle barriers. A main concern was that their knowledge and experiences were "mined" by researchers, who they never heard from again and that the research made no perceivable impact on their lives. The subjects who participated in the previously discussed UCSB experiments knew that their knowledge was cherished by the researchers and was used to frame continuing research. Many of them made suggestions after the experiment and their comments on open-ended questions led to further research based on problems and barriers they had acknowledged. Some subjects even refused payment for their participation, saying that the funds should go to further research and implementation. None of the subjects quit during any experiment, even though the tasks could become quite long, or scheduling problems resulted in time allocation that was much longer than anticipated. They all seemed determined to add to the body of knowledge about this topic that directly affects their daily lives. This research was not some strictly academic laboratory experiment that would not directly affect them, but research into their needs to gain more information, spatial knowledge, accessibility, freedom, independence, social equity and to improve their overall quality of life.

2.7. Chapter Summary

The independence of people with little or no sight is greatly affected by their restricted access to information, environmental cues, and safe walking. Since ancient times, blind people have been depicted walking with a stick, sometimes as a gift from the gods (Levy, 1872/1949). The Bible curses those who "maketh the blind to wander out of his way" (Deuteronomy 27:18) and warns that "thou shalt not put a stumbling block before the blind (Leviticus 19:14). Over a hundred years ago, Levy, who was blind, offered this striking observation about independence and mobility: "The importance to every blind man of acquiring the power of walking in the streets without a guide can scarcely be exaggerated. Loss of sight is in itself a great privation, and when to it is added the want of power of locomotion, the sufferer more nearly approaches the condition of a vegetable than that of a member of the human family" (Levy, 1872/1949, p. 106). In more modern terms, Golledge (1993) says that, second only to the inability to communicate through reading and writing, the inability to travel independently and to interact with the wider world is one of the most significant handicaps facing the vision-impaired. Navigation without sight usually means staying on known or learned routes. Independent exploration off these learned paths can easily lead to panic, fear and even danger or death when a person becomes disoriented.

This chapter's background review points out the problems that a vision-impaired person faces in gaining access to urban opportunities and the shortcomings of current accessibility measures in determining barriers and the impedance to access caused by lack of vision. Previous research was examined that led to the current experiment design. This design allows for a quantitative measurement of accessibility and provides specific data that will help improve our understanding of the difficulties, affective states, and environmental placements that lead to travel barriers for this population.

3. Specific Transit Tasks and Locations That Restrict Travel

- **Hypothesis 1**: Experiment data will show that, for those with limited vision, specific locations and tasks cause difficulty when using transit. The use of auditory signage will mitigate much of the difficulty.

Previous research gave strong indications that specific transit tasks are identified by blind travelers as causing time and effort constraints on their travel and can also lead to a person not making a trip (Golledge et al., 1995; Golledge, Costanzo, & Marston, 1996; Golledge & Marston, 1999; Golledge, Marston, & Costanzo, 1996; Golledge et al., 1997; Golledge et al., 1998; Marston & Golledge, 1998a, 1998b; Marston & Golledge, 2000; Marston et al., 1997).

The first section describes the field test experiment where vision-impaired subjects performed various transit tasks with their regular method of guidance and also with RIAS. This research investigates how specific locations and tasks are functional barriers to efficient navigation, and how the use of RIAS might mitigate many of these barriers, providing a much higher level of informed and effective transit use. Results of the timed trials are discussed and analyzed. Later in this chapter specific location difficulties, as reported by subjects through responses to questions, will be examined.

3.1. Caltrain Field Test

3.1.1. Procedures

The complete instructions given to the subjects are listed in the questionnaire in APPENDIX 4 (under the field test section.) In addition to transferring from one mode to another, the experiment was made more realistic by requiring the subjects to find different amenities along the route, such as ticket windows, bathrooms, public phones, etc. Subjects were told which locations to search for or which direction to go to find a street corner. They were allowed to ask others (but not the researcher) for verbal assistance only.

Task 1: Subjects were walked, in a disorienting fashion, to the doors leading to track 7 at the Caltrain station. They were told to imagine they had just disembarked from the train and had entered the station. With their back to the train track door, the researcher took one of their hands and drew an upside down "T" on their open palm to show the shape of the interior. It was explained that the train tracks were behind them, opened into a long hallway, and that the main hall to the exit was in front and toward the left. Subjects were told that the terminal amenities were either located in the main hall or nearby on the opposite wall. This was the only spatial information they were given about the site layout. Their task was to first find the proper bathroom and then find where to buy a candy bar. From there, they were to walk out the station's main entrance, turn right, and go to the corner. After listening for at least one cycle of the traffic signal, they were to cross King Street to the median Muni platform. They were required to tell the researcher when they wanted to cross, so that the researcher could monitor their safety. Once at the platform, they were to find a fare machine, which sold tickets for the Muni Light Rail station.

Task 2: Subjects started at the mid-street platform corner by the Muni station fare machine. They informed the researcher when they wanted to cross and then were to cross from the platform to the Caltrain side of King Street. From there, they were to walk back to the Caltrain station and find the ticket window. Subjects then were to search for the flower stand, and then walk to the bank of pay phones inside the station. From there, they were told to find the door for gate 2.

Task 3: Because of construction barriers, subjects were led from gate 2 and proceeded out the main entrance of the station where they were to turn left toward Townsend Street and left again down Townsend to the cabstand. Walking independently, they were told to choose any route in order to locate the water fountain, then locate the ticket window, and finally, locate the door for gate 11.

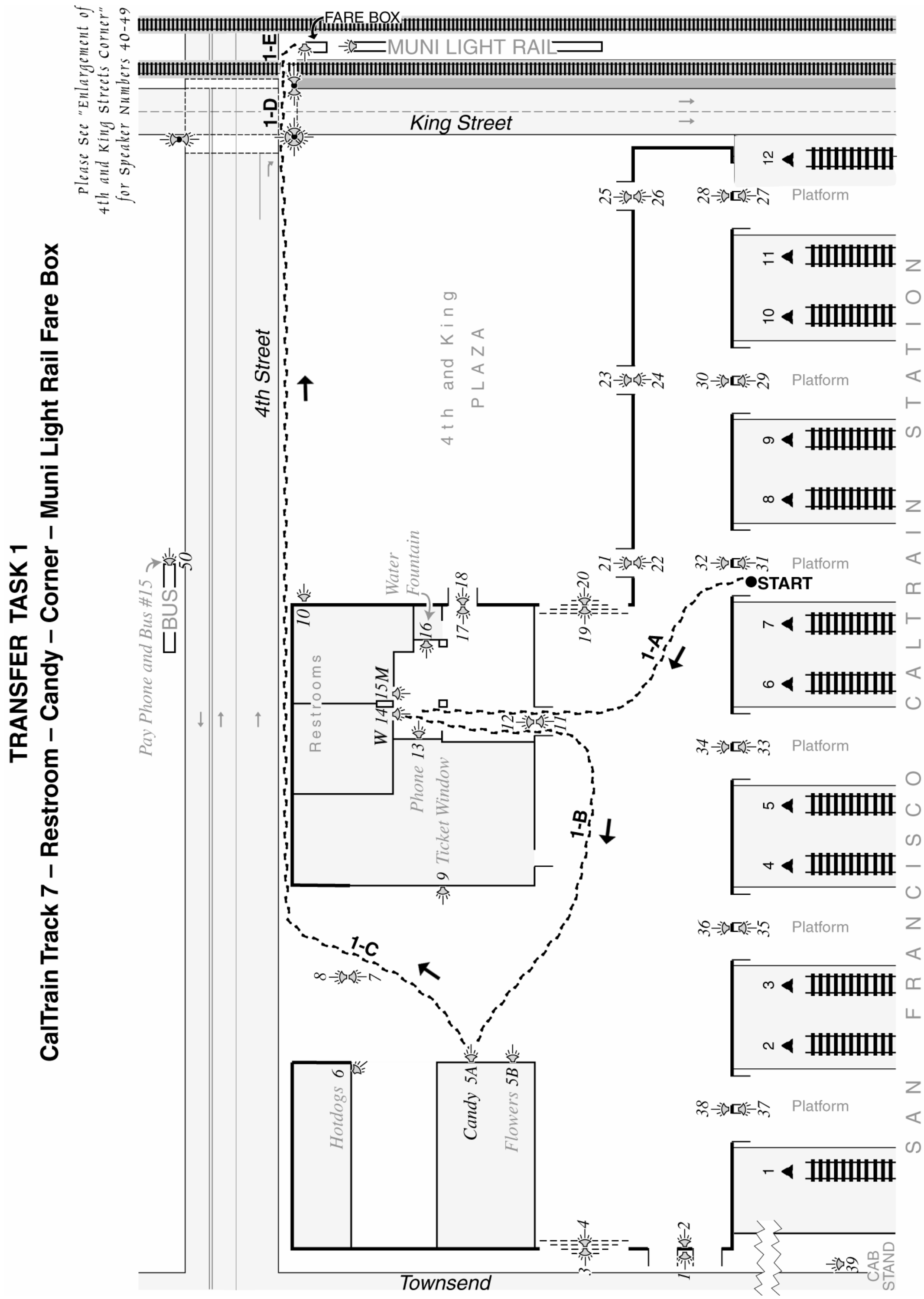
Task 4: Subjects left gate 11 and were told to return to the first corner that they had visited, the one across from the Muni station. However, here they were to cross the street (4^{th} St) in front of the station. Again, subjects notified the researcher before they attempted to cross 4^{th} street. Once across the street, they were to turn left and find a pay phone further down the street. After finding the pay phone, they were to locate the bus shelter for the Muni #15 bus line.

Task 5: Subjects started at the corner of 4th and King. Here they independently crossed the street toward the Caltrain station, and then the researcher took them to the ticket window in the station. From the window, they independently searched for the concession stand that sold hot dogs and then searched for and walked to the door for gate 3.

For each of these five transfer tasks, data were collected on the time it took to complete each leg of the task, the number and types of errors made, and the number of times they asked for help from others.

All times recorded were in seconds. A maximum of four minutes (240 seconds) was allowed for each sub-task. For this task, 15 subjects used their regular skills first (NRIAS) for all five sub-tasks and then later repeated the same tasks using the RIAS. Fifteen subjects used the RIAS first and 10 people repeated the task later using their regular skills. The t-tests statistics were calculated for analysis of mean times between the two conditions, *NRIAS* 1st versus *RIAS* 2nd and *RIAS* 1st versus *NRIAS* 2nd. The t-test statistics were also calculated on the difference between the 30 *RIAS* scores and the 25 *NRIAS* scores, regardless of the order of the condition. The results are presented next for each sub-task of these transfer tasks.

Figure 3.1 Transfer Task 1 Path of Travel



3.1.2. Transfer Task 1: Track 7 To Muni Fare Box

All Times in seconds (s)

NRIAS = No RIAS   RIAS = Using RIAS

			Condition 1		Condition 2	
Task	From	To	NRIAS 1st	RIAS 2nd	NRIAS 2nd	RIAS 1st
1-A	Track #7	Bathroom	142s	60s	92s	85s

The difference in times when using *RIAS* after the regular method was highly significant (p<.0005). There was no significant difference when using *RIAS* first and then the regular method (p<.4). Overall, the difference between the two conditions was highly significant (p<.003).

Ten subjects asked for help from others 13 times when using their regular method. No one using *RIAS* asked for help.

			Condition 1		Condition 2	
Task	From	To	NRIAS 1st	RIAS 2nd	NRIAS 2nd	RIAS 1st
1-B	Bathroom	Candy	134s	86s	81s	112s

The difference in times when using *RIAS* after the regular method was highly significant (p<.008). There was no significant difference when using *RIAS* first and then the regular method (p<.08). Overall, the difference between the two conditions was not significant (p<.23).

Eight subjects asked for help from others nine times when using their regular method. No one using RIAS asked for help

			Condition 1		Condition 2	
Task	From	To	NRIAS 1st	RIAS 2nd	NRIAS 2nd	RIAS 1st
1-C	Candy	Corner	134s	102s	131s	114s

The difference in times when using *RIAS* after the regular method was highly significant (p<.0006). There was no significant difference when using *RIAS* first and then the regular method (p<.24). Overall, the difference between the two conditions was not significant (p<.06).

Vision-impaired people are quite used to using traffic sounds and the cane or dog to find a street corner, and no one asked for help on this task.

			Condition 1		Condition 2	
Task	From	To	NRIAS 1st	RIAS 2nd	NRIAS 2nd	RIAS 1st
1-D	Corner	Corner	48s	12s	42s	13s

Knowing when to cross a busy street can be a difficult task, depending on intersection types, turn lanes, and traffic flow. RIAS gives a distant and definite "WALK" or "WAIT" signal, and this advantage is clearly shown at this crossing. The difference in times when using *RIAS* instead of the normal method was highly significant in both condition orders and also overall (p<.006, p<.01, and p<.0001 respectively). Eight subjects out of 25 using their regular method made a total of 15 unsafe attempts to cross the street. Nobody using RIAS made any unsafe attempts, again showing the benefits in terms of safety for the user with RIAS. In addition, one subject completely missed the opposite corner when using the regular method of travel.

			Condition 1		Condition 2	
Task	From	To	NRIAS 1st	RIAS 2nd	NRIAS 2nd	RIAS 1st
1-E	Corner	Fare Box	140s	15s	30s	21s

The difference in times when using *RIAS* after the regular method was highly significant ($p<.00006$). The fare machine was in a very inconspicuous spot, and, without RIAS, many people missed it completely. Those that used *RIAS* first appeared to learn this location well and were able to find it much easier the second time after having used the RIAS. There was no significant difference when using *RIAS* first and then the regular method ($p<.14$). Overall, the difference between the two conditions was highly significant ($p<.00001$). One subject asked for outside help.

	Condition 1		Condition 2	
	NRIAS 1st	RIAS 2nd	NRIAS 2nd	RIAS 1st
Task #1 Total	596s	277s	374s	345s

The total of the five sub-tasks that make up Transfer Task 1 shows how much better people traveled when using RIAS. Once having used the system, their spatial knowledge appears to increase so that, on their second attempt using their regular method, the results, although quicker in the *RIAS* condition, show no significant difference ($p<.34$). When using *RIAS* 2nd after their regular method, the results are highly significant ($p<.00001$). The results are highly significant over all the trials for the two conditions ($p<.0004$). There was no significant difference when using *RIAS* first or second, showing that the initial trial with the regular method did not help them learn the route ($p<.11$). For the 25 subjects who attempted the five sub-tasks with their regular method, there were a total of 21 tasks that they could not finish and were “timed out.” The group of 30 subjects attempting the same five sub-tasks with RIAS only had two that were “timed out.” The data for the five transfer tasks are shown in APPENDICES 5 through 9.

3.1.2.1. Time Penalties and Accessibility

To identify how specific locations and tasks affect blind navigation, the travel times in the two conditions to the FSU (familiar sighted user) were compared (see Section 1.6.6, Sighted Subjects for Baseline). The excess travel time in the two conditions, compared to the FSU, is expressed as a percentage of the baseline time. This standardized the effect of different distances between the task locations. This method shows the time penalty faced by people with vision loss, and how that penalty is not consistent, but varies according to the characteristics of various locations, including the non-visual cues available. This method allows for better understanding of which locations present the biggest barriers to successful and independent travel. Examining the time penalty also shows how the use of RIAS affects the time required to perform these tasks. A few caveats to better understand these data are:

- This experiment was conducted in a busy area with various obstacles, such as crowds, that varied during the experiment.
- Different locations offered various degrees of non-visual cues that affect the data, and, as the experiment went on, some locations had been discovered earlier.
- These times represent not just finding the location but navigating the path from the previous location as well.

- Although all subjects were allowed to ask others for help, no users of RIAS asked for help and this sometimes affected their performance to a degree.

- A few locations had signals that were partially blocked or obscured at certain locations.

- Since there was a 4-minute maximum allowed for each sub-task, walks that took longer for the FSU did not have excess time penalties as high as those for shorter walks.

These findings for each location will be discussed and explanatory comments from the researcher's information will be offered later (see Section 3.5, Modeling Impedance of Different Transit Tasks). The figures in this section on the five transfer tasks use data from the 30 subjects on their first attempt only. This removes any effect of learning from a second trial and increases the validity. Therefore, it is a between subjects test with fifteen subjects in each condition.

3.1.2.2. Time Penalty Formulation

One way to measure how access is restricted for certain groups or individuals is to compare the effort of travel (such as time or distance) for that group or individual to a user with less restricted travel means. For example, the time it takes to commute by bus can be compared to the use of a private car to show if there is extra time spent by using the transit mode. In this section, the travel time of legally blind people is compared to a sighted person, to determine the excess time, or penalty, for travel without vision. If a person who was blind took 10 minutes to walk from the entrance of a train station to the proper boarding gate and a sighted person took only two minutes, there would be an extra time penalty of eight minutes for the trip without sight. A ratio accessibility measure can be formulated to show the excess time or distance required by people who have restrictions on their travel. This can be shown as the additional extra time compared to the sighted traveler. For this example, it would be expressed as ((10/2) –1), or 4 times that required with sight. Relative accessibility (in this case the extra travel time--see Church & Marston, (in press), can be formulated as:

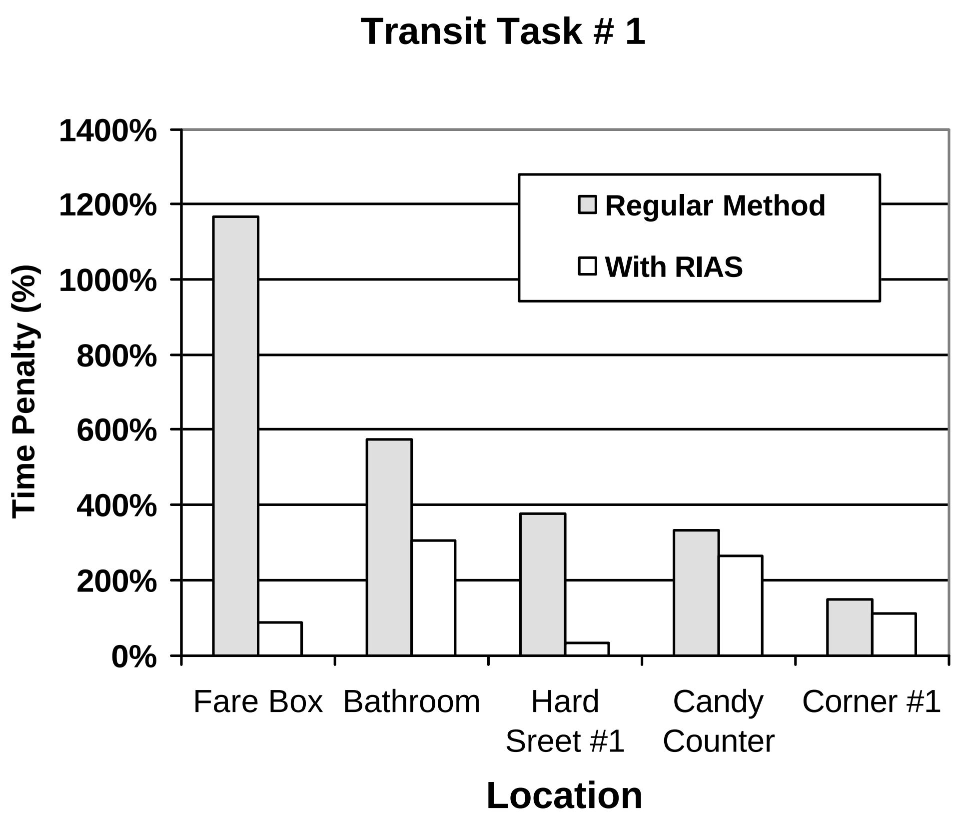
Equation 1 $$R_{iklm} = \frac{d_{ikl}}{d_{ikm}} - 1.0$$

where:

- d_{ikl} is the time or distance from i to the desired location that offers activity k to serve a person at i with access type l.
- R_{iklm} = relative accessibility of activity k from location i for person type l relative to person of type m.

Person of type *m* is the sighted walker, and in the above example, 4 is the relative accessibility measure, or time penalty, when comparing a trip from the station door to a boarding area for the two travelers. In the following sections, a person of type *l* is used to represent the blind person in either of the two test conditions, using regular navigation skills (*NRIAS*) or using *RIAS*. With this formulation, a relative access score of 0.0 would represent a location that could be reached by the sighted and the blind traveler in the same amount of time. A score higher than 0.0 would represent an excess time penalty caused by lack of vision. Figure 3.2 compares the excess travel time required for blind people with and without the use of RIAS.

Figure 3.2 Excess Time using Regular Methods and RIAS - Task 1



3.1.2.2.1. <u>Fare Box</u>

In transfer task 1, the hardest location to find was the fare box at the Muni rail station. The entrance ramp to the station was itself hard to locate, and, since there were no turnstiles to signal the paid area, many people missed the fare box. It was placed in a position that did not correspond with typical “environmental grammar,” meaning a common and consistent location. This location was categorized as an inconsistent or random transit amenity location with no cues. The 15 subjects using their regular method of travel took 1168% longer than the familiar sighted user

(FSU). A RIAS signal allowed easy access for the other 15 subjects who only took 87% more time than the FSU.

Using the first trial data only, t-test statistics for the two conditions, regular method and *RIAS*, showed a significant difference ($P<.00002$). After subjects that reported they could see shapes or objects up close were eliminated, subjects who had no vision at all had t-tests that showed a significant difference ($P<.00002$). The subjects with no useful vision are discussed later (see Section 3.5.1, Accessibility of Grouped Tasks and Locations).

3.1.2.2.2. <u>Bathroom</u>

The bathroom was located in a waiting room off the main terminal area. Once the waiting room is located, there are many obstacles of chairs, people, and pillars. The bathroom doors had the standard round (F) or triangle (M) tactile information. This location was categorized as an amenity with few cues. Subjects using their regular method took 575% longer than the FSU. The *RIAS* subjects took 304% longer than the FSU, partially due to the various obstacles in the waiting room.

The t-test statistics for the two conditions showed a significant difference ($P<.01$). For those subjects with no vision, t-tests showed a significant difference ($P<.03$).

3.1.2.2.3. Hard Street Crossing #1

Blind travelers use auditory cues from traffic to align themselves for a street crossing and also to understand the flow of traffic. Turn lanes and high-speed traffic confound these problems. This crossing of King Street was quite difficult for many blind people. King Street is a high-speed arterial road, and the nearest stop light from this one is two long blocks away so traffic moves at a high speed. In addition, most of the cars on 4th Street turn right onto King, so there is almost a constant flow of traffic, except for the short walk cycle (see Figure 2.6 on page 59). This location was categorized as a hard street crossing. Regular method subjects took 377% longer than the FSU, and, with *RIAS*, users took only 31% longer.

The t-test statistics for the two conditions showed a significant difference ($P<.004$). For those subjects with no vision, t-tests showed a significant difference ($P<.009$).

3.1.2.2.4. Candy Counter

This amenity was located in the main entrance hall of the terminal. There were often people around and the voices of the counter clerks were audible. The counter was "L" shaped and quite long and this arrangement provided much room for errors by the subjects. Usually, subjects found a part of a counter and then asked others if candy was sold there. The smells of popcorn and candy did allow some users to locate the area when close. Only after getting a verbal response from the clerk did they know their location. This amenity was categorized as one with few cues. The *regular method* subjects took 332% longer than the FSU, and, with *RIAS*, this time was cut to 262%.

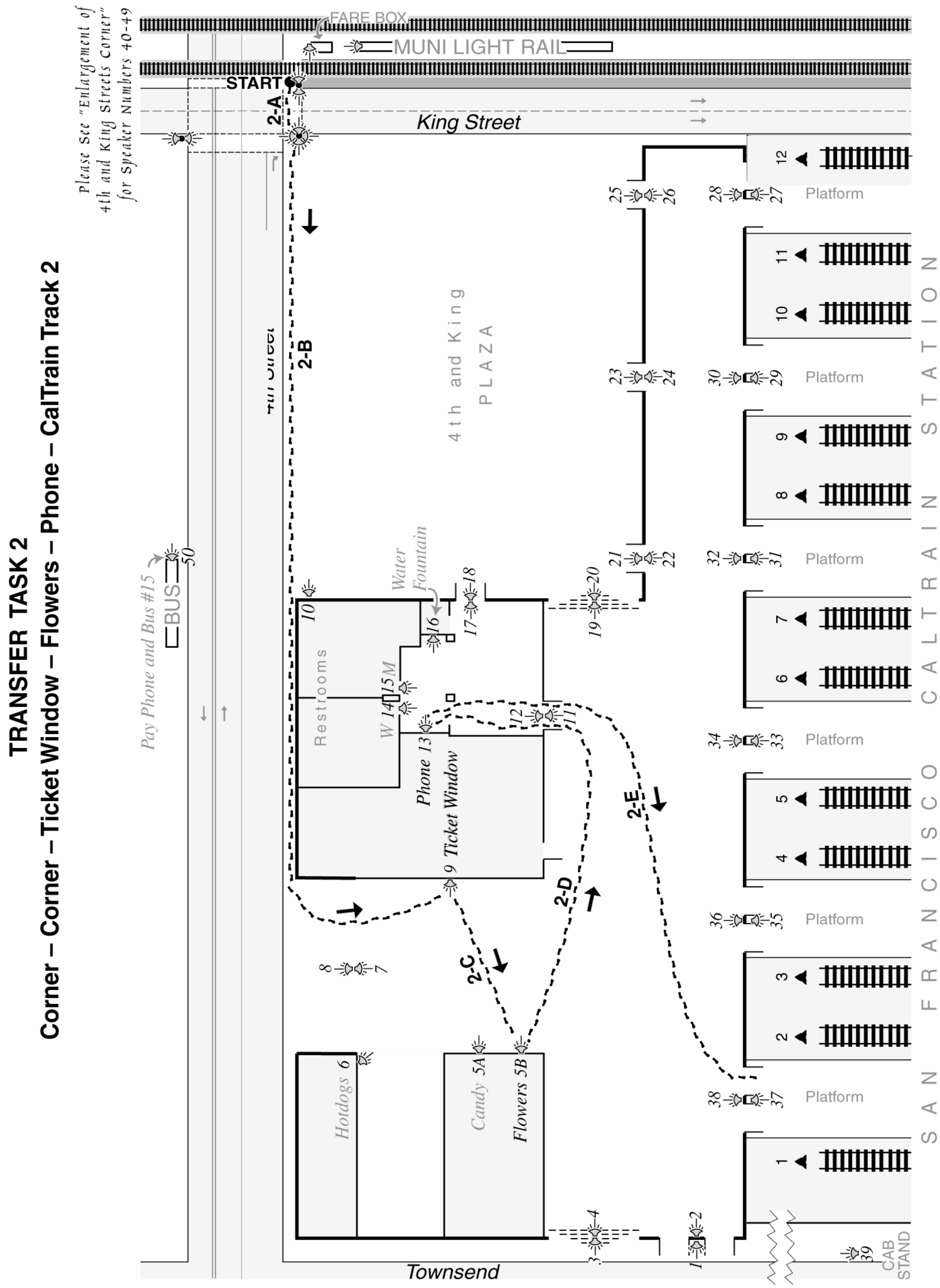
The t-test statistics for the two conditions showed no significant difference. For those subjects with no vision, t-tests also showed no significant difference.

3.1.2.2.5. Walk to Corner #1

From the candy counter, subjects were to walk out the main door, turned right, and walk to the corner. Both long cane and dog users are well trained in following curbs and using auditory cues to find street corners. The *regular method* subjects took 147% longer, and the *RIAS* subjects took 111% longer, than the FSU.

The t-test statistics for the two conditions showed no significant difference. For those subjects with no vision, t-tests showed no significant difference.

Figure 3.3 Transfer Task 2 Path of Travel



3.1.3. <u>Transfer Task 2: Muni Corner to Track 3</u>

For this task, 15 subjects used their regular skills first for all five sub-tasks, and then they later repeated the same tasks using RIAS. Fifteen subjects used the *RIAS* first and 10 people repeated the task later using their regular skills. The t-tests statistics were calculated for analysis of times between the two conditions, *NRIAS* 1^{st} versus *RIAS* 2^{nd} and *RIAS* 1^{st} versus *NRIAS* 2^{nd}. The t-test statistics were also calculated for the 30 *RIAS* scores and the 25 *NRIAS* scores, regardless of the order of the condition.

			Condition 1		Condition 2	
Task	From	To	NRIAS 1^{st}	RIAS 2^{nd}	NRIAS 2^{nd}	RIAS 1^{st}
2-A	Corner	Corner	72s	13s	74s	15s

Because of the turn lanes and traffic flow at this crossing, the effects of the RIAS were highly significant. Without RIAS there was much hesitation and many mistakes. The results for the *NRIAS* 1^{st} condition were $p<.006$, for *RIAS* 1^{st} $p<.002$, and for 30 *RIAS* subjects and 25 *NRIAS* subjects, regardless of order, the results were also highly significant ($p<.00004$). There is no “learning” effect over two attempts at a dangerous crossing like this one.

Thirteen subjects out of 25 without RIAS made a total of 20 unsafe attempts to cross the street. Twelve of the 25 subjects using their regular method missed the corner, another dangerous situation when traveling without vision. One person out of the 30 using RIAS missed the corner. Two subjects not using the system refused to even attempt the street crossing. The times and errors show that, when using RIAS, there was little hesitation, and that safety was vastly increased.

			Condition 1		Condition 2	
Task	From	To	NRIAS 1st	RIAS 2nd	NRIAS 2nd	RIAS 1st
2-B	Corner	Ticket Win	128s	100s	115s	107s

The difference in times when using *RIAS* after the regular method was highly significant ($p<.017$). There was no significant difference when using *RIAS* first and then the regular method ($p<.47$). Overall, the difference between the two conditions was not significant ($p<.085$).

Four subjects asked for help from others a total of four times when using their regular method. No one using RIAS asked for help

			Condition 1		Condition 2	
Task	From	To	NRIAS 1st	RIAS 2nd	NRIAS 2nd	RIAS 1st
2-C	Ticket Win	Flowers	93s	15s	45s	21s

The difference in times when using *RIAS* after the regular method was highly significant ($p<.0006$). There was no significant difference when using *RIAS* first and then the regular method ($p<.069$). Overall, the difference between the two conditions was highly significant ($p<.00006$).

Seven out of 25 subjects asked for help from others a total of 11 times when using their regular method. No one using RIAS asked for help.

			Condition 1		Condition 2	
Task	From	To	NRIAS 1st	RIAS 2nd	NRIAS 2nd	RIAS 1st
2-D	Flowers	Phone	109s	101s	80s	109s

No significant difference was found for this task. Seven out of 25 subjects asked for help from others a total of eight times when using their regular method. No one using RIAS asked for help. In this location, the light beam did not extend complexly to the adjacent wall, where most of the subjects walked as they shorelined along the building wall, causing trouble in picking up the signal easily.

			Condition 1		Condition 2	
Task	From	To	NRIAS 1st	RIAS 2nd	NRIAS 2nd	RIAS 1st
2-E	Phone	Track #2	172s	86s	107s	85s

The difference in times when using *RIAS* after the regular method was highly significant ($p<.0002$). There was no significant difference when using *RIAS* first and then the regular method ($p<.14$). Overall, the difference between the two conditions was highly significant ($p<.0001$).

Seven out of 25 subjects asked for help from others a total of 12 times when using their regular method. No one using RIAS asked for help. Four people reported they were “not sure” they were at the correct track when using their regular method.

There was no Braille signage at these doors, and, if people were not around to ask, blind people have no confirmation of the correct location.

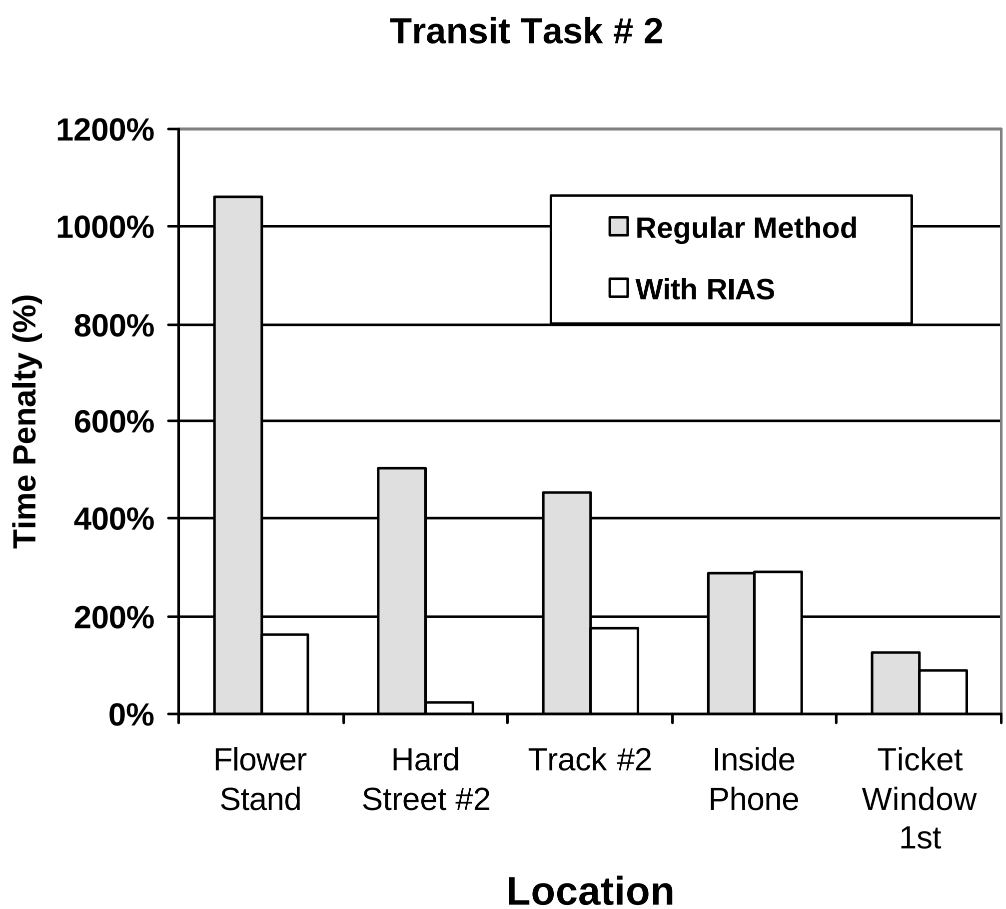
	Condition 1		Condition 2	
	NRIAS 1st	RIAS 2nd	NRIAS 2nd	RIAS 1st
Task #2 Total	574s	315s	421s	388s

The total of the five sub-tasks that make up Transfer Task 2 show how much better people traveled when using RIAS. Once having used the system, their spatial knowledge appeared to increase so that, on their second attempt using their regular method, the results, although quicker in the *RIAS* condition, are not significant ($p<.14$). When using their regular method of travel first and then using *RIAS*, the results were highly significant ($p<.00001$). The difference between the 30 trials with *RIAS* and the 25 trials without *RIAS* was also highly significant ($p<.0006$). For the 25 subjects who attempted the 5 sub-tasks with their regular method, there were a total of 17 tasks that they could not finish and were "timed out." The 30 subjects attempting the same five sub-tasks with RIAS only had three that were "timed out."

The order of the *RIAS* condition was shown not to be significant in this task. Comparing *RIAS* 1st to *RIAS* 2nd gives a value of ($p<.35$). This shows that the improvement in performance when using the system is not due to the learning effect of a second trial.

3.1.3.1. Time Penalties and Accessibility

Figure 3.4 Excess Time using Regular Methods and RIAS - Task 2



3.1.3.1.1. Flower Stand

The hardest location to find in the second transfer test was the flower concession, which was located in the main area of the terminal. Subjects could not find the counter, because flowerpots on the floor in front of the counter seemed to obscure the counter. Subjects without the RIAS took 1063% extra time over the FSU to find the counter. First attempts by those with *RIAS* took only 162% more time than the FSU. Once they picked up the signal and got positive identification, they knew to push forward through the scattered flowerpots to the desired counter. Because of the blockage, this location was categorized as another random or inconsistent amenity location with no cues.

The t-test statistics for the two conditions showed a significant difference (P<.0007). For those subjects with no vision, t-tests showed a significant difference (P<.0006).

3.1.3.1.2. Hard Street Crossing #2

The second crossing of King Street was in the opposite direction than the first crossing. This direction, toward the Caltrain terminal, was even harder, because the traffic turning right from 4th St. was across the street and harder to hear and comprehend. This problem and the high speeds kept some people from even attempting the crossing, and others took time to listen to 2 or 3 signal cycles before crossing. The regular method subjects took 504% longer than the baseline FSU. The RIAS gave a direct beam and positive identification of the WALK signal and users with RIAS crossed this street only 22% longer than the baseline FSU.

The t-test statistics for the two conditions showed a significant difference (P<.005). For those subjects with no vision, t-tests showed a significant difference (P<.007).

3.1.3.1.3. Train Track #2

The entrance doors to the boarding area for outbound trains had no Braille or tactile information to identify the proper door. It took 454% longer than the FSU to walk to, locate, and identify the proper door for those using their regular method. The RIAS gave a direction beam and positive identification of the track number, and those who used the system were only 176% longer than the FSU.

The t-test statistics for the two conditions showed a significant difference (P<.00004). For those subjects with no vision, t-tests showed a significant difference (P< 0001).

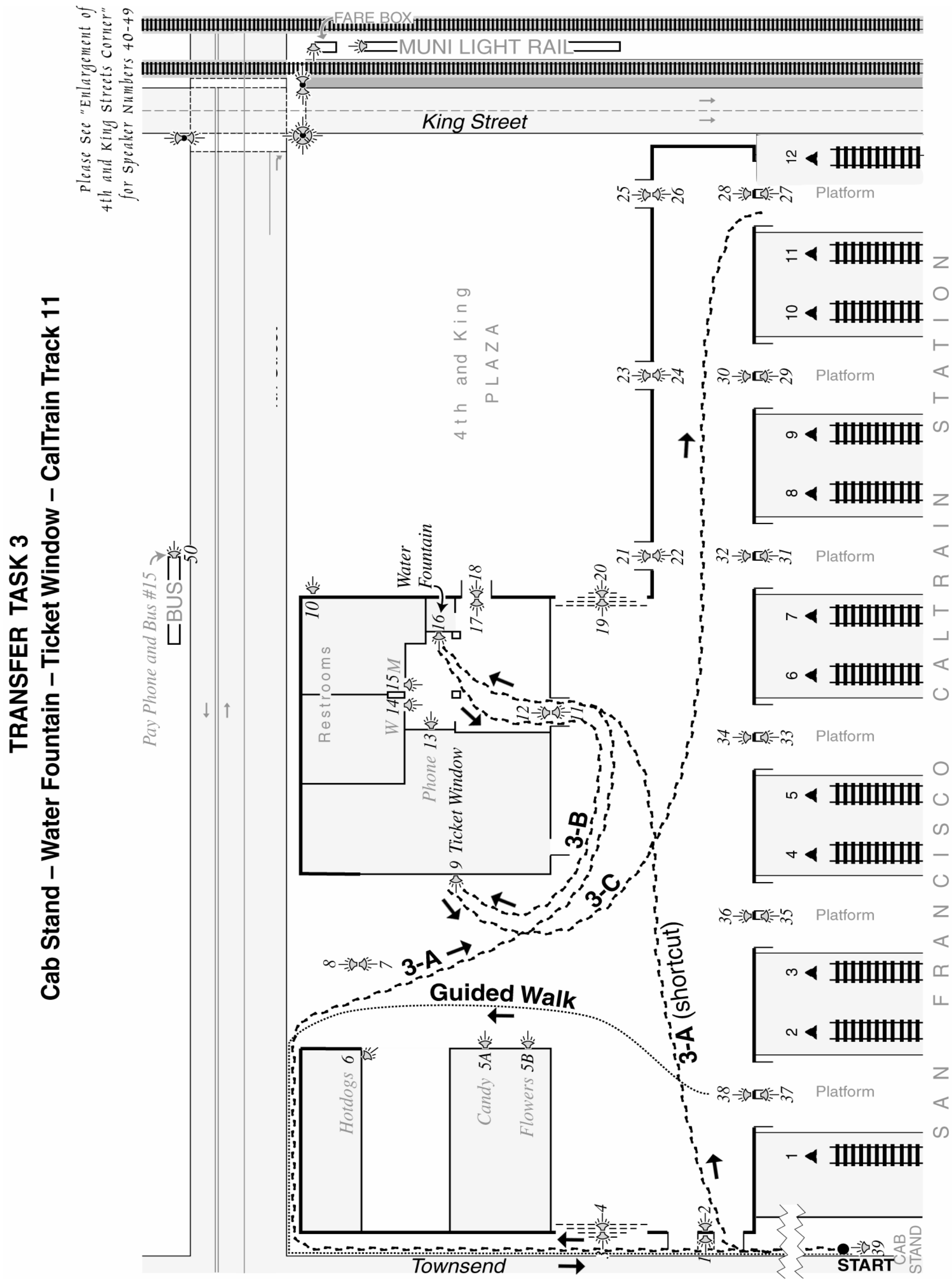
3.1.3.1.4. Inside Phone

The phone bank in the terminal was located in the waiting room near the bathrooms. Subjects had passed them on their first trip to the waiting room. There are non-visual cues available if people are on the phone talking or coins are heard. The RIAS signal at the waiting room was partially blocked by building columns, and inside the room there were problems with many obstacles and crowds. The excess times were quite similar at this location, with the regular method subjects taking 289% longer and the RIAS users taking 290% longer than the FSU. Since the subjects had been past this location previously and there are other auditory cues, this amenity location was categorized as one with good cues. The t-test statistics for the two conditions showed no significant difference. For those subjects with no vision, t-tests also showed no significant difference.

3.1.3.1.5. Ticket Window 1st time

The ticket window is rationally located directly inside the terminal. For this test, the subjects walked back from the corner, retracing along the curb to the building entrance. Subjects had passed this area previously, there were usually lines of people queued up, and there were theatre-type stanchions with ribbon-tape designating the waiting area. There were also voices from the window agent and from people in line. Subjects using their own aids took 125% longer, and those with *RIAS* took 88% longer than the FSU. This location was categorized as an amenity with good cues. There was no significant difference for the first attempt in either the full all subjects and the no vision subjects' data.

Figure 3.5 Transfer Task 3 Path of Travel



3.1.4. Transfer Task 3: Taxi Stand to Track 11

For this task, 15 subjects used their regular skills first for all three tasks and then repeated the same tasks later using the RIAS. Fifteen subjects used the *RIAS* for their first and only trial. They did not repeat the experiment with their regular method.

			Condition 1		Condition 2
Task	From	To	NRIAS 1st	RIAS 2nd	RIAS 1st
3-A	Taxi stand	Water	174s	141s	128s

The water fountain was quite distant from the cab stand and was difficult to locate in either condition for some subjects The difference in times when using *RIAS* after the regular method was significant ($p<.01$). Overall, the difference between the two conditions was significant ($p<.045$).

Without *RIAS*, seven out of 15 subjects asked for outside help a total of 10 times. In this trial, subjects were told to find the water fountain, with no mention of any specific path. They had previously been led out the front entrance and around to the side of the terminal, never using the side door (Townsend St). Six of the 15 *NRIAS* subjects (40%) made a shortcut through the side door of the terminal. When using the *RIAS*, 29 out of 30 subjects (97%) made a shortcut through the side door. This was quite revealing, because many blind people have trouble making shortcuts in an unknown space. Some of the subjects had some residual vision, but, while using the RIAS, even the totally blind were able to understand the spatial layout and find the side door entrance that they had never used. As shown in Figure 3.5, the side doors had identifying RIAS transmitters, and it appears that although they did not use those doors previously, they must have learned and stored that knowledge on the previous tasks.

			Condition 1		Condition 2
Task	From	To	NRIAS 1st	RIAS 2nd	RIAS 1st
3-B	Water	Ticket Win	81s	51s	65s

The results in the *NRIAS* 1st condition were significant (p<.02). In this sub-task, the results between the two conditions were not significant (p<.09). Without *RIAS*, three out of 15 subjects asked for outside help. This was their second trip to the station ticket window, and, by this time, it appeared that the subjects were learning where it was located.

			Condition 1		Condition 2
Task	From	To	NRIAS 1st	RIAS 2nd	RIAS 1st
3-C	Ticket Win	Track #11	178s	79s	99s

Track gate doors are not marked with Braille, and this door was at the far end of the terminal where often there were no people to ask for help. People with vision restrictions often rely on asking for help from others, but there are many situations where few, if any, people are available for assistance. This was certainly the case in this task. Six of fifteen people without *RIAS* could not find the door in the four minutes allowed. All 30 subjects using the RIAS found the correct track door. The results for those who used the system second were highly significant ($p<.00001$), and the overall results wee also highly significant ($p<.000002$).

In addition, over half (8/15) of the subjects not using the RIAS asked for outside help a total of nine times. Three of the regular method users also reported they were not sure if they were at the proper door, although they were actually there.

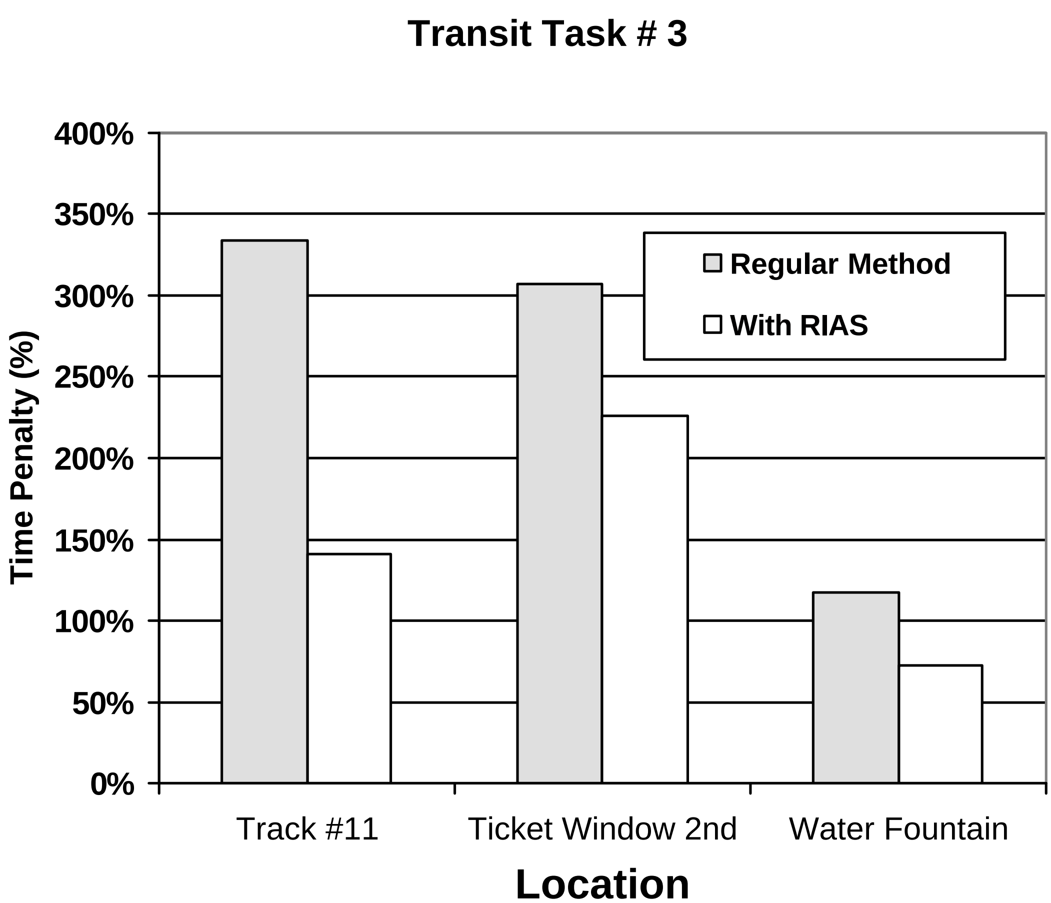
	Condition 1		Condition 2
	NRIAS 1st	RIAS 2nd	RIAS 1st
Task #3 Total	433s	272s	302s

For the entire trip from the cabstand to track 11, the results were highly significant for both the *NRIAS* 1st – *RIAS* 2nd condition, and the overall average ($p<.00002$ and $p<.002$ respectively). For the 15 subjects who attempted the three sub-tasks with their regular method, there were a total of 11 tasks that they could not finish and were "timed out." The 30 subjects attempting the same three sub-tasks with *RIAS* only had five that were "timed out."

The order of the *RIAS* condition was shown not to be important in this task. People performed just as well if they used the system first or second. There was no significant difference based on order of use. The t-test showed that ($p<.3$).

3.1.4.1. Time Penalties and Accessibility

Figure 3.6 Excess Time using Regular Methods and RIAS - Task 3



Train Track #11

This door was located at the far end of the terminal where subjects had not yet traveled. That area of the station was much less crowded and offered fewer people to ask for help. Those subjects using their regular navigation aids took 334% longer than the FSU. With RIAS, subjects could "see" the door numbers as they walked down the hall and were able to keep going until they found the proper door. Many subjects without the system were not aware of how many gate doors were in the station and often stopped short. Those using the *RIAS* were able to locate the proper door within a time period that was 141% longer than the baseline.

The t-test statistics for the 2 conditions showed a significant difference ($P<.0006$). For those subjects with no vision, t-tests showed a significant difference ($P<.00002$).

3.1.4.1.1. Ticket Window 2nd time

Regular method subjects took 307% longer, and *RIAS* subjects took 226% longer than the FSU baseline. No significant difference was found for this task on the first trial.

3.1.4.1.2. Water Fountain

The water fountain was also located in the waiting room. Subjects had been there twice before this sub-task. They could have found it or heard cues on those trials. This location was classified as an amenity with good cues. To get to the start location for this path, subjects were guided out the main entrance and around the building. There was a shortcut from the start point to the water fountain through side doors of the terminal, which the subjects had not used before. The shortcuts are discussed later (see Section 4.6.1, Spatial Knowledge Revealed by Navigation and Wayfinding Tasks). For the excess time comparison, and because the subjects had no previous knowledge of the side doors, a comparison was made between these times and those of the FSU taking the path subjects learned on their guided walk. Subjects using their own aids took 117% longer and *RIAS* subjects took 73% longer than the baseline. When subjects' times are compared to the FSU taking the shortcut, the regular aids subjects took 185% longer and the *RIAS* subjects took 126% longer. The two conditions were almost significant (P<.052) for the full group and not significant for those with no vision.

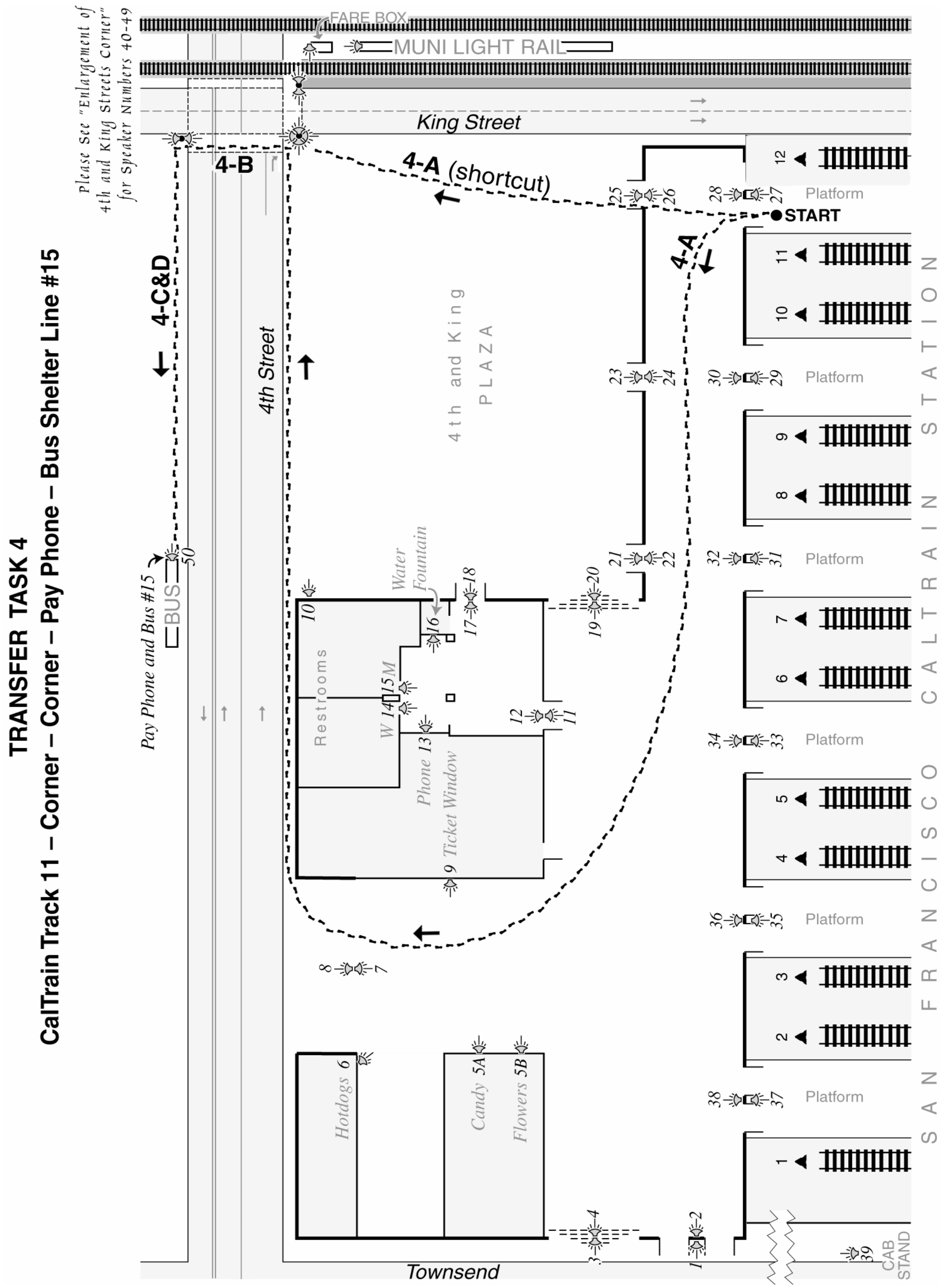
3.1.5. Transfer Task 4: Track 11 to Bus Shelter Line #15

For this task, 15 subjects used their regular skills first for all three tasks and then repeated the same tasks later using the *RIAS*. Fifteen subjects used the *RIAS* for their first and only trial. They did not repeat the experiment with their regular method.

			Condition 1		Condition 2
Task	From	To	NRIAS 1st	RIAS 2nd	RIAS 1st
4-A	Track #11	Corner	159s	87s	88s

Significant performance differences were found both for the *NRIAS* 1st condition and the average overall performance (p<.0003 and p<.0003 respectively). In this walk, no specific route was mentioned; they were just told to go to the corner that they had previously visited.

Figure 3.7 Transfer Task 4 Path of Travel



Previously, they had gone out the main entrance to reach this corner. There were doors near the end of the station that would be a shortcut, although they had never used them or been told about them. Three out of 15 (20%) of those using their own methods were able to use this shortcut to the corner. Those that used RIAS appear to have learned about the existence of these doors while performing the previous task as 24 out of 30 (80%) were able to find and use these side doors to make a shortcut to the corner. Finding and using paths never used before is quite an accomplishment for many blind people.

			Condition 1		Condition 2
Task	From	To	NRIAS 1st	RIAS 2nd	RIAS 1st
4-B	Corner	Corner	24s	16s	15s

This street crossing on 4th Street was not as difficult as the one on King Street. The cars traveled much slower, and almost all made turns in front of the pedestrian. Except for a one-lane bus route on the far side, it was mostly a one-way street in front of the pedestrian. The differences in performance were highly significant for both the *NRIAS* 1st condition ($p<.001$) and the *RIAS* versus *NRIAS* results ($p<.00005$).

			Condition 1		Condition 2
Task	From	To	NRIAS 1st	RIAS 2nd	RIAS 1st
4-C	Corner	Pay Phone	110s	58s	65s

This task was made difficult by the fact that the pay phone was inside a glass-enclosed bus shelter. There was no outside tactile evidence as to where it was located. Significant performance differences were found both for the *NRIAS* 1st condition and the overall performance of *RIAS* versus *NRIAS* ($p<.025$ and $p<.006$, respectively). Two subjects out of 15 in the *NRIAS* condition had to ask for help. Four out of 15 subjects using their regular method "timed-out" and could not find the phone. One person out of 30 using RIAS could not find the phone.

			Condition 1		Condition 2
Task	From	To	NRIAS 1st	RIAS 2nd	RIAS 1st
4-D	Pay Phone	Bus Shelter	71s	0s	0s

The RIAS transmitter at this location identified both the phone and the fact that it was a stop for the #15 bus line. Those without the system had to continue their search to find the correct bus shelter. Seven of the 15 subjects using their normal skills had to ask others to get a positive identification of the proper bus shelter. In addition, two subjects without the system found the correct shelter but reported they "were not sure" if it was for the correct bus line. All of the RIAS users knew they were already at he bus shelter, and, therefore, no extra search time was needed.

	Condition 1		Condition 2
	NRIAS 1st	RIAS 2nd	RIAS 1st
Tasks #4 Total	364s	161s	168s

For the entire trip from Caltrain track 11 to the bus shelter for line #15, the results were highly significant for both the *NRIAS* 1st – *RIAS* 2nd condition and the overall results ($p < .00001$ and $p < .000002$, respectively). For the 15 subjects who attempted the four sub-tasks with their regular method, there were a total of 10 tasks that they could not finish and were “timed out.” Of the 30 subjects attempting the same four sub-tasks, only two were “timed out.”

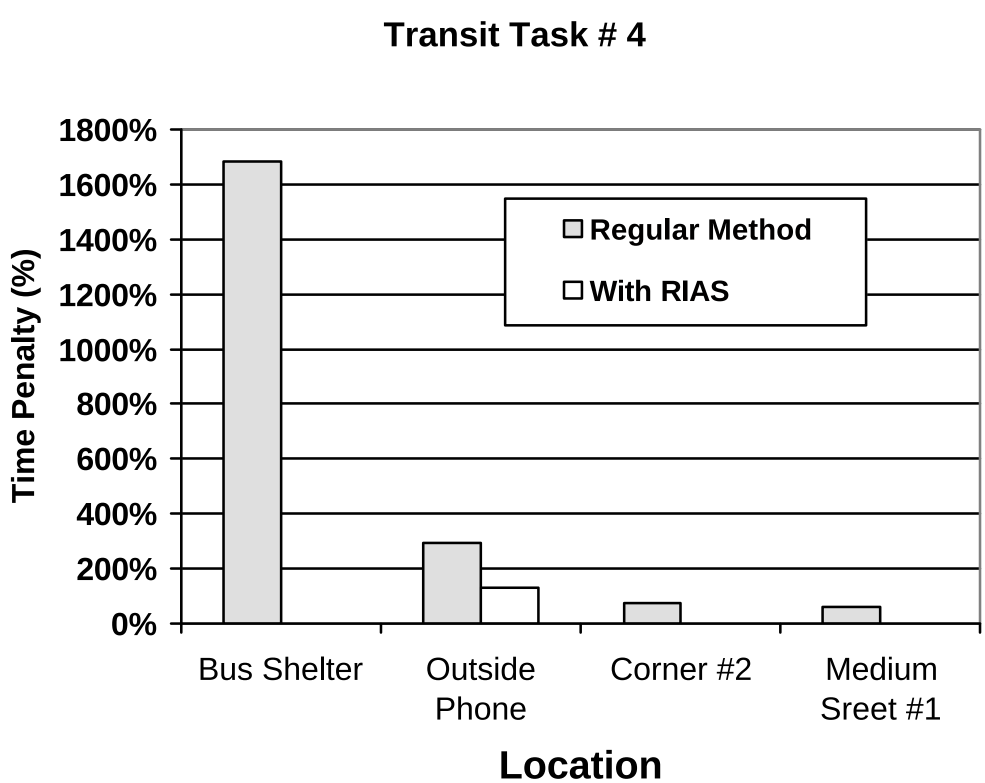
The order of the *RIAS* condition was shown not to be important in this task. People performed just as well if they used the system first or second. There was no significant difference based on order of use. The t-test showed ($p < .43$).

3.1.5.1. Time Penalties and Accessibility

3.1.5.1.1. Bus Stop for Route #15

The difficulty of finding bus stops has been confirmed in difficulty ratings in this and previous studies. There is no consistent pattern of their placement, and some are merely placed on pre-existing poles, such as streetlights. Field tests have also showed how difficult these tasks are (Marston & Golledge, 1998b). Crandall et al. (1996) and Bentzen et al. (1999) found that not one of their subjects could find a bus stop pole even when it had tactile information about the stop. The bus shelter in this experiment had no tactile information about which bus stopped there, and there was another shelter nearby, further confusing the test subjects. The start point for this task was adjacent to the shelter, but with no way to identify which bus stopped there, they had to search for help or other information. To avoid calculating a penalty with a FSU user time of zero, four seconds was used to indicate the time it took to move to the front of the bus shelter. It took 1685% longer to find and identify the proper bus stop than the baseline FSU. With RIAS, subjects knew exactly which bus stopped there, and all subjects completed the task as fast as the FSU. The t-test statistics for the two conditions showed a significant difference (P<.0009). For those subjects with no vision, t-tests showed a significant difference (P<.006).

Figure 3.8 Excess Time using Regular Methods and RIAS - Task 4



3.1.5.1.2. Outside Phone

The phone was located about half way down the street from the start point, and those subjects who followed the curb could run into it. There was a wastebasket in front of the phone, and this obstacle slowed many people. The subjects that used their normal aids took 289% longer than the FSU, and those who used RIAS took 137% longer. Unlike the phone in the terminal, subjects had not been to this location previously and there was never anyone using it to give auditory cues. Therefore, this amenity was categorized as one with few cues.

The t-test statistics for the two conditions showed a significant difference (P<.029). For those subjects with no vision, t-tests showed a significant difference (P<.003).

3.1.5.1.3. Walk to Corner #2

Subjects were asked to walk to the first corner that they had visited in the experiment. Although finding information about the street corner might be quite difficult, the task of finding a corner is something in which most blind people are well trained. Subjects made previous trips to the corner by going out the main exit of the terminal. There were some side doors that allowed a short cut to the location. Because the subjects had never used that route, their time was compared to the FSU taking the longer but familiar route. For the subjects who used their regular navigation aids, it took them 78% longer than the FSU. Users of RIAS were usually able to detect the doors for the shortcut, and their average time was equal to that of the FSU taking the longer route. If subjects' times are compared to the FSU taking the shortcut, the regular aids subjects took 429% longer and the *RIAS* subjects took 200% longer (see Section 4.6.1, Spatial Knowledge Revealed by Navigation and Wayfinding Tasks for more information about making shortcuts).

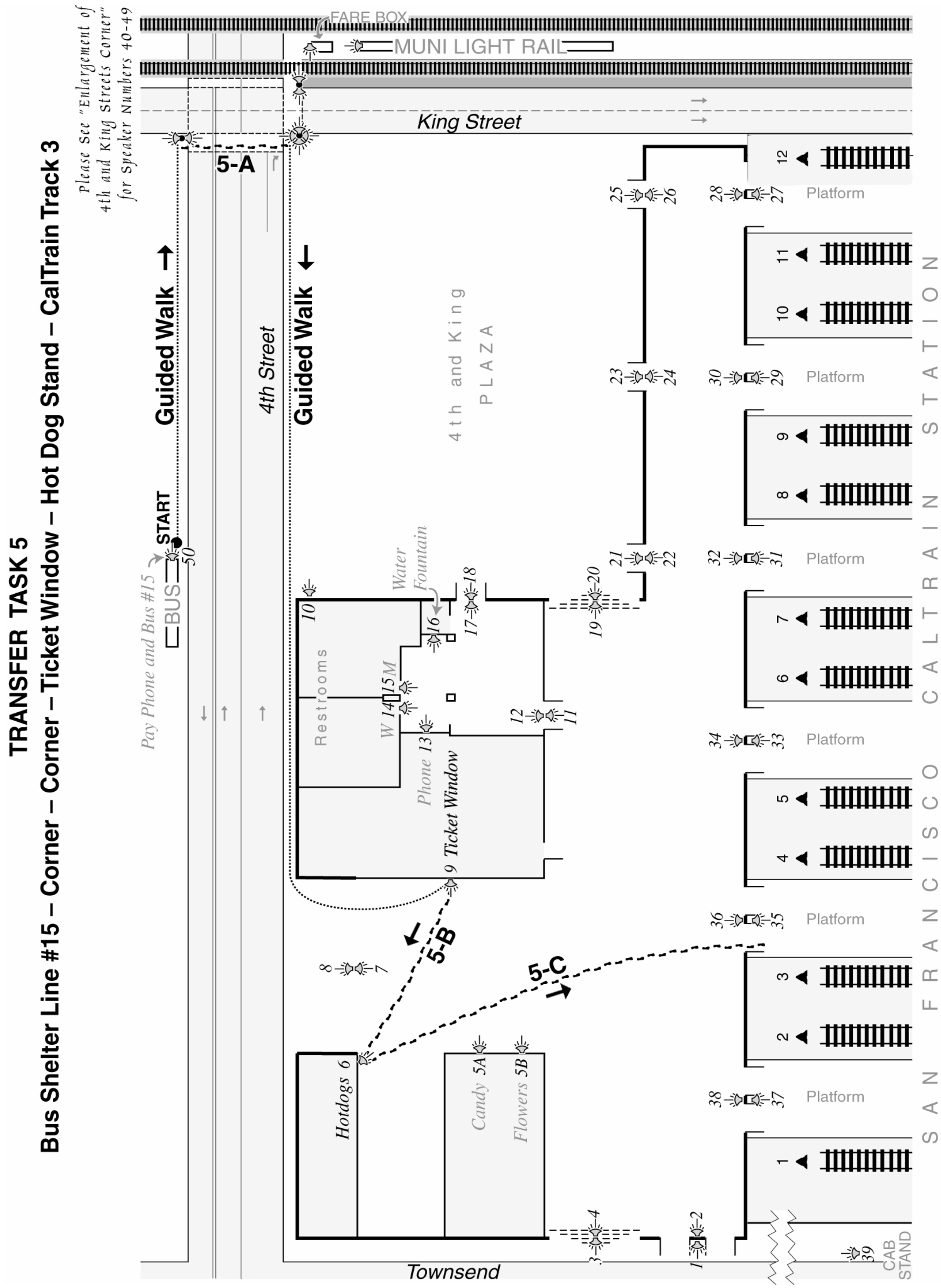
The t-test statistics for the two conditions showed a significant difference (P<.001). For those subjects with no vision, t-tests showed a significant difference (P<.02).

3.1.5.1.4. Medium Difficulty City Street #1

Crossing 4th Street was much easier than King Street. On the north side was a one-lane dedicated bus lane, which was usually vacant. The south had two lanes with a third turn lane at the corner. This was a much more typical congested city street, with cars parked in front of the terminal. The block was quite short and also had a traffic signal at the other end, so there was no high-speed traffic. Because of the bus lane, there were no vehicles turning onto the street, and few cars went straight across King. Most cars turned right at the terminal. It took the subjects with their regular navigation 58% longer than the FSU. Subjects using RIAS took, on average, no longer than the FSU.

The t-test statistics for the two conditions showed a significant difference (P<.0006). For those subjects with no vision, t-tests showed a significant difference (P<.001).

Figure 3.9 Transfer Task 5 Path of Travel



3.1.6. Transfer Task 5: Bus Shelter #15 to Track 3

For this task, 15 subjects used their regular skills first for all three tasks and then repeated the same tasks later using the RIAS. Fifteen subjects used the *RIAS* for their first and only trial. They did not repeat the experiment with their regular method.

Bus Shelter #15 – Corner = Guided Walk

			Condition 1		Condition 2
Task	From	To	NRIAS 1st	RIAS 2nd	RIAS 1st
5-A	Corner	Corner	23s	16s	15s

The street crossing on 4th Street was not as difficult as the one on King Street. The cars traveled much slower, and all traffic, except for buses, was in one direction. Therefore, it was much easier to hear when the cars stopped. The differences in performance were highly significant for both the *NRIAS* 1st condition and the overall performance of *RIAS* versus *NRIAS* ($p<.001$ and $p<.0001$, respectively). The RIAS gave immediate confirmation that it was safe to cross the street and also gave a directional beam to follow in order to stay in the crosswalk. One subject without the RIAS made an unsafe attempt to cross the street.

Corner – Ticket Window = Guided Walk

			Condition 1		Condition 2
Task	From	To	NRIAS 1st	RIAS 2nd	RIAS 1st
5-B	Ticket Window	Hot Dog Stand	73s	26s	34s

The differences in performance were highly significant for both the *NRIAS* 1st condition and the overall performance ($p<.004$ and $p<.0004$, respectively). Seven subjects without the RIAS asked for outside help a total of 10 times.

			Condition 1		Condition 2
Task	From	To	NRIAS 1st	RIAS 2nd	RIAS 1st
5-C	Hot Dog	Track #3	126s	63s	60s

Because there were no accessible signs on the track doors, it was difficult to find the correct track. Six subjects using their normal skills had to ask for outside help a total of nine times. Again, both the *NRIAS* 1st condition and the overall performance using *RIAS* were significant ($p<.004$ and $p<.0002$, respectively).

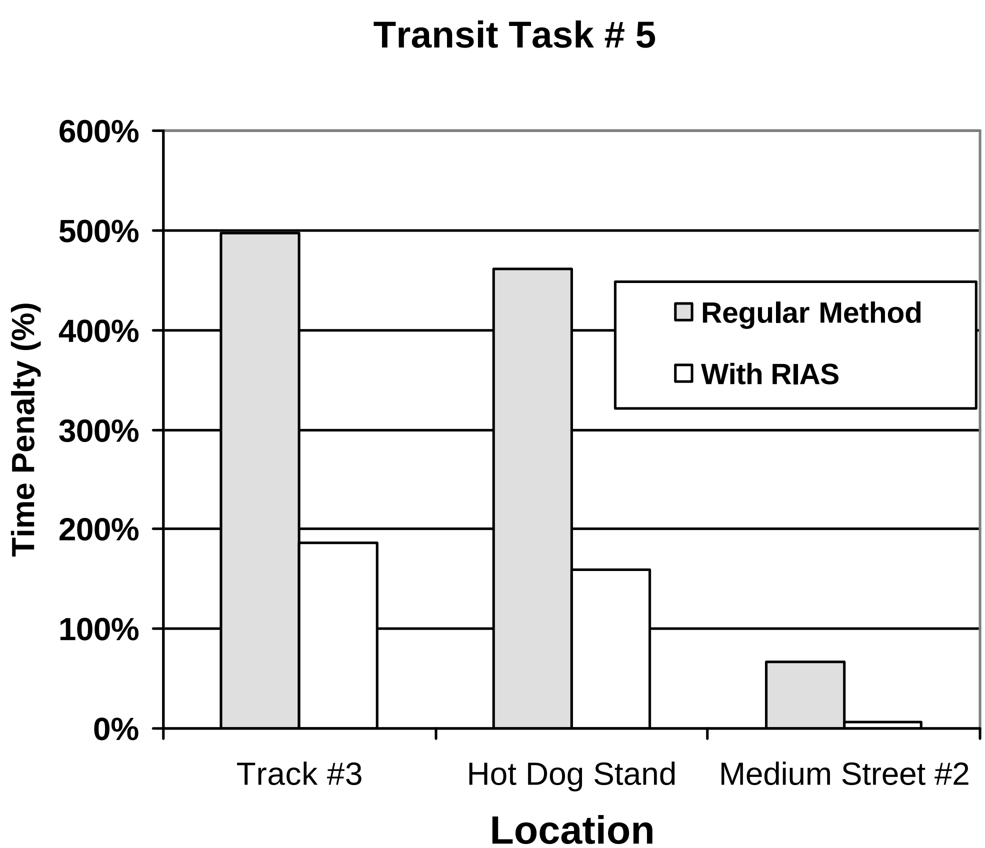
	Condition 1		Condition 2
	NRIAS 1st	RIAS 2nd	RIAS 1st
Task #5 Total	222s	105s	109s

For the entire trip from the #15 bus shelter to Caltrain track 3, the results were highly significant for both the *NRIAS* 1st - *RIAS* 2nd condition and the overall performance ($p<.0003$ and $p<.00002$, respectively). For the 15 subjects who attempted the five sub-tasks with their regular method, there were a total of five tasks that they could not finish and were "timed out." The 30 subjects attempting the same sub-tasks with RIAS had no tasks that were "timed out."

The order of the *RIAS* condition was again shown not to be important in this task. People performed just as well if they used the system first or second. There was no significant difference based on order of use. The t-test showed (p<.43).

3.1.6.1. Time Penalties and Accessibility

Figure 3.10 Excess Time using Regular Methods and RIAS - Task 5



3.1.6.1.1. Track Door #3

In their third and final attempt to find one of the track doors, subjects walked from the hot dog stand to track #3. Finding this unlabeled door took 498% longer than the baseline time. For those who used RIAS, it took them 186% longer. There was a significant difference between the first-time attempts (P<.003). For those with no vision, the results were also significant (P<.005).

3.1.6.1.2. Hot Dog Concession

It was a short walk from the ticket window to the hot dog area, but it was placed so close to the front exit that it seemed to confuse the subjects. It was about 15' from the other two concessions that they had visited. It took the subjects using their normal navigation aids 462% longer than the FSU baseline, and the subjects who used RIAS took only 160% longer. At times there were voices at the counter to give some cues, so this amenity was categorized as one with few cues.

The t-test statistics for the two conditions showed a significant difference (P<.01). For those subjects with no vision, t-tests showed a significant difference (P<.01).

3.1.6.1.3. Medium Difficulty City Street #2

Walking south across 4^{th} Street was a bit harder than going the other direction. The turn lanes were at the opposite side of the street; so auditory cues from the street were a bit harder to pick up than when the right turns and traffic were directly in front of the subjects. Those subjects who used their regular navigation skills took 67% longer, and the RIAS users took only 6% longer than the FSU baseline.

The t-test statistics for the two conditions showed a significant difference (P<.002). For those subjects with no vision, t-tests showed a significant difference (P<.0004).

3.1.7. Totals for all Five Transfer Tasks

The degree of efficacy when using RIAS to enable blind and vision-impaired travelers to navigate in large and confusing urban transit environments has been shown here to be highly significant, and system use adds to safety, speed, and spatial knowledge. The results of the five transfer tasks show that this type of system is very beneficial to blind travelers. The total times for the five tasks are shown below. This might represent a normal day for a person making five transfers to different modes. The ability to travel with increased efficiency in a timely and direct manner, complete more tasks, not having to locate people and ask for help, and being able to easily and safely cross busy streets gives people with vision impairments a much better chance to access and use the urban environment. It allows them to achieve more equal access to transit and public buildings in a safe, dignified, and independent manner.

3.1.7.1. Total Travel Task Time

	Condition 1		Condition 2
	NRIAS 1^{st}	RIAS 2^{nd}	RIAS 1^{st}
All 5 Tasks Total	2189s	1129s	1261s

For the 15 subjects who completed all five transfer tasks using *NRIAS* 1st and *RIAS* 2nd, the results were highly significant ($p<.0000002$). The average time for *NRIAS* 1st was about 36 minutes, and the time fell to 19 minutes with *RIAS*. All 15 subjects who tried their regular methods first (*NRIAS*) saved time when they tried *RIAS* 2nd, but RIAS helped the slower test subjects the most. One subject saved 28 minutes and two saved 27 minutes. For the fastest subjects, who all had the ability to see objects, and did not use a mobility aid, RIAS helped reduce their time by one, six, and eight minutes. Data points were plotted for each subject, with their *NRIAS* 1st value and their *RIAS* 2nd value. A regression line of best fit showed a high correlation effect of $R^2 =.73$. When one subject was removed from the analysis because of very inferior navigation skills, the results for the remaining 14 subjects showed a value of $R^2 = .85$, indicating a fairly constant effect. They all saved time with RIAS but the high R^2 value showed that users were consistently slow or fast, relative to the condition mean, whether they used *RIAS* or *NRIAS.*

The benefits of RIAS appears so powerful that there is no significant difference between those that used the system for their first trail and those that had first tried the tasks on their own and then tried the experiment again with the RIAS. The t-test value showed that the order was not significant ($p<.25$).

People found locations quicker and missed them less often when using RIAS them when using their regular methods. This was achieved with only 10 to 15 minutes of training. Street crossing results showed that, without the system, many people made potentially fatal decisions and that there was much hesitation and even some refusals to cross dangerous streets. In all, subjects using their own skills made 38 attempts to cross the street when it was unsafe to do so.

These five tasks were designed to approximate a typical day's transfer tasks for a daily urban traveler. The travel times for the *RIAS* 1st condition was fully 39% less than for those using *NRIAS* first. When those using *NRIAS* first tried the RIAS, their times fell, on average, by 49%. This is a tremendous saving in effort and personal stress. The times would certainly drop even more with repetition and learning. But even in a novel environment, the ability to save 49% of the normal time of these tasks, and the increased completion rate, are a great incentive for more and safer travel.

A sighted research assistant (FTSU) who had never been to the site received the same instructions, and it took him 9.47 minutes to complete the route on his first attempt (see Section 1.6.6, Sighted Subjects for Baseline). The 15 vision-impaired subjects who tried their regular method first took, on average, 36.48 minutes. The time "penalty" for vision loss was thus 3.85 times more effort than for the sighted. This penalty shows that to date there is no "equal access" to transit. The average time for those who used *RIAS* first was 22.13 minutes. Their penalty fell to a more tolerable and equitable 2.34 times the time for the sighted.

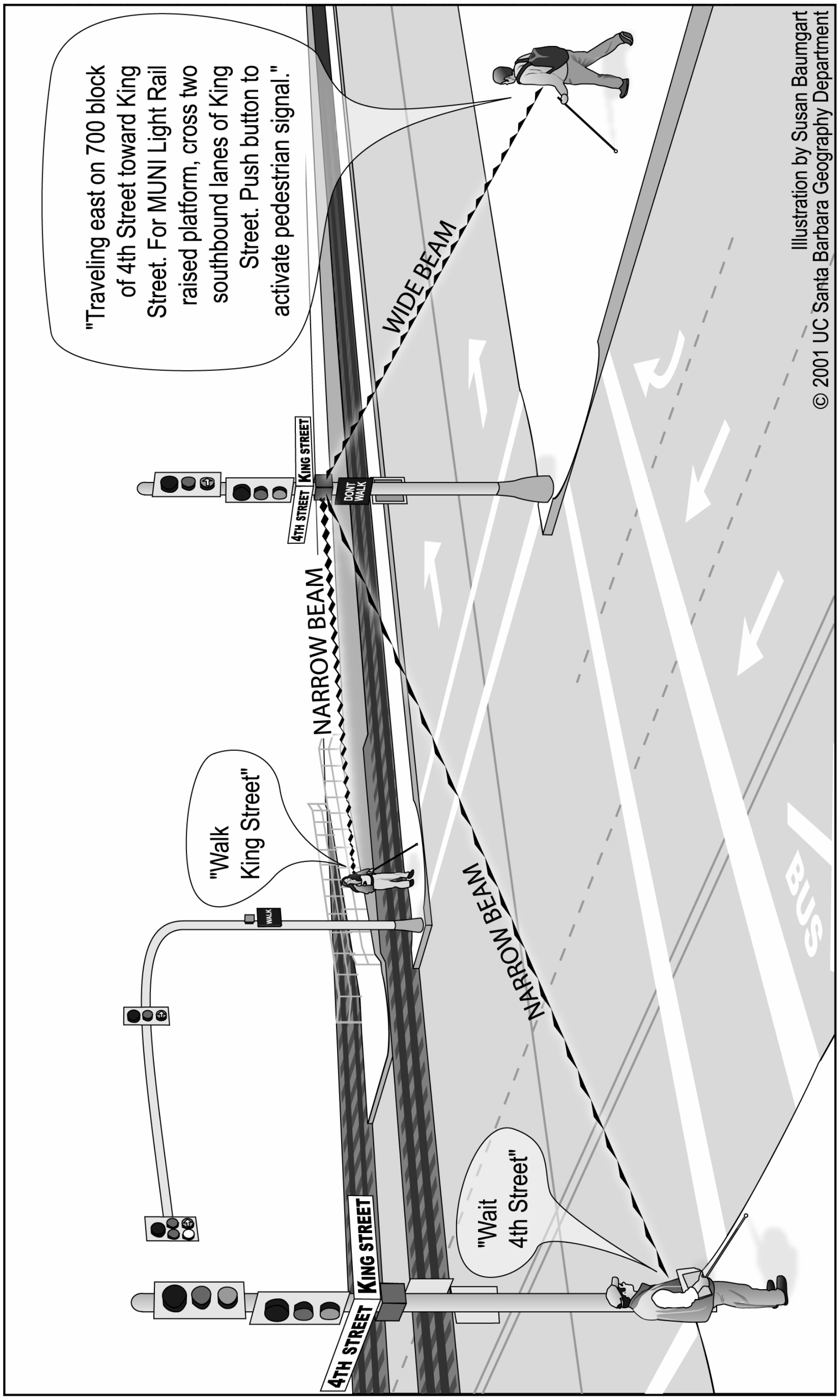
There was a wide range of subjects with various skills and degrees of vision loss. If only the top performers on these transfer tasks are compared, some very revealing evidence for RIAS is uncovered. Of those 15 that used *RIAS* first, six (40%) had times that were less than twice as long as the FTSU baseline data. The best time was only 9% longer than the baseline, with the next five having times of 21%, 24%, 67%, 85%, and 88% longer. That is certainly more like the reasonable accommodations and equity that is the focus of the ADA. When the results of those vision-impaired people who used *RIAS* for their second trial are compared against a fully sighted first-time person, the results are even more powerful. Nine of 15 subjects (60%) had times within twice that of the sighted baseline. One person actually completed the task 1% faster than the sighted subject. The next lowest eight times were 7%, 30%, 31%, 33%, 41%, 51%, 57%, and 68% longer.

The possible savings of so much time, effort, and stress shows that the ability to identify locations and access directional cues is quite helpful in providing increased access to transit and public buildings for the vision-impaired.

3.1.8. Unsafe Attempts to Cross Streets

Street crossing can be very unsafe for a blind pedestrian. With proper training, this group can perform amazing and fearless (to the sighted) feats of mobility. However, many intersections are not easy to cross. Irregular angles of intersection, and configuration and timing of turn lanes and traffic flow can make many intersections quite difficult. In the *NRIAS* condition, subjects crossed streets 80 times and made 38 unsafe (48%) attempts to cross those streets while the WAIT light was on and traffic had the right-of-way. At the most dangerous crossing, Task 2-A, three subjects waited their full four minutes and did not cross the two-lane street. If there had been no researcher watching for traffic or helping them across, this one intersection bottleneck could have completely halted any further travel progress or resulted in bodily harm. At this same intersection, fully 13 of 25 subjects (52%) attempted unsafe crossings with their regular method a total of 20 times. In addition, 17 out of 80 (21%) attempts to cross missed the opposite curb, also putting them in danger. When using RIAS, not one unsafe attempt was made to cross the street, because the receiver told them the status of the WALK and WAIT signal. Only one person using RIAS missed the opposite corner. Figure 3.11 shows the wide and narrow beams at the intersection that give the traveler both street information and specific information about the phase of the WALK signal and other interaction information. Independence, environmental information, and trip making enhancements are wonderful outcomes from using RIAS, but the safety of the blind pedestrian is a major benefit of this system.

Figure 3.11 Oblique View of RIAS Installation at King and 4th Streets



3.1.9. Dependency on Others

Often, the only way a vision-impaired person can navigate about an environment is to search for a sighted person and then ask for help. This makes some people feel vulnerable and dependent on others. Many objects in the environment are not marked in any fashion, and, without vision, there is no way to differentiate objects such as a bank of doors. Often there are few, if any, people around to ask, and some of them might not know the answer, refuse to help, or be unable to speak the same language. Fear of personal assault makes some people want to avoid drawing any undue attention to their vulnerability as a blind person. These fears are yet another factor that might keep people from making the trips they desire and might negatively impact their ability to enjoy full and active travel and activity participation. Many subjects in this experiment, when using their regular method of travel, had to ask people for help, and often there was no feedback to help identify locations.

- There were 75 sub-tasks for the *NRIAS* 1st condition in Task 1 and these subjects asked for assistance from others 23 times (31%) of the time.
- There were 75 sub-tasks for the *NRIAS* 1st condition in Task 2 and these subjects asked for assistance from others 35 times (47%) of the time.
- There were 45 sub-tasks for the *NRIAS* 1st condition in Task 3 and these subjects asked for assistance from others 22 times (49%) of the time.
- There were 60 sub-tasks for the *NRIAS* 1st condition in Task 4 and these subjects asked for assistance from others 9 times (15%) of the time.
- There were 45 sub-tasks for the *NRIAS* 1st condition in Task 5 and these subjects asked for assistance from others 18 times (40%) of the time.

Since subjects knew this was a test and that the researcher was with them, they must have felt safer than if they were truly on their own. In a real situation, some of these people would have probably not bothered to risk their safety and ask for help, giving up on the task instead. When subjects used the RIAS, not one person asked for help. In fact, two people were offered help by strangers and they politely refused, not needing any assistance. What is even more revealing is the fact that, for those who tried *RIAS* first and then used their regular method, there were only three requests for assistance out of 100 sub-tasks (3%). Having found the locations first using *RIAS*, many questions of identity or location had already been answered. These data indicate how dependent a blind traveler is on other people and how vulnerable they might be in an urban environment. Having to rely on others for simple verification of objects and directions can be a heavy penalty to pay. This reliance on others contradicts attempts to promote access or independence.

3.2. User Rated Difficulty of Transit Tasks

Later in this document (see Section 4.3, Activity Participation, Trip Behavior, and Travel Times) evidence is given to show that blind travelers often have very restricted travel and activity participation, but little is known about what specific areas cause the most problems and thereby limit travel and access to activity sites. To better understand specific problems when using transit as a vision-impaired person, a series of questions designed to identify problem areas was asked. Subjects were asked before (No *RIAS*) and after the experiment (with *RIAS*) to rate how difficult 26 specific tasks were, using a scale that went from “extremely difficult” (1) to “not at all difficult” (5). The data in this table are sorted from the hardest task to the easiest task, when using their regular methods.

Table 3.1 Ratings of Transit Task Difficulty

“How difficult would the following transit and modal transfer tasks be?”

Extremely difficult (1), Very difficult (2), Difficult (3), Somewhat difficult (4), Not at all difficult (5)

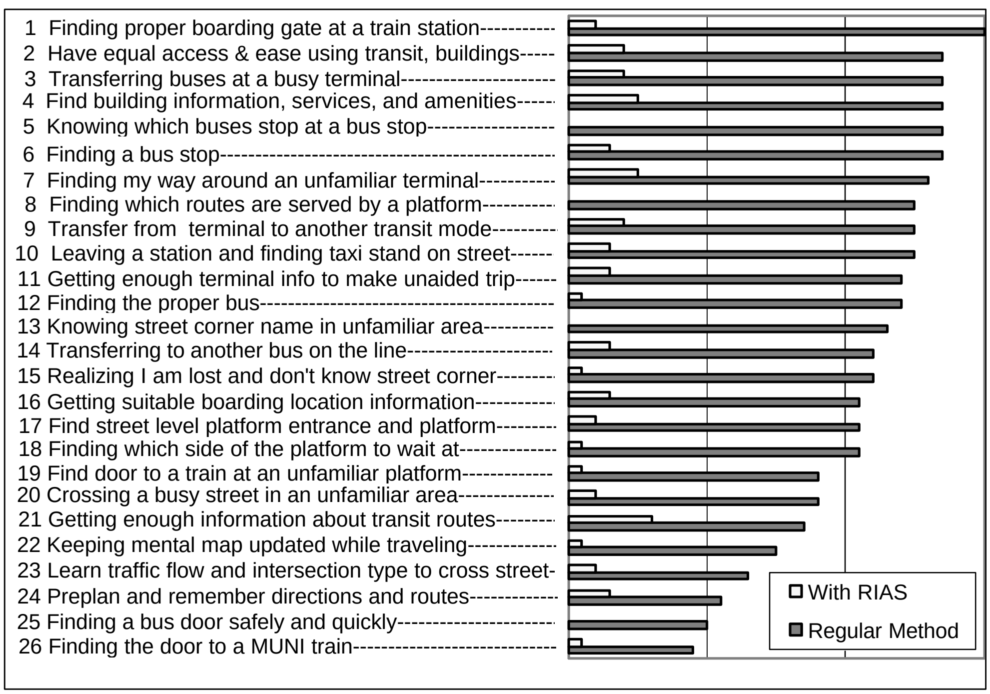
Q #	Difficulty of Transit Tasks	Regular Method	With RIAS
1	Finding the proper boarding gate at a train station when there are many doors or gates to various platforms.	2.0	4.8
2	Having the same access and ease of use of transit and public buildings as enjoyed by the general public is?	2.3	4.6
3	Transferring buses at a busy terminal.	2.3	4.6
4	Finding information or ticket windows, services and amenities such as phones and bathrooms in a new building or terminal.	2.3	4.5
5	Finding a bus stop.	2.3	4.7
6	Knowing which buses stop at a bus stop.	2.3	5.0
7	Finding my way around an unfamiliar train or bus terminal.	2.4	4.5
8	Finding out which Muni routes are served by a platform.	2.5	5.0
9	Transferring from a train or bus terminal to another mode of transit (light rail or bus) one block away.	2.5	4.6
10	Leaving a station and finding a taxi stand on the street.	2.5	4.7

Q #	Difficulty of Transit Tasks	Regular Method	With RIAS
11	Getting enough suitable information about an unfamiliar transit terminal or building so that you could make an unaided trip.	2.6	4.7
12	Finding the proper bus.	2.6	4.9
13	Knowing what street corner I am at when in an unfamiliar area.	2.7	5.0
14	Transferring to another bus on the line.	2.8	4.7
15	Realizing I am lost while traveling and don't know which street corner I am at.	2.8	4.9
16	Getting enough suitable information about transit boarding locations on an unfamiliar transit route so that you could make an unaided trip.	2.9	4.7
17	Finding the entrance and the platform for a street level Muni platform.	2.9	4.8
18	Finding which side of the platform to wait at for the proper train.	2.9	4.9
19	Finding the door to a train at an unfamiliar platform.	3.2	4.9
20	Crossing a busy street in an unfamiliar area.	3.2	4.8
21	Getting enough suitable information about an unfamiliar transit route so that you could make an unaided trip.	3.3	4.4
22	Keeping my mental map continually updated so that I know which block or crossing I am at while traveling.	3.5	4.9
23	Determining the traffic flow and intersection type in order to safely cross at an unfamiliar street intersection.	3.7	4.8
24	Preplanning and remembering instructions, directions and routes for an unfamiliar area so that you can make an unaided transit trip.	3.9	4.7
25	Finding a bus door safely and quickly for easy boarding.	4.0	5.0
26	Finding the door to a Muni train.	4.1	4.9
	Average Rating of Task Difficulty	**2.87**	**4.76**

No matter what their original rating, degree of experience, or vision, all 30 subjects rated the overall difficulty of all these tasks as much less within a RIAS environment. Many people changed their rating from "extremely difficult" to "not at all" or "somewhat difficult" after using the RIAS. Average ratings for the degree of difficulty for each of these tasks with RIAS were between "somewhat difficult" and "not at all difficult." Only one task had a score that leaned more toward the "somewhat difficult" rating with a 4.4 average score, and that had to do with getting enough suitable information about an unfamiliar transit route. Two tasks were midway between "somewhat difficult" and "not at all difficult." The other 23 tasks were rated closer to "not at all difficult" with ten tasks (38%) rated 4.9 or 5.0. This type of support for additional cues and the poor ratings using their current methods shows that there are many problems with transit use by the blind, and that location-based audible signage does a superb job in leveling the playing field for this population.

The second question demands closer scrutiny. It asked subjects how they felt about "having the same access and ease of use of transit and public buildings as enjoyed by the general public." This is basically what the Americans with Disabilities Act mandates for public buildings and transit. In the preliminary interview, they rated this task at a rank of 2.3 (close to "very difficult."), the second worst rating. After using the RIAS system for an hour or so, these same people said that, with the additional cues, they would rank the difficulty at 4.6, closest to the "not at all difficult" rating. All the data from these tests point to these conclusions, but here it is from the subjects themselves. They are not getting the accommodations needed for independent travel and access. Many other transit tasks were rated as becoming more than one or two categories easier when using RIAS. These data show many of the specific areas that affect travel for the blind and vision-impaired. Figure 3.12 displays the large magnitude in the reduction of difficulty perceived for these various tasks.

Figure 3.12 Difficulty of Transit Tasks



Difficulty ratings:	Not at all Difficult (5)	Somewhat Difficult (4)	Difficult (3)	Very Difficult (2)

3.3. Qualitative Analysis of User Opinion Data

The next set of questions shed light on how these difficulties affect everyday travel behavior for this population. This section examines subjects' responses to a series of open-ended question used to elicit information that can add to the results obtained from the previous, more structured, questions and the field experiment.

3.3.1. <u>General Transportation Problems</u>

During the pre-test interview, before subjects had used the RIAS system, they were asked questions about problems that occurred when using transportation and then, more explicitly, when making transfers. Subjects were asked to "List any transportation problems that restrict your choices for employment or job search" (for all subjects' comments, see APPENDIX 10: Transit Problems That Restrict Employment)**.**

3.3.1.1. Sample of Comments

- "Limited service hours & weekends, limited service areas, expensive cabs, transit not close, too much time, long walks."
- "Having to transfer buses, expensive cab rides, unsure when transferring."
- "Lack of service, info is hard to get, not easy to make connections."
- "Transit is a disadvantage, limited area, slow service, unsafe street crossings."

3.3.1.2. Categorization of Responses

Subjects' responses were broken down by individual statements and parsed to yield a list of single responses. These responses were sorted alphabetically and naturally occurring categories, those with many similar or identical responses, were identified (for category analysis, see APPENDIX 11: Categorization of Transportation Problems).

Table 3.2 Transit Problems That Restrict Employment

"List any transportation problems that restrict your choices for employment or job search"

Category	25 subjects
Limited service	29
Excess time	11
Lack of information	8
Transfer problems	5
Safety	2
Misc.	5

Only 25 subjects answered the question, with the other five subjects indicating they had no problems with transportation that affected their employment opportunities By far the most common problem indicated was "limited service," with 29 responses. This category included comments about limited service areas, frequency of vehicles, limited hours (especially on weekends and late at night), work destinations having to be close to transit, and that it was hard to travel long distances because various transit agencies and routes are not connected.

Excessive travel times were mentioned 11 times. This category included comments about slow travel times, long waits, and other time constraints. Lack of information was mentioned eight times. These included comments about drivers not announcing stops, finding buses and bus stops, and, in general, a lack of personal spatial orientation and other identifying information.

Transfer problems were mentioned five times. This category included comments about problems while making transfers and the uncertainty and difficulty inherent in transfer tasks. Comments about safety were made twice. One subject mentioned unsafe street crossing, and another mentioned having had an accident.

There were five comments that did not fall easily into any category. Two people mentioned "expensive cab rides," and another mentioned "poor driver attitudes." Two more general statements were "transit is a disadvantage" and "not reliable."

There was evidence of an order effect for this question. It was asked before any other discussion of transit difficulties for blind people. The comments were about limited hours and service and inconvenience. Few comments were made that would not also be made by the general transit-dependent population. For this question, subjects did not mention problems caused by their lack of vision, but dealt with problems of a fixed route transit system. Later on, as the questions got more specific, they opened up and talked about problems caused by lack of vision.

3.3.2. <u>Problems with Transit Mode Transfers</u>

During the pre-test interview, questions were asked about problems when making transfers between transit modes. Subjects were asked, "Are there any specific problems with transferring between different transit modes which restrict your choice of employment or job search?" (for all subjects' comments, see APPENDIX 12: Transfer Problems That Restrict Employment).

3.3.2.1. Sample of Comments

- "Time constraints, have to learn many systems, don't know where stops and transfer points are, stations not built alike, can make mistakes, time problems, requites research and preplanning."
- "Use 3 modes for work, no unified pass, don't know where stops or modes are, have to know many time schedules, no unified transit information, many calls needed, hard to get info on stops, street #, crossing, buildings."
- "Connection time problems, long waits, knowing which bus to take, stations not accessible, can't read signs and directions."
- "Finding bus stops and bus #'s, drivers don't call stops, finding ticket machine, find fare gate."

3.3.2.2. Categorization of Responses

Subjects' responses were broken down by individual statements and parsed to yield a list of single responses. These responses were sorted alphabetically, and naturally occurring categories, those with many similar or identical responses, were identified (for category analysis, see APPENDIX 13: Categorization of Transfer Problems).

Table 3.3 Transfer Problems That Restrict Employment

"Are there any specific problems with transferring between different transit modes that restrict your choice of employment or job search?"

Category	23 subjects
Problems with identity or spatial information	56
System problems	24
Poor signage	6
Safety problems	2
Misc.	2

Only 23 subjects answered the question, with seven subjects indicating that they had no problems with making transfers that affected their employment opportunities. This question asked subjects to think about "transferring between different transit modes." This question appeared to cause subjects to think beyond their previous answers that mostly criticized the transit system itself and to start to deal with problems caused by their lack of vision.

By far the most common problem indicated was "problems with identity or spatial information." Subjects made 56 comments that fit this category. They included general statements about lack of information and making connections to more specific comments about the difficulties in finding, buses, bus stops, fare machines, gates, and other amenities. They also mentioned how they "did not know" where many of the transit locations were. They also mentioned how hard it was to get help about the system. These subjects' responses confirm the basic premise that the blind and vision-impaired lack access to information, especially spatial information that restricts their use of transit and, therefore, restricts their ability to travel independently and to take advantage of urban opportunities.

Problems with the transit system were mentioned 24 times. These comments included concerns about long wait times, limited hours and service areas, and other time constraints. They also mentioned stations not being accessible or standardized.

Poor signage was mentioned six times. These comments could have been included in either of the first two categories, but it is treated separately here, because signage for the blind has been largely ignored. These responses were from those who had some limited vision. After they had used RIAS (see sections 3.4.2, 3.4.3, 3.4.4), the problem of signage became apparent even to those with no vision.

Comments about safety issues were made two times: one subject mentioned unsafe street crossings and another mentioned that bus transfer points were unsafe. There were two comments that were not categorized. One mentioned that mistakes can be made, and another mentioned how advance trips had to be made in order to understand the system before it can be effectively used. These could have fit into several of the categories like poor signage or problems with spatial information.

The results of these two questions shed some light on problems facing the vision-impaired traveler. Subjects mentioned many of the same problems of transit that are inherent in any fixed-route transit system, such as inadequate or restricted service areas, long waits between vehicles, long walks or expensive rides to a transit stop, inadequate signage, and the confusion of multiple systems. In addition, they mentioned specific problems relating to their lack of vision, such as having trouble finding locations and the difficulty of finding information and assistance. These vision-related difficulties and their possible mitigation by the use of RIAS are examined in depth in the next section.

3.4. Subject Observations on the Benefits of RIAS

Subjects also answered open-ended questions that elicited any differences between their regular method of travel and their opinion of travel behavior when using RIAS in a rich and robust environment such as they experienced in the test area. After having just completed rigorous transit and transfer simulations, all subjects offered a wide range of opinions. There was no limit on the time to answer the five open-ended questions.

These comments strongly indicate the potential for RIAS to increase independent and safe travel with much less stress and difficulty for those with visual impairments. In addition, they offer insight into the mind-set of this population. Blind and vision-impaired people often avoid making negative comments about the difficulties they face living in a sighted world (see responses in Section 3.3.1General Transportation

Problems). It is therefore hard to understand the difficulties of navigation without sight because of this mind-set. It might even be true that congenitally blind people do not really understand what vision is like and so may not be aware of what is truly different about their world.

RIAS offers positive identification and directional cues to spatial environments that can substitute for some of those given by vision, and the results of these following opinions reveal how this new knowledge radically changed the opinions of these subjects regarding travel behavior. After using RIAS, they had a new knowledge of how to access their environment, even in a novel setting. For example, in pre-test interviews, no person mentioned that having to ask for help while traveling was a problem or concern. However, after using RIAS, every person mentioned it as an improvement to their regular method. These data should be viewed on two levels: (i) the value of RIAS to enhance travel and quality of life, and (ii) what their answers reveal about the restrictions and difficulties endured by those without sight in the present state of affairs. By extrapolation, one can see that a positive statement made about RIAS is also a negative statement about their current situation.

3.4.1. Categorization of Responses

For the five opinion questions, all subjects' responses were broken down by individual statements and parsed to yield a list of single responses. These responses were sorted alphabetically, and naturally occurring categories, those with many similar or identical responses, were identified.

3.4.2. Street Crossings

Fear and uncertainty at street crossings can create a barrier to travel for this population. There are many anecdotal stories about people avoiding entire areas of their environment because of difficulties at crossings. People without vision receive much training from their O&M instructors on this important skill. Without this skill, some people do not leave their homes or they might lead a very dependent life with little personal freedom.

At street crossings, two RIAS transmitters are used. One beam gave an indication of the WALK and WAIT signal, and also provided a directional beam across the intersection. In addition, another beam gave information about which street subjects were on, which direction they were facing, the block #, and the name of the cross street they were approaching. Information about transit locations across the street and the presence of a push button for the pedestrian signal were also available. Although not provided at this installation, information can also be given about safety islands and turn-lane (or any other pertinent information) on this second beam.

The first question in this series was: "Think about the street crossings we just made. What was different from your regular method when using Talking Signs(R)?" (For all subjects' comments, see APPENDIX 14: Comments about Street Crossing Differences).

3.4.2.1. Sample of Comments

- "Got info on walk signs, don't have to listen & wait for cycle, much faster, know block #, direction I'm facing, street names, knew when not to go, more secure, gives additional info."
- "Extra tool for alignment, know when to start, don't have to pause, know there is a push button, saves search time for button, gives directional info, gives cardinal direction, can fill in visual map in my mind."
- "Follow beam when walk sign comes on, with regular method couldn't hear traffic, safer, knew direction, block #, didn't have to search, no ask, knew to only cross 2 lanes for Muni, gave me info without learning."
- "Incredible difference, wouldn't have to wait for passers-by to ask, didn't have to assume they spoke English, got positive ID, timely info, able to align myself, not distracted crossing street, easy to find push button, knew when to safely walk."

3.4.2.2. User's Response Categories

Subjects' responses were broken down by individual statements and parsed to yield a list of single responses. These responses were sorted alphabetically and naturally occurring categories, those with many similar or identical responses, were identified. (For category analyses, see APPENDIX 15: Categorization of Street Crossing Differences).

Table 3.4 Effect of RIAS at Street Crossings

"Think about the street crossings we just made. What was different from your regular method when using Talking Signs(R)?"

Category	30 subjects
Confirms walk signal	35
Increased spatial orientation	22
Confirms direction	17
Confirms crosswalk alignment	16
Identifies street names	13
Identifies block number	11
General efficiency	10
Gives more independence, assurance	9
Confirms presence of push buttons	8
Identifies intersection & lanes	5

All subjects offered positive opinions on this question. There were a total of 146 comments. The categories reflect each of the types of messages given by RIAS at the street crossing, in addition to some general statements.

The 30 subjects offered 35 comments about how the system confirmed the WALK signal. They said they knew when to walk or start and commented on how it was faster, safer, and easier to know when to cross the street.

General statements about the increase in spatial orientation were made 22 times. They reported learning what was around them, how the system gave them additional information and positive identification, and how they learned needed spatial information. One subject reported that he could "fill in a visual map in my mind."

Except for the presence of a hot sun shining on a person, there is little way for a blind person to know objectively the cardinal direction one is facing. This fact was reflected by the 17 people who made comments on how the RIAS gave them cardinal direction information when they were walking, or where they were facing.

Similarly, 16 people mentioned that the system confirmed crosswalk alignment. RIAS gives a directional beam across to the opposite corner, and, as long as a person stays in that beam, they will arrive at the correct destination instead of possibly being outside of the crosswalk zone. Subjects' comments mentioned how the system gave them a beam to follow across the street, how it helped them to align for the walk, and that they did not veer when crossing. This constant feedback of correct alignment is something that no other intersection system offers to the blind user. The positive influence of RIAS is strongly confirmed by the number of these comments.

Positive street name identification remains a mystery to most blind travelers. RIAS gives the name of the street being walked and also the upcoming intersection. Subjects made 13 comments about how RIAS identified street names.

Another 11 comments were made to the effect that RIAS identified block numbers of the street. This information is sometimes on street signs, but usually one has to be able to read a nearby building number.

Ten comments were made that were categorized as “general efficiency.” Subjects mentioned that they didn’t have to count blocks, deduce, or remember information. They also commented that travel was faster, safer, and more secure, and one subject said there was an “incredible difference.”

A possible subset of “general efficiency” is a group categorized as “gives more independence and assurance” with nine comments. Subjects specifically mentioned that they wouldn’t have to ask for help, that they felt more independent and wouldn't't’ have to wait for, and rely on, other people, and that they had more confidence and assurance.

A blind person has no way to know, without a tactile search, if a traffic signal push button exists or where it is. Eight people specifically mentioned that RIAS confirms the presence of push buttons. They reported that this information saved search time.

Urban areas can have very confusing and diverse intersections, traffic patterns, and turn lanes. Another four comments were made about how RIAS helped identify street intersection types, traffic flow and change, and the number of lanes.

Subjects used the WALK signal and directional beam four times in the experiment; the other street information was only available two times, and many subjects did not use it in their tasks. The subjects commented on every message type that the system offered. They realized that information about the WALK signal, the direction across the street, the type of intersection and number of lanes, the identification of street names, block numbers, cardinal direction, and push button locations was a vast improvement over their regular method. The vision-impaired participants praised the amount of additional spatial information about the environment and the increased independence, safety, and efficiency of travel available to them when using RIAS.

3.4.3. Navigating the Terminal

Navigating around a new or even familiar terminal can be quite a daunting task. Finding gates and boarding areas can be confusing, and gaining access to amenities can leave the best blind traveler frustrated and tired. A typical trip to a terminal would entail finding the entrance, a ticket machine or window, locating any amenities needed, such as bathrooms or food stands, and then finding the right track, gate or boarding area. As with crossing busy streets, this is another of the many tasks that can be so difficult that some blind people will not dare try to explore and use a new terminal, especially with normal time constraints. Other people might require the use of a sighted guide to teach them the paths necessary to accomplish the tasks.

To better understand problems of navigating terminals and the effect of using RIAS, subjects were asked: "Think about finding various features in the terminal. What was different from your regular method when using Talking Signs(R)?" (For all subjects' comments see APPENDIX 16: Comments about Terminal Differences).

3.4.3.1. Sample of Comments

- "Didn't have to ask, independent, didn't have to feel dirty walls & counters, knew where I was & where I was going, able to find platform, locations, spatial relationships, can make shortcuts, can find landmarks without going there, learned what was sold even though not looking for it, able to quickly locate & use amenities"

- "Easy, not frustrating, makes things do-able, had a clear spatial orientation, learn more than from O&M training, more detailed spatial orientation, got specific info, didn't have to grope, could tell things from a distance, easy to line up and go to it, veering was easy to fix, didn't have to re-orient, didn't have to ask, knew I could do it with ease."

- "Concentrate on hazard & safety instead of spatial configuration & orientation, shorter distance, quicker travel, would have had to ask for help, was not distracted by noise & movement, more focus, knew which direction I was to go, learn more detail, found things I didn't know, explains layout."

- "Much quicker to get idea where things are, much quicker to find out what is around you, gives spatial info, helps emotionally when I can know what's around, makes it fun to go out & explore, "it's the difference between a walk in the park & a walk on a treadmill facing a wall", can go right to track or location rather than counting, don't have to search for landmarks, don't have to ask, independent."

3.4.3.2. User's response categories

Subjects' responses were broken down by individual statements and parsed to yield a list of single responses. These responses were sorted alphabetically and naturally occurring categories, those with many similar or identical responses, were identified. (For category analyses see APPENDIX 17: Categorization of Terminal Differences).

Table 3.5 Effect of RIAS at Transit Terminal

"Think about finding various features in the terminal. What was different from your regular method when using Talking Signs(R)?"

Category	30 subjects
Positive identification of locations	46
Increased knowledge of spatial relationships	40
Increased independence, no asking	39
Better mental state	30
Gave direct path to locations	9
Don't have to count or feel	8
Discovery of new locations	5

All subjects offered opinions favoring RIAS on this question. There were a total of 177 comments. The categories reflect a comprehensive view of the benefits of RIAS in aiding blind travel through positive identification and spatial direction and the resultant change in attitude.

The 30 subjects offered 46 comments about how the system offered positive identification of locations. In addition, they listed a wide range of specific locations they could find easily at the terminal, they noted that it told them where to go, and they made comments about the instant access and feedback to information they received. One said that it was like "looking around" and another reported, "I can point and get info instead of someone else moving my hand with no logical sequence."

Another 40 comments specifically mentioned the increase in spatial orientation they received from the system. They mentioned increased knowledge of the environment and in their mental maps of the area. They remarked on how they could explore better with the increased knowledge of orientation and layouts, and that they could make shortcuts because of this knowledge. They also mentioned they didn't have to memorize, accumulate knowledge, re-orient, or shoreline to successfully navigate a terminal.

Increased independence or not having to ask for help formed a category with 39 comments. The problem of having to find people for help is highlighted by 28 comments saying they didn't "have to ask". Others mentioned not having to find people, and how they avoided getting bad directions from others. Another eight comments were made using the word "independent" or mentioning not having to use a sighted guide.

Some comments dealt more with positive mental attitudes resulting from using the system and its increased information. A category for "better mental state" had 30 comments. Some remarks included comments about faster and easier search times, increased safety, confidence, and less worry. One commented that RIAS "helps emotionally when I can know what's around." Another said it "makes it fun to go out and explore" and a third made a special request that, when sighted people are told about the benefits of RIAS, to report that "it's the difference between a walk in the park or a walk on a treadmill facing a wall"

In addition to the 46 comments about positive identification of locations and the 40 comments about increased spatial orientation, there were an additional nine comments made about getting a direct path of travel to locations. These comments highlighted the directional aspect of the RIAS, i.e., that it leads them directly to objects.

Another eight comments were categorized as “don’t have to count or feel.” This is also part of the increased spatial orientation available to RIAS users, but they were kept separate because this reflects the problems of blind orientation and shows another benefit of the system. People don’t have to count doors or feel around what are often dirty areas to find cues to aid orientation or identification.

Altogether, there were 103 comments by 30 subjects that related to general spatial orientation, positive identification of locations, and the direct path information that was afforded by this system. It is easy to see how sparse this information is when using regular methods of blind orientation and travel.

Blind travelers might spend their mental energies searching for and finding only locations that are needed to accomplish their tasks. With typical vision, a person’s knowledge base, spatial awareness, and cognitive map are constantly updated; even non-essential or low utility information (to that person for solving the immediate travel problem at hand) is learned and stored. A sighted person can easily learn spatial locations that they are not looking for, but this serendipitous type of spatial learning is usually not part of a blind person's activity, unless they practically run into something they are not searching for. Throughout the experiment, many subjects mentioned how they found things they weren't looking for, and, on these open-ended question, people specifically mentioned that they found objects or locations they weren't looking for. This is another benefit of receiving cues from distal objects, and learning their identity without taking time to investigate each location. Learning about the surroundings while making a direct path from A to B greatly expands the spatial information and configuration knowledge for people with little or no vision.

With 177 positive comments from 30 subjects about the use of RIAS in a transit terminal environment, there can be little doubt that the system aids mobility, spatial orientation, navigation, and successful trip making abilities while decreasing stress and greatly increasing the independence of the blind user.

3.4.4. <u>Making Transfers</u>

Making transfers between routes, and especially between different modes often run by different agencies with different rules and fares, can be quite challenging for even the sighted traveler. Without visual cues, transferring can be so difficult that those types of trips might be avoided or require lengthy practice and training to be accomplished. People must learn each location they wish to use; there is little consistency between locations, and so it is quite difficult to transfer knowledge from one transit area to other locations. This greatly affects the ability of some blind people to independently explore a system or make transfers at any but those place where they have had training, limiting their access to restricted locations and routes. Without external cues, unfamiliar locations are still "terra incognitae." When no external cues reach the blind traveler, that person must take bodily action to maintain physical contact with the environment (Millar, 1981). However, vision can actively focus attention on distal cues and they can be used as landmarks, even if they are never used as destinations (von Senden, 1960).

To better understand problems encountered when making modal transfers, the experiment simulated five such transfers. At the end of the experiment, subjects were asked to "Think about the transfers we made between different modes of transit. What was different from your regular method when using Talking Signs(R)?" (For all subjects' comments, see APPENDIX 18: Comments about Transfer Differences).

3.4.4.1. Sample of Comments

- "I could easily find modes on my own, didn't have to ask & hope it's right, felt secure to do it, able to find various locations in a timely manner, wouldn't miss connections, didn't have to ask, felt independent, would not have done it on my own, assured of correct info, wouldn't have known where cab stand was, didn't have to get escort, knew where bus was located would not have known, learned that phones were in bus shelters."

- “When you ask people for directions you can get close enough to use TS, didn't have to ask many people, opens up the world to independent travel, can find exact locations, don't have to guess, ID's bus stop. ID's where you are, know exact pole or gate to wait at, no missed connections, ID's bus #'s that stop”

- “Can expand your usage of different modes, knew direction, street names, what was on other side (of street), more beneficial, told me what bus stops at platform, saves much time, saves agony & frustration.”

- “Usually waste SO much time, TS helped me navigate quicker, can go to unfamiliar areas & navigate efficiently, TS helps make travel & transfers quickly & safely, don't have to ask, or deal with strangers, feel more independent, self-sufficient.”

- “Told me where fare machine was, bus was, knew which way to go, help find taxi, knew which direction to leave station, knew exactly where bus stop is, which bus stops there, saves time, don't wander around, feel at ease, secure, had fun, makes travel simpler.”

3.4.4.2. User’s response categories

Subjects’ responses were broken down by individual statements and parsed to yield a list of single responses. These responses were sorted alphabetically and naturally occurring categories, those with many similar or identical responses, were identified. (For a listing of how the parsed responses were categorized, see APPENDIX 19: Categorization of Transfer Differences).

Table 3.6 Effect of RIAS on Making Transit Transfers

"Think about the transfers we made between different modes of transit. What was different from your regular method when using Talking Signs(R)?"

Category	30 subjects
More efficient travel	35
Increases independence	27
Identifies locations, general information	25
Improves mental state	24
Identifies locations, bus stop	22
Identifies locations, doors and platforms	12
Spatial information, directions	10
Identifies locations, fare machine	8
Increases spatial orientation	5
Identifies locations, taxi stand	4
Identifies locations, street names	2
Identifies locations, phone	2

All subjects offered opinions concerning Talking Signs' ability to provide distal cues, with 176 comments. The categories reflect a comprehensive view of the difficulties faced when making transfers in a timely manner. They point out specific areas where RIAS greatly increases spatial knowledge and orientation and how this increased knowledge leads to more efficient travel and a more relaxed state of mind.

A total of 75 comments were made indicating that RIAS helped identify locations. Statements about identification and knowledge of a general nature were made 25 times. Subjects mentioned how the system gave positive identification and how one can know for sure and get information from a distance. Another 22 comments were made specifically about how RIAS helped find and identify bus stops. Positive identification of doors, and train and subway platforms, were mentioned 12 times. Fare machines can often be hard to identify and locate and eight people said that RIAS helped them find those locations. Four people mentioned locating and identifying taxi stands, phones were mentioned two times, and two people mentioned the identification of street names.

The belief that RIAS would lead to more efficient travel was stated 35 times. Comments were made about travel being faster and easier and they would not wander around or miss locations. They could expand their use of transit and make transfers more often, and they would not miss connections if the systems were installed.

Increased independence and not having to ask for help were mentioned 27 times. Not having to ask was mentioned specifically 13 times, the word independent was used seven times, and the rest mentioned that they didn't have to wait for people, get help, and that they could travel on their own. People don't like to complain about being dependent or having to ask for help, and these data show again that this is something they do not like or want to do, and that the availability of distal environmental cues frees them from reliance on other people and greatly increases their independence.

In addition to the comments about independence, subjects made 24 statements that were classified as "improves mental state." They spoke of confidence and self-assurance, being more at ease, and not having to guess. They mentioned feeling more secure, safe and comfortable, and having less stress and frustration. One person said, "felt equal to sighted people," another said, "felt worthwhile." "Hell of a lot easier" and "saves agony and frustration" are other comments that reflect on this category. Little has been researched on the effects of stress and frustration on blind travelers, but these data show the mental anguish that can stem from blind navigation.

Ten people mentioned knowing for sure which direction to travel. They commented on being able to know cardinal directions, how the system helped them know which way to go, and how the system gave them information about vehicle travel direction.

Spatial orientation was mentioned five times. These people remarked that RIAS gave them better mental maps, good spatial layout or orientation, and that the system gave them relationships and helped define areas.

3.4.5. Summary of Subjects' Comments

Table 3.7 Summary of Comments from 3 Open Ended Questions

	Street	Terminal	Transfers	Total
Tasks and locations	127	100	90	317
Trip behavior	10	0	35	45
Improved mental attitude	9	77	51	137
Total	146	177	176	499

The three previous questions asked people to explain the difference when using RIAS during three tasks. Most (317) of the responses dealt with specific tasks and location that were made easier to access, 45 comments were made dealing with improvements to trip behavior in general and 137 comments dealt with the improvement in affective states and attitudes. There were no negative or neutral comments made out of almost 500 comments. The high number of responses, over 5 comments per person, demonstrated the enthusiasm of these travelers for enhanced environmental cues.

3.4.6. User Suggestion for Installation at Other Location

In the earlier Santa Barbara experiment, the RIAS was installed only on buses, bus stops, and at the small terminal. Comments were invited about other locations subjects would like to see RIAS installed. Only a summary of those comments was offered in that report (Marston & Golledge, 1998b), the data were later more fully analyzed and are presented here. Subjects were allowed to list as many places as they wanted. A total of 163 locations were given. It should be noted that this question was asked soon after they had answered a series of structured questions about the use of Talking Signs® in the transit environment and at street crossings.

This question showed the value of open-ended questions, as some responses were given that the researchers had not considered. One blind subject who often rides in cars 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, six people used that term and others said things such as "all over" and "world-wide." On a smaller geographic area, nine suggestions were placed in a category "Multi-purpose / 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 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 RIAS at street corners and intersections were made 16 times. Transit, including buses, airports, and transit stations was mentioned 23 times. Seven people suggested using RIAS to label amenities or provide information such as to the location of restrooms, public phones, building directories, and information kiosks.

The suggestions show the extent to which blind and vision-impaired people have difficulty using the urban environment and its services. Their agreement on large areas such as malls, public buildings, stores, and offices indicates how difficult access can be in these areas. 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.

3.5. Modeling Impedance of Different Transit Tasks

In this section, the field test data are examined in the light of how the environment and the placement of locations and their cues affect the blind traveler. Kevin Lynch, in his seminal work "The Image of the City" (1960) used the term "legibility" to explain how certain parts of a city had features that led to a greater knowledge and awareness of feature locations and spatial interaction with other parts of the city. This section will show that "legibility" can also be applied to various locations and transit tasks in and around a transit terminal.

3.5.1. Accessibility of Grouped Tasks and Locations

In a previous section on the field tests, each of the test destination locations were examined, and the kinds of cues they provided were discussed. It was also noted if their spatial placement could be considered as part of the typical layout of locations in an environment, thus aiding accessibility to them, or, conversely, if their inconsistencies exacerbated the difficulty of locating them. This section will examine these different types of location categories and then propose a model to estimate the time penalties faced by blind people in other environments. The effect that RIAS has on these locations will also be modeled. This will allow planners and O&M instructors to better understand the major barriers to successful independent travel for this group and how providing basic spatial information such as directional and identity cues can mitigate these problems.

Previously, *time penalties* faced by the vision-impaired were examined, using all 30 of the subjects while they made their first attempt in the test environment. Some of those subjects reported sufficient residual vision to potentially introduce error and noise into the models. To increase validity, this section and the models that follow use only those 20 subjects that had no useful vision. These subjects reported they could not see shapes or objects at all, and so the variance caused by residual eyesight can be eliminated. There were 11 such subjects who used their regular aids first and nine such subjects who used *RIAS* first. As with the travel time data for the 30 subjects, times to find the correct locations were compared to the "optimal" time based upon the familiar sighted user's (FSU) travel time to determine the extra time it took to perform these tasks without vision. This time penalty, caused by the lack of visual cues, can also be formulated to obtain a measure of "relative" access as compared to absolute access. People who use wheelchairs can face physical barriers, which, in some cases, deny absolute access to a location. Situations exist that also block some blind people from completing or even starting travel, such as difficult intersections or especially, travel in a new environment. For blind and vision-impaired people, the barriers they face are more of a **functional** rather than an absolute **physical** nature, and with training and familiarity they might gain access. However, the travel times are often much longer for the vision-impaired, and this can be termed a matter of *relative accessibility.* They do have access to locations and opportunities, but the extra time spent searching and traveling can decrease the number and types of activities they can perform in a given time frame. Building on Equation 1 on page 94, a frequency variable is added.

Equation 2 $$R_{iklm} = \frac{f_k d_{ikl}}{f_k d_{ikm}} - 1.0$$

Where:

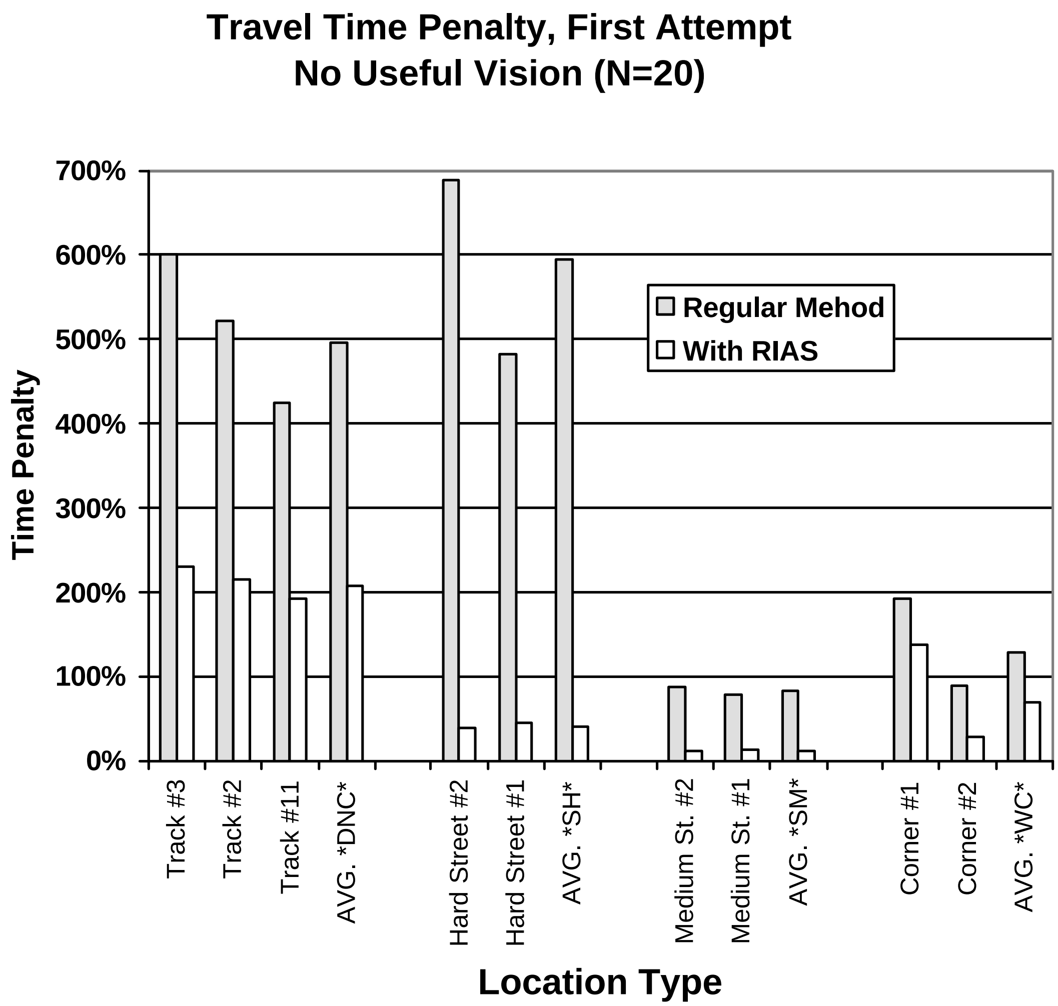
- f_{ikl} = the frequency of each type of activity
- d_{ikl} is the time or distance from i to the desired location that offers activity k to serve a person at i with access type l.
- R_{iklm} = relative accessibility of activity k from location i for person type l relative to person of type m.

In its typical use, this formulation can be used to compare relative access for multiple trips to the same or similar activity. An office worker might make three trips to the copy room each day and if that person faced travel restrictions or barriers, compared to a typical user, the time penalties would increase as the number, or frequency, of identical trips, from i to k, increased. A modified and relaxed formulation is used here to measure trips to an activity k, from the previous location i. For example, the subjects went to three different doors for the train boarding area, from different starting points. By adding those trip penalties, an average time penalty for finding an unmarked gate door can be revealed. The next section deals with measuring the relative access for various types of locations or activities. Later, a combined relative access measure that sums up this measure for all the various activities will be given.

3.5.1.1. Access Problems for Specific Tasks

The first four location types examined included nine of the 20 test destinations. Figure 3.12 shows these nine locations grouped into the four specific types. The averages for each group are also shown, representing the frequency of each type of activity. Later, the other 11 locations that had a wide range of non-visual cues available to the blind traveler are examined.

Figure 3.13 Travel Time Penalty for Four Specific Types of Tasks



3.5.1.1.1. <u>Track door</u>

Subjects started the experiment with their back at an unnamed track door, and it was explained to them that all the trains came in from behind them. Therefore, they were aware of the spatial arrangement of all track doors being located only at the back wall of the terminal. The doors to the train boarding area were not marked with Braille or any raised or tactile information. Because of this, there was no way for blind subjects to identify the proper door. Even when they found a door, they had no way to know if that was the correct door or if they should go to their left or right to continue their search. If they did not ask for help, there was little possibility that a totally blind individual could find the proper location. This task was also rated as the most difficult from the 26 transit tasks shown in Table 3.1. The difficulty of this task was also evident from the travel time data collected as subjects visited 3 different doors during the experiment. The extra time needed to find these 3 different unlabeled doors was quite similar, and the mean time penalty was 496% more than the FSU. The use of RIAS lowered this penalty to 208%. These penalties could be applied to other unlabelled doors that have some order but offer no other cues to their identity. These locations will be referred to as “Door, No Cues” or DNC.

3.5.1.1.2. Hard Street Crossings

Blind people are given training on crossing streets, and these locations certainly offer many non-visual cues. However, as the experiment showed, some streets are just too dangerous for them to cross because of high-speed traffic and complicated traffic flows, such as turn lane cycles. Subjects crossed to the mid-street transit platform (King St.) twice in the experiment, and both directions were categorized as very difficult or hard. Some subjects refused to cross the 2 lanes to the platform on their own, and others had to wait through several cycles of the light to understand the traffic flow. Crossing this street in both directions had a mean time penalty of 595%, while with RIAS the extra time was only 41% more than a sighted pedestrian. These locations are referred to as "Street, Hard Difficulty" or SH.

3.5.1.1.3. Medium Difficulty Street Crossing

Crossing 4th Street was much different than crossing King Street. It was a congested city block with many cars and cabs stopped at the terminal and had slow traffic. Therefore, there were many audible cues to the traffic and turn cycle and much less danger from high-speed traffic. Orientation and Mobility instruction and the subjects' training are well represented in this task. Subjects who used their regular aids and skills were able to cross this street in both directions with a mean time of 82% more than the FSU. With RIAS, subjects were able to cross the streets with only 12% more time than the FSU. This measure was labeled "Street, Medium Difficulty" or SM. An easy street might be one with little traffic and stops signs.

3.5.1.1.4. Walking to a Street Corner

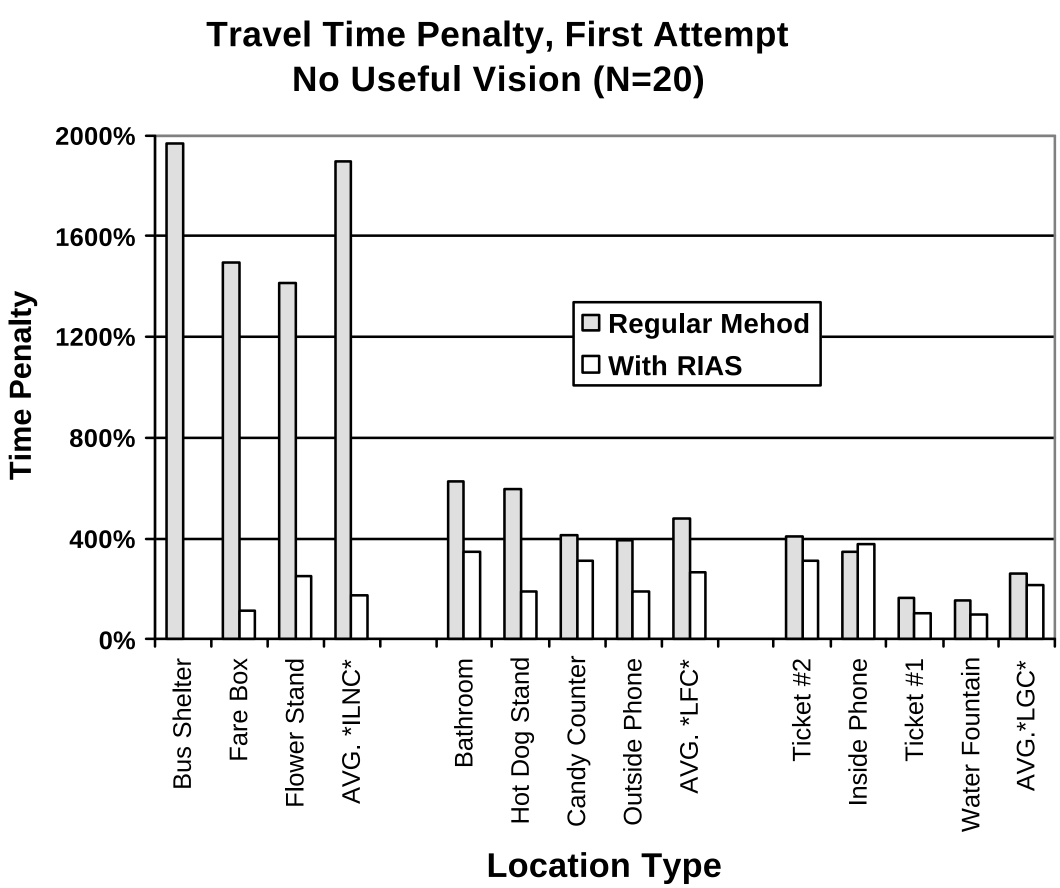
Twice in the experiment, subjects walked to a street corner. There are many non-visual cues to help identify a busy intersection. Orientation and Mobility instructors also spend much time teaching these skills, and their efforts are well documented here by these results. Subjects used dogs, their cane, and traffic noise to identify the street and its intersection. Both of these walks were at a significant distance from the start point, but, as Figure 3.13 shows, this was not a difficult task for this group. The mean extra time for the people using their regular aids and skills was 128% more than the FSU, and when they used RIAS they got there with only 69% more time. This location measure is referred to as “Walk to Corner” or WC.

For these four specific locations, it can be seen how difficult it is to find unlabeled doors and how RIAS reduces the needless search time to collect this information. Crossing a difficult street can be such a barrier that one failed or stressful crossing may cause a trip to be abandoned. While the blind subjects did quite well crossing the medium difficulty street, the use of RIAS in both of these street crossing tasks took away the uncertainty and stress of learning an intersection’s traffic flow, signal cycle, and other idiosyncrasies. Without full attention to all these cues, any street crossing can lead to injury or even death. It is no wonder that many blind people do not travel independently to new areas. The task of walking to a corner was not too difficult for this group, but, again, RIAS helped speed up this process, especially in finding their way out of the building and to the sidewalk.

3.5.1.2. Location Types Based on the Availability of Non-Visual Cues.

The other 11 locations were not so easily categorized as to specific types of locations. They were grouped using the “legibility” (how easy they are to understand and locate, see Lynch, 1960), or “rationality” of their placement, as well as whether or not other cues were available to inform the blind population. For example, it is usually a good spatial search heuristic or tactic to assume that the bathroom for one sex is near that for the other. Ticket sales are usually in a high-traffic, central area near the entrance to a terminal or near the tracks. Other locations, however, have no 'standardized" or rational legibility. They might have non-visual cues such as smells or distinctive sounds that might be heard (for example, one might hear coins at a vending machine or people using a phone or buying a ticket). Air currents and temperature or light intensity changes can signal doorways and openings. Other locations offer little in the way of cues to their existence. Figure 3.14 shows the time penalty for subjects with no useful vision on their first attempt for the other 11 tasks.

Figure 3.14 Travel Time Penalty for Cue-based Location Tasks



3.5.1.2.1. Random or Inconsistent Amenity Placement with No Cues

The two hardest locations to find were also directly necessary for successful transit and transfer use. Inconsistent placement and no cues made the bus stop and the Light Rail fare machine almost invisible to the blind person trying to use these modes. These two locations highlight the lack of access to needed information to effectively use transit.

Finding a bus stop is one of the hardest tasks for blind travelers. Indeed, subjects rated it as one of the most difficult tasks (see Table 3.1 Ratings of Transit Task Difficulty) and research by Crandall, et al. (1996), Bentzen, et al. (1999), and Golledge & Marston (1999), confirms this, using other field tests. In fact, not one of the 15 subjects in the experiment reported by Crandall and Bentzen was able to find a bus pole that was identified by tactile signs. Bus stops can be located anywhere along the entire block face, and their signage, amenities, and cues are widely varied. Signage can be on trees, traffic sign poles, streetlights, or a separate pole. Stops can sometimes be identified by the location of a bench or shelter, but finding a bench does not always indicate a bus stop. Some shelters or benches are along the curb face, while others are set back near a building line. To make things even worse, if there are no tactile or Braille markings, even when people find a stop they have no positive feedback about which bus stops there. These problems were clearly exposed in this experiment. It took those who used their regular methods, including asking for help, 1970% longer than the FSU. Those who used RIAS knew exactly where they were and identified the correct bus stop in the same time as the FSU. This kind of positive identification can be priceless to the vision-impaired traveler and can save much time, stress, and frustration, and help increase overall access.

The fare machine at the Muni station was also hard to find, and it took the regular method users 1498% longer to find, while the RIAS users took only 116% longer to identify the fare machine.

In the current experimental setup, the flower stand did not have much legibility because of the low level of activity there and the unexpectedness of this type of business being in a transit station. There were also few cues, insofar as there was usually no one in line talking to a clerk to give any auditory cues. It took the subjects who used their normal skills 1414% longer than the FSU, while those using RIAS found it within 251% of the standardized time.

These three locations were categorized as “Inconsistent Locations and No Cues” (ILNC), and, for this type of location, the mean time penalty was 1899% longer, and the RIAS users took only 174% longer than the FSU.

3.5.1.2.2. Amenities with Some or Few Cues

The bathrooms, hot dog stand, candy counter, and the outside public phones had some non-visual cues. These types of locations had a mean penalty for the regular users of 491%. When using RIAS, the penalty was reduced to 265% more than the FSU. This measure is “Location, Few Cues” or LFC.

3.5.1.2.3. Amenities with Good Cues

The ticket window offered many cues, it almost always had a solid line of people (to bump into), and there were often voices from the people in line or at the window. In addition, in the field test, subjects passed directly by it once before they attempted to locate it on two subsequent tasks. The inside phones and water fountain and bathrooms were in the small waiting room just a few feet from each other. The bathroom was the first location that was visited in this experiment. Because of the field test order, subjects had already walked directly by the phones to get to the bathroom before they later searched for the phones. The phones offered good cues, as there were often people talking on them or coins being inserted could be heard. Water fountains can also offer distinctive sounds when used. By the time they were to locate the water fountain, they had already been in the immediate area twice; for the bathroom and for the phones. Search and exploration of the environment allowed some subjects to find these locations, or gain valuable cues, while searching for other locations.

For these four locations that offered good non-visual cues, the mean *time penalty* was 260%, and, for the RIAS users, 217% more than the FSU. This measure is called “Location, Good Cues” or LGC. Because the fixed order of the location search tasks required multiple exposures in these areas, these four locations had too many confounds to be valid for modeling purposes. They were included here in the explanation but will not be discussed in the next sections on location difficulty coefficients or in the models. The order of the search tasks caused some of these locations to be easier to find than would be the case if a person searched for them only when needed. These results are a confound of the station layout and experiment task order and should not be interpreted to apply to other locations of the same type. Even though an area like the ticket window, with its distinctive sounds and lines of people, posed less difficulty than most other locations, it is a vital and necessity part of each traveler's transit experience. These high traffic demand and necessary amenities should be given as many cues as possible.

3.5.1.3. Summary of Location Tasks

Unlike the person with physical mobility impairments, such as severe arthritis, a bad hip, chronic fatigue, or a weak heart, there is no consistent time penalty that can be measured relating to the travel time of blind people. These data show that the problems that cause a blind person to travel with less efficiency in an environment are not necessarily some inherent disadvantage caused by the lack of vision. Inconsistent locations with no cues and doors with no labels cause large time penalties and stressful travel, while locations with more environmental cues are much easier to find. It appears that it is often the lack of directional and location identity cues that cause the inefficient travel behavior (longer travel times) exhibited by many blind travelers.

3.5.2. Coefficients of Location Difficulty and Successful Mitigation

Time penalties increase as the number and types of trips increase. A more active traveler, who faces barriers to efficient travel, has more cumulative penalties than an inactive person. By summing up Equation 2 on page 167, a formulation can be presented that compares two types of users, with different access mode criteria, over a wide range of activities. This formulation can be used to compare the daily, weekly, or longer variation in travel time for different groups. The cumulative *relative access measure* thus allows for examination of how time penalties combine, depending on the choice of activities, to restrict access due to time constraints.

Equation 3 $$R_{iklm} = \frac{\sum_k f_{ikl}\, d_{ikl}}{\sum_k f_{ikl}\, d_{ikm}} - 1.0$$

This equation is the same as Equation 2, except the time penalties are added together. Using this formulation, the access mode type can be varied to examine the overall time penalties or *relative access measures*. This formulation is modified so that starting location i is relaxed to mean <u>any</u> location i for a trip to activity or location k. For example, the mean time penalty for trips to the doors is added to the penalty for crossing the hard street, and all the other types of locations, to produce the total time penalty of the 20 destinations in this experiment. Table 3.8 shows five different ways to judge the time penalties faced by people with vision restrictions.

- Mean times of the totally blind subjects using their regular skills (including canes and dogs) divided by times of the familiar sighted user (FSU). This shows the time penalty faced by blind travelers.
- Mean times of the totally blind subjects using RIAS divided by times of the familiar sighted user (FSU). This shows the extra time needed when using RIAS.
- The difference between the two condition coefficients.
- Time coefficients for the regular method divided by those times when using RIAS. This shows the extra time needed by regular users versus performance with RIAS.
- Time savings (in percent) when using RIAS instead of the regular skills (including canes and dogs).

Table 3.8 Impedance Coefficients for Various Locations

	Specific Tasks and Locations				General Locations	
Coefficients of Difficulty for Transit Tasks	Door No Cues	Hard Street	Med. Street	Corner Walk	Location No Cues	Location Few Cues
Variable Name	**DNC**	**SH**	**SM**	**WC**	**ILNC**	**LFC**
Blind, Regular Method / Sighted Baseline	6.0	6.9	1.8	2.3	20.0	5.8
Blind, with RIAS / Sighted Baseline	3.1	1.4	1.1	1.7	2.7	3.7
Blind, Regular Method – Blind, with RIAS	2.9	5.5	0.7	0.6	17.2	2.2
Blind, Regular Method / Blind, with RIAS	1.9	4.9	1.6	1.3	7.3	1.6
% Time Saved with RIAS versus Regular Method	48%	80%	38%	26%	86%	37%

A short discussion of Table 3.8 follows for the five rows of difficulty coefficients. The location variables with the highest degree of difficulty were (in decreasing order) ILNC, SH, DNC and LFC. The coefficients ranged from 20.0 to 5.8. These types of locations can be so inconsistent in placement, legibility, safety, and availability of cues that there is no effective way to be trained to find them. The less difficult location variables were the WC and SM. These last two locations require skills that are well learned with O&M instruction, training, and practice. These "less difficult" tasks still had penalty coefficients from 2.3 to 1.8.

When using the RIAS, the difficulty coefficients drop to a range of 3.7 to 1.1. Using RIAS lowered the difficulty coefficients of all six location variables. The biggest savings were for the location variable ILNC, where the penalty was lowered by 17.2 (from 20.0 to 2.7). The next three locations most improved by RIAS were SH, DNC, and LFC, with a savings range from 5.5 to 2.2. Even the lowest savings, WC and SM, were 0.7 and 0.6 times the FSU respectively.

The same pattern exists when one computes the time penalty of regular methods over that for RIAS. ILNC, SH, and DNC were still the most difficult locations, when compared to *RIAS*, with a range of 7.3 to 1.9, while the less difficult tasks were SM, LFC, and WC with a difficulty rating of 1.6 to 1.3 more than when using RIAS.

It is important to realize how much time could be saved with the addition of directional and identity cues in an environment that is lacking cues for the blind traveler. Using RIAS saved people searching for ILNC locations 86% of the regular method time, and it saved 80% of the time it took to normally cross a difficult street (SH). For location types DNC, SM, and LFC, the savings ranged from 48% to 37%. Even the lowest savings were notable, with the WC task saving 26% of the time that it took people to find these locations using their regular aids and travel skills.

3.5.3. Modeling Transit Task Difficulty and Mitigation

Using the above location time penalty coefficients, models can be produced that will assist people interested in navigation without sight, especially planners and O&M instructors, to apply these findings to other environments. Producing a linear model of both experimental conditions and also of the time saved between the conditions can identify more completely which types of tasks present the most resistance to efficient travel. Three linear models are presented that can be used to estimate the total travel time required for a blind traveler, based on the time for a sighted and familiar user. Prudent application of these models would allow a better understanding of the difficulties that people without sight might face in a new environment, without the need to collect data from a group of blind users first. Architects and design professionals, especially transit planners, could test their designs before they are built in order to ensure the best compliance with ADA mandates. These models could help planners know where to concentrate their mitigation efforts and add to the body of knowledge about barriers to accessibility in urban environments. As the models show, it is the environment, placement of destinations, and lack of cues that helps create the penalty to navigation without sight much more than the inherent lack of vision itself. A better designed and equipped environment would go a long way to ensure that this group could use the facilities with independence, efficiency, and dignity and would make the travel experience less stressful and provide a higher degree of personal safety. Simply stated, the model takes the time penalty coefficients for each of the six location or activity types and multiplies them by the time it takes for a sighted traveler to complete the tasks. When those numbers are summed, it reveals the total time penalty.

The model is based on a linear model with the equation:

$Y= e +B_1X_1 +B_2X_2 +B_3X_3 +B_4X_4 +B_5X_5 +B_6X_6$

where:

- Y = the predicted value of a blind person's total walk and search time in an environment.
- e is an error coefficient
- $B_1 – B_{-6}$ are the penalty coefficients of the different types of locations
- $X_1 – X_6$ are the walk and search times of sighted users to find the locations
- X_1 = DNC = Door, No Cue
- X_2 = SH = Street, Hard Difficulty
- X_3 = SM = Street, Medium Difficulty
- X_4 = WC = Walk to Corner
- X_5 = ILNC = Inconsistent Locations, No Cues
- X_6 = LFC = Locations, Few Cues

The first model computes the extra time that blind travelers expend in different locations, compared to a baseline (FSU) time. (Y) is the predicted value of the time it would take for the blind to complete the tasks.

Equation 4

Model 1: $Y = e + (6.0)DNC + (6.9)SH + (1.8)SM + (2.3)WC + (20.0)ILNC + (5.8)LFC$

It can be seen that "inconsistent locations, no cues" (ILNC) has a time penalty of 20, and crossing the difficult street (SH) has a penalty of 6.9. In contrast, a location with little or few cues (LFC) has a penalty of only 5.8 and crossing the medium difficulty street has a penalty of only 1.8. This type of model can be used in several ways. It is easy to see that adding a few cues at certain locations (changing a location from ILNC to LFC) would reduce the overall time penalty for a trip. In addition, re-routing the trip could also reduce overall penalties. In this example, it would be faster to cross two medium difficulty streets (SM) than to cross one street with hard difficulty (SH). The goal of increasing access can be met by designing spaces to reduce the cumulative penalty (Y).

The second model allows for computation of the reduced time penalty in an environment if directional and identity cues were available, as when using RIAS. (Y) is the predicted value of the time it would take for the blind to complete the tasks when using RIAS, as compared to a sighted user.

Equation 5

Model 2: $Y = e + (3.1)DNC + (1.4)SH + (1.1)SM + (1.7)WC + (2.7)ILNC + (3.7)LFC$

In this model, it is clear that the time penalty between hard (SH) and medium difficulty (SM) streets has become quite similar, unlike in Model 1, and other penalties are smaller as well. This would produce a much lower total penalty (Y) than Model 1, for the same route and activities.

To determine how much time could be saved when a blind person has access to additional auditory cues, a third model shows the effect on environments' "legibility" and ease of use when a system like RIAS is installed. (Y) is the predicted value of the time saved when using RIAS to the time of the blind using their regular methods. In this model, $X_1 - X_6$ are the walk and search times of the regular blind user.

Equation 6

Model 3: $Y = e + (48\%)DNC + (80\%)SH + (38\%)SM + (26\%)WC + (86\%)ILNC + (37\%)LFC$

Using the mean travel time of blind travelers, this model can estimate the savings when using accessible cues, such as RIAS. For example, it shows that RIAS might save 48% of the time to find unlabeled doors (DNC), 80% to cross hard streets (SH), and 86% at those locations that are inconsistent and have no cues (ILNC).

3.5.4. Section Summary

There is no consistent restriction or time penalty that can be assigned to the search times for blind travelers. These data and the models should allow planners to consider which locations demand attention in order to help mitigate barriers to access. Spatial knowledge acquisition, especially for people who are blind, can be increased with proper attention to the consistent location of amenities. Accessibility for the blind can also be increased by giving more attention to providing cues to these locations, including the use of identity and directional cues as provided by RIAS. The continued existence and acceptance of such high penalties and barriers to independent travel should be robustly questioned and examined by anyone concerned about providing access to urban opportunities and an equitable society for all people.

3.6. Chapter Summary

The preceding chapter has demonstrated that vision loss restricts access to transit. Field tests conclusively showed that there are many problem spots (in the sense of physical locations) when trying to access urban transit. User responses that looked at the improvements made by using a remote auditory signage system also confirmed the vast increase in efficiency, knowledge, independence, and spatial knowledge acquisition.

- Search times were significantly lower when subjects used external environmental cues.

- Subjects made significantly fewer errors when using the external cues.
- Many more people were able to complete the tasks in the allotted time when using the system.
- RIAS users did not have to rely on others to complete their tasks.
- Subjects using RIAS made much safer and faster street crossings.
- Transit tasks were rated as much less difficult when using RIAS.
- Many tasks were rated at or close to "not at all difficult."
- User comments stressed the increased spatial knowledge available to them with this system.
- Users also stressed that this information would positively affect their travel.
- They agreed that it would also relieve stress, and increase overall enjoyment and efficiency of travel.
- There is no consistent time penalty associated with blindness, but rather, the environment affects how difficult various tasks can be.
- The RIAS reduced this time penalty in each of the 7 types of locations evaluated.

Other research also confirms findings that the use of RIAS greatly helps blind travelers use transit at specific locations such as a subway station, finding buses and bus stops, and navigating buildings (Bentzen et al., 1999; Bentzen & Mitchell, 1995; Brabyn & Brabyn, 1983; Crandall et al., 1996; Crandall, Bentzen, & Myers, 1995, 1999; Crandall, Bentzen, Myers, & Easton, 1999; Crandall, Bentzen, Myers et al., 1995; Crandall, Brabyn et al., 1999).

4. The Effect Of Difficult Transit Tasks On Travel Behavior And Activity Choice

- **Hypothesis 2**: Difficulties of transit tasks will affect travel activity and behavior and reduce trips and accessibility. Subjects will estimate they would make more trips and access more places if RIAS was installed.

In the previous chapter, specific situations and locations that caused difficulty for blind navigation were examined. There is little doubt that the loss of vision adversely affects travel and independence. This chapter deals with how these difficulties directly affect activity and travel behavior. This part of the experiment dealt with how the loss of vision restricts personal mobility and action. A series of questions were asked to elicit information about these types of limitations and to ascertain if the addition of environmental cues can help mitigate these restrictions on individual behavior, thus increasing interaction with the urban environment.

In the preliminary interview, data were collected from the 30 subjects about travel behavior, mode choice, and activity choice. Subjects reported making an average of 12 trips per week. Nine subjects made five or less trips per week, and eight reported making over 20 trips per week. Subjects were asked if they made fewer trips than before they were blind. Five said they did make fewer trips after their visual impairment, three said it was about the same, and one person indicated that he did not make fewer trips because of his condition. Those that said they made fewer trips gave reasons such as “it is hard to get places without a car,” “can’t walk a lot,” “only go when need to,” “transit problems,” and “has to depend on others.” This question did not apply to 21 people, who were congenitally blind or blind at a very young age,

.

For an average week, subjects reported making 4.7 bus trips, 3.8 trips using the BART subway system, and 1.6 trips using the Muni Light Rail. Only 0.7 trips per week were reported using door to door van services, 1.7 trips were made by a friend's or family private car, 2.1 trips were made by taxi, and an average of 4.3 trips were made by walking.

On a five-point scale (1= "strongly agree" and 5= "strongly disagree"), subjects rated their opinion on the following three statements.

- "My vision impairment has caused problems in transit use which restrict my range of non-job related activities." They agreed most strongly on this statement with an average rank score of 1.8.
- "My vision impairment has caused problems in transit use which restrict my range of locations for jobs." They agreed with this statement with a rank score of 2.2.
- "If transit and mode transfers were made less difficult I could find a better job." This statement also received a rank score of 2.2.

In addition to the exhaustive field test, many data were gathered before and after the time trials. Many of the same questions were asked of the participants on both occasions in order to determine if their attitudes and beliefs about travel and trip making had changed once they experienced the RIAS. The results shed light on the travel needs faced, and problems experienced, by blind and vision-impaired people.

There were dramatic changes in attitudes and perceived trip making capabilities, and these results are shown and discussed in this chapter.

4.1. Travel Confidence and Frequency of Visiting New Environments

4.1.1. Self-Reported Ratings of Confidence while Traveling

A pre-test question was asked during the phone interview that attempted to capture participants' self-rated skills and behavior in their normal living and travel situations. The same question was asked after the test, requiring subjects to imagine their environment filled with the same types of RIAS installations that they had experienced during the field tests at the Caltrain station and its immediate surroundings. Subjects were asked to rate their confidence levels on a 1 to 5 scale in three areas (1="very confident" and 5="very unsure").

- Before using RIAS, subjects rated their level of confidence about "independent travel" as 1.8, and, after using the system; they said that if it were installed they would rate themselves as 1.3.
- Subjects rated their "sense of direction" as 2.1 before using the system and said that confidence would increase to 1.4 if RIAS was installed.
- Subjects rated their confidence when traveling in a "new environment" at only 2.8 when first asked about their travel. They said that if RIAS was available they would rate their confidence at 1.7, more than a full category level in the direction of positive confidence.

All three answers show an increase in very general categories of self-worth, when considering RIAS, with the most dramatic increase being the confidence gained in new environments. When making travel and activity decisions, increased confidence is a basic attitude that can affect a wide range of decisions.

Table 4.1 shows the number (N=30) in each category for both the pre and post-test conditions. None of the subjects perceived that they would be “Unsure” or “Very Unsure” if RIAS was installed, and there was a dramatic shift toward a perception of high confidence in daily travel with the addition of these environmental cues.

Table 4.1 Frequency Distribution of Reported Confidence Levels

Confidence in?	Condition	Very Confident	Confident	Avg.	Unsure	Very Unsure
Independent Travel	Pre-test	13	13	1	3	0
Independent Travel	Post-test	20	10	0	0	0
Sense of Direction	Pre-test	6	18	3	2	1
Sense of Direction	Post-test	20	9	1	0	0
New Environments	Pre-test	1	13	9	6	1
New Environments	Post-test	14	12	4	0	0

4.1.2. <u>Learning New Routes and Traveling to New Environments</u>

How might this basic attitude adjustment affect behavior? Subjects were asked, “How often do you learn a new route or navigate around a new place?” Available choices were 1= daily, 2= several times a week, 3= weekly, 4= several times a month, 5= once a month, and 6= less than monthly.

Table 4.2 Frequency Distribution of Travel in New Environments

Choice =	#1	#2	#3	#4	#5	#6
Pre-test	1	4	7	10	6	2
Post-test	8	12	7	2	1	0

The table shows how perceptions about the frequency of accessing new routes or environments increased when people with vision impairments considered using a system that provided heretofore missing spatial cues. On average, respondents reported currently learning new routes or environments between "weekly" and "several times a month", with a score of 3.7. They reported that if RIAS was installed they would learn new environments closer to several times a week, with an average score of 2.2. This shift of 1.5 points demonstrates a marked increase in perceived access to new environments. Since a major problem regarding access to work and other activities is the need to travel freely in new environments, the data give a very strong indication that blind people do want to travel more if additional information was available, and therefore they are held back by the lack of accessible cues.

4.2. Perceived Travel Behavior while Making Transfers

In order to specify more clearly how perceptions about mobility affect activity, two hypothetical situations were given to subjects in order to determine how they would make travel decisions and what, if any, financial tradeoffs they would offer to make travel easier. These monetary valuations are discussed later (see Section 5.6, Monetary Benefit of Independent Travel).

4.2.1. <u>Perceived Trip, Transfer, and Activity Behavior: One-Time Event</u>

The first of these two questions asked subjects to consider the following transit, navigation, and mobility situation. In the pre-test question, they answered on the basis of their normal travel skills; in the post-test question, their answers were based on considering an environment that was as rich with RIAS as was the field experiment environment. A typical situation that might face a blind person wishing to access typical urban situations was presented. The specific question was: "If a special concert or movie I was looking forward to attending was being held 10 miles away in an unfamiliar location that was served by an unfamiliar transit route and also required a transfer to another mode, I would probably-----?"

Table 4.3 Trip Behavior and Mode Choice for a One-Time Event

Pre-Test %	Post-Test %	Response
3%	0%	Forego the event
17%	3%	Ask a friend for a ride
0%	0%	Ask a family member for a ride
3%	0%	Ask someone to teach me the transit route
13%	0%	Pay for a cab
23%	0%	Call dial-a-ride
40%	97%	Get information and then rely on my travel skills and by asking for help on the way

In the pre-test interview, 12 people (40%) said they would make this trip independently. The other 18 would more likely rely on paratransit, friends and cabs or forego the event. With RIAS, 29 of 30 subjects (97%) said they would make the trip independently. It appears that vision-impaired and blind people perceive they would function much more independently and use the services provided to the general public if the proper environmental information was available to them.

4.2.2. <u>Perceived Trip, Transfer, and Activity Behavior: Daily Job</u>

The same scenario was repeated, but, instead of a one-time event, people were asked to perceive their behavior when considering daily travel to a job. The specific question was: "If a job that you wanted was located 10 miles away in an unfamiliar location that was served by an unfamiliar transit route and also required a transfer to another mode, I would probably ----?:"

Table 4.4 Trip Behavior and Mode Choice for a Daily Job

Pre-Test %	Post-Test %	Response
0%	0%	Forego the event
7%	0%	Ask a friend for a ride
0%	0%	Ask a family member for a ride
23%	0%	Ask someone to teach me the transit route
7%	0%	Pay for a cab
10%	0%	Call dial-a-ride
53%	100%	Get information and then rely on my travel skills and by asking for help on the way

With RIAS, all 30 subjects said they would travel independently to the new job. This is compared to the pre-test interviews, where only 16 subjects (53%) said they would attempt the trip independently. The other 14 would have relied on other people to get them to a job. This highlights the difficulty in finding a way to get to work for this population.

In this section, data were presented concerning how RIAS was perceived to increase confidence, allow for more travel exploration, and result in specific behavior changes, including increased mobility and independence. They also offered monetary benefits for this increased information, which is discussed in the next chapter (see Section 5.6 Monetary Benefit of Independent Travel). The next section examines actual travel behavior reported by the respondents and also their perceptions of how that activity might change if additional environmental cues were made available to them.

4.3. Activity Participation, Trip Behavior, and Travel Times

Another procedure used to determine the effect of non-sighted navigation on people's lives is to examine the activities they participate in, how often they participate, and how long it takes to make the necessary trips. Conventional accessibility measures have long used these types of data to help determine how much time or effort is required to access various locations. These models have a *utility function*, which often assumes that people want to minimize time or distance in their daily trips. In the travel environment faced by certain groups, especially those with limited vision, an examination is called for to determine whether time or distance expense is really the utility that they desire to minimize.

For instance, they might want to avoid busy or dangerous intersections, shop at stores with familiar layouts or personnel, or stay on a bus instead of making a transfer, even though these choices might increase travel time or distance. Instead of searching for the most optimal spatial location, activities might be more focused on making sure the actual task or trip purpose can be performed easily and with less stress.

For a blind person, these are not "incorrect" decisions, as typical models would indicate. There are other problems when using conventional accessibility methods to measure blind people's accessibility, and, before discussing the data on time and trip behavior these other problems and difficulties are discussed, and an analysis is made of how conventional measures might not be suitable for the study of certain groups.

4.3.1. Accessibility and the Vision-Impaired

In Section 2.3, Measuring Accessibility, accessibility measures and problems associated with accurate modeling were introduced. In its most basic form, "accessibility" is a measure of an individual's freedom to participate in activities in the environment (Weibull, 1980). Previously, a discussion of some of the restrictions on independent travel was made, such as time penalties, safety concerns, and the fear and stress that are faced by a traveler without vision. These restrictions diminish the individual's freedom to participate in accessing urban opportunities.

4.3.1.1. Special Access Considerations for People with Vision Restrictions

Conventional accessibility measures assume "perfect knowledge" of the environment by users, meaning that they know of all choices for all activities. Just like a visitor or new resident in a town who makes "incorrect" spatial decisions, many blind people can have trouble quickly assimilating enough spatial knowledge to afford them completely rational decision making. The lack of access to printed signs, distal cues, and spatial and environmental information, as well as confinement to fixed transit and learned walking routes of travel, all restrict spatial knowledge acquisition. Because of this, blind people might be unaware of changes and opportunities in the environment, even including what is available across a street or around the corner from their normal path. Anecdotal evidence is replete with stories about blind people not being aware of changes in the urban landscape and of making "incorrect" spatial decisions because of the lack of spatial knowledge. Work on feasible opportunity sets (Golledge et al., 1994) shows the effect of an individual's spatial knowledge on the size and spatial configuration of the available choice set of locations when making spatial decisions. Therefore, the blind person with restricted spatial awareness is an imperfectly informed decision-maker and might be faced with a limited opportunity or choice set when making spatial search decisions.

When working with a subset of the general public, such as people with visual impairment, it is necessary to make sure not to confuse a measure of *place or location accessibility* with *individual accessibility* (how easily a person can actually reach activity locations). Individual accessibility is determined not by the number of opportunities that are close by, but whether or not these opportunities are within reach, considering the person's life situation and adaptive capacity (Dyck, 1989). Conventional accessibility models based on the proximity of locations of urban opportunities cannot account for the personal, highly diverse differences of human behavior and skills. They often tend to actually reflect place accessibility, more than a measure of an individual's accessibility. Therefore, it is inappropriate to mistakenly attribute the *locational* or *place accessibility*, such as of a traffic zone or census tract, to a person in that area (Pirie, 1979). This conceptual framework is important in understanding the "true" accessibility experienced by blind people.

Because persons who are legally blind do not drive cars, they are often transit-dependent and, in addition, might need to make several transfers to reach a location. These rides, and especially the transfers, can introduce much more travel time randomness into their trip. In many cities, it is not easy to plan an arrival time when using transit and making transfers, and this certainly adds a great deal of variance to trip times. In addition, people with vision restrictions might have to budget more time for unforeseen barriers, unfamiliar environments, or new obstacles in the environment. Time constraints, spatial knowledge acquisition and processing, fear of new environments, safety concerns, and stress all figure in the spatial search equation for the blind. For these reasons, traditional measures of access that rely on location-based properties do not capture the true accessibility of this group.

For the general public in the built environment, all locations are accessible from all other locations. There might be high levels of time, effort, or expense to overcome, but locations can be reached. For people who use wheelchairs, areas and locations still exist that cannot be reached, no matter how much effort is expended. The same appears to be true, in many situations and locations, for many visually impaired people when traveling independently.

In previous sections, documentation was provided on the difficulty of tasks (see Section 3.2 User Rated Difficulty of Transit Tasks) and the increased travel time required by navigation without sight (see Section 3.1 Caltrain Field Test). However, restrictions to access and travel go far beyond the increased effort and time. There are locations that are so difficult to access that they form a barrier as formidable as a physical barrier is for users of wheelchairs. If a street cannot be crossed, or a bus stop or entrance can't be found, that one task can cause the whole trip to be abandoned. Even one difficult street crossing can cause an entire area of the environment to become totally inaccessible. In addition, a series of difficult tasks, especially in an unfamiliar area, can cause a trip to not be attempted at all because of daily time constraints and increased apprehension and fear. Therefore, there are some trips that are not taken by this group even though there are no true physical barriers preventing them. Access for the blind is restricted by more than time constraints, they also face barriers, such as the lack of spatial information, fear, confusion, safety concerns, and other perceived stressful situations. Thus, independent travel for the blind can be blocked by the effect of the environment on the potential traveler. These types of barriers to travel are not addressed in conventional measures that deal mostly with the physical relationship between locations.

Gender bias and ethnic or minority bias can also occur in traditional accessibility measures. Kwan (1998a, 1999) says that conventional spatial accessibility measures of access to jobs or shops are meaningless for women whose activity choices were continually complicated by additional time constraints due to their gender roles. It is postulated here that people with vision restrictions also can face many constraints on their travel time and spatial knowledge, and that these can be quite different than those faced by the typical traveler.

People with vision impairments might try to maximize a different utility than simple time or distance reduction, due to apprehension while in new environments and situations. This, for example, leads to the belief that there also exists a “disabled bias” to conventional accessibility models. In addition, different levels of an individual’s physical mobility (or mode of travel) can affect the distance or time effort of the shortest accessible path in small-scale areas, like buildings, such as the graphic display referred to by Okunuki, Church, & Marston (1999) or larger scale areas, such as a campus sidewalk network (Church & Marston, in press). Thus, there are often longer but still "correct" shortest paths that are used to overcome physical and other barriers in the environment.

4.3.1.2. Spatial Mismatch and Interpreting Trip Time Data

Travel times have long been used as a measure of accessibility to various locations and functions. There is little agreement, however, on how to interpret these data. For example, a long work commute might represent a successful professional's trip from a desired and isolated residential area to a prestigious job in the central city. Conversely, a long work trip might be the result of a spatial mismatch between an employer-abandoned inner city and an employer-rich suburban area. This situation often requires a long and arduous transit trip with many transfers in order to find employment. A short work trip might be the result of child-care and other gender-role constraints on suburban women whose choices of jobs are from the many female-oriented jobs available in the suburban area. In the past, short work trips were often associated with blue-collar workers who, for economic reasons, lived near the factory or warehouse. However, a short trip can also result from a highly paid worker's decisions to live in or near the central city.

The same inconsistencies are also found in other trip types, such as shopping, social, or recreational activities. People with cars and economic resources might choose to live far from commercial locations and prefer to shop or recreate at various and prestigious places scattered around the urban area. A short shopping trip could represent a person on a limited budget who is forced to walk and must perform these activities at a location close to home. Conversely, an inner-city resident might be forced to take long trips by transit to find a full-service grocery store. A short recreation-based trip might indicate that the only affordable spot is one they can walk to, while a long trip might be made by an economically successful person choosing to travel a long distance to play golf at different courses. For these reasons, it is impossible to assess a "correct" interpretation of the true meaning of travel times and accessibility. Examples of both long and short activity travel times are examined in the following data from the blind subjects in this experiment.

4.3.2. <u>Activity Travel Times</u>

In this section, the data collected about transit trip times, walking times, and the total roundtrip time taken to access various urban opportunities are reported. Data were collected during the pre-test interview about subjects' current weekly travel activities. Subjects reported the number of trips they made for nine different activity purposes. They also reported the roundtrip transit time and also their walk time.

4.3.2.1. Travel Time by Activity Type

Table 4.5 shows the mean roundtrip transit travel time, the walking time, and the total trip time in minutes. Activities are shown sorted from the longest trip to the shortest trip. Some subjects did not report walk time for their transit trip (cabs and other at-location pickups) and others walked the entire trip without using a vehicle. For these reasons, the total trip times are not the simple sum of the total transit and walk times shown on the table.

Table 4.5 Transit Time, Walk Time, and Total Travel Time

Trip Activity	**Transit Time**	**Walk Time**	**Total Trip Time**
	Round Trip Time In Minutes		
Work	107	33	136
Education	63	33	84
Social	75	30	82
Entertainment	65	23	72
Religious	75	37	59
Recreation	44	33	54
Medical	38	16	38
Shop	25	27	35
Banking	18	23	26
Mean of those making trip	503 (8.4 Hours)	250 (4.2 Hours)	586 (9.8 Hours)
Mean for all 30 subjects	193 (3.2 Hours)	105 (1.8 Hours)	298 (5.0 Hours)

Many people did not make all types of trips. The mean travel time for all the subjects was 3.2 hours in-vehicle and 1.8 hours walking, for a total of 5.0 hours of travel per week. The data in the table and that discussed below are only for those who reported making a trip for that activity. The mean weekly travel time for those who made trips was 9.8 hours, with 8.4 hours riding a vehicle and 4.2 hours walking. The use of private car rides was very low, as reported in another part of the interview. Almost all trips were made independently using public transportation, and the term transit is used here to include any vehicle ride.

4.3.2.1.1. Work Trips

The mean transit time for those who made work trips was 107 minutes; they walked 33 minutes, and the total roundtrip time was 136 minutes. There were 17 trips reported, and 17 people reported transit use and two people did not report any walk time. The longest work trip was 390 minutes and the shortest was 30 minutes.

4.3.2.1.2. Education

The mean transit time for those who made trips to participate in educational activities was 63 minutes; they walked 33 minutes, and the total roundtrip time was 84 minutes. There were eight trips reported, six people reported transit use and walking, one reported transit only, and one reported walking only. The longest education trip was 165 minutes and the shortest was 30 minutes.

4.3.2.1.3. Social

The mean transit time for those who made trips for social activities was 75 minutes; they walked 30 minutes, and the total roundtrip time was 82 minutes. There were 25 trips reported, 12 people reported transit use and walking, nine reported transit only, and four reported walking only. The longest social trip was 270 minutes and the shortest was 10 minutes.

4.3.2.1.4. Entertainment

The mean transit time for those who made entertainment trips was 65 minutes; they walked 23 minutes, and the total roundtrip time was 72 minutes. There were 16 trips reported, 10 people reported transit use and walking, three reported transit only, and three reported walking only. The longest entertainment trip was 150 minutes and the shortest was 20 minutes.

4.3.2.1.5. Religious

The mean transit time for those who made religious trips was 75 minutes; they walked 37 minutes, and the total roundtrip time was 59 minutes. There were 12 trips reported, three people reported transit use and walking, one reported transit only, and eight reported walking only. The longest trip was 200 minutes and the shortest was 10 minutes.

4.3.2.1.6. Recreation

The mean transit time for those who made trips to recreational locations was 44 minutes; they walked 33 minutes, and the total roundtrip time was 54 minutes. There were nine trips reported, four people reported transit use and walking, one reported transit only, and four reported walking only. The longest trip was 105 minutes and the shortest was two minutes.

4.3.2.1.7. Medical

The mean transit time for those who made medical trips was 38 minutes; they walked 16 minutes, and the total roundtrip time was 38 minutes. There were six trips reported, three people reported transit use and walking, one reported transit only, and two reported walking only. The longest trip was 60 minutes and the shortest was 20 minutes.

4.3.2.1.8. Shopping

The mean transit time for those who made shopping trips was 25 minutes; they walked 27 minutes, and the total roundtrip time was 35 minutes. All 30 subjects reported making shopping trips, 10 people reported transit use and walking, eight reported transit only, and 12 reported walking only. The longest trip was 130 minutes and the shortest was two minutes.

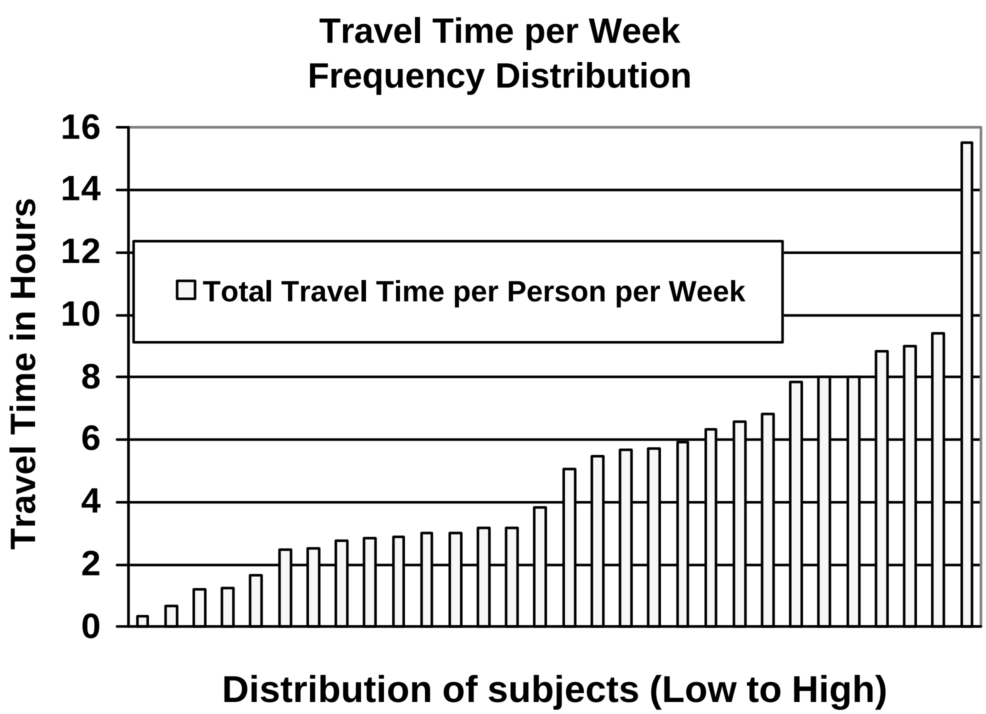
4.3.2.1.9. Banking / Financial

The mean transit time for those who made banking trips was 18 minutes; they walked 23 minutes, and the total roundtrip time was 26 minutes. There were 15 trips reported, three people reported transit use and walking, no one reported transit only, 11 reported walking only, and one person reported no extra time (ATM at the store). The longest trip was 65 minutes and the shortest was 10 minutes.

4.3.2.2. Travel Times per Person

There is a large variation in reported total trip times and trip frequency. The mean weekly travel time was 5.0 hours. Figure 4.1 shows the data for each subject sorted from lowest to highest weekly trip times.

Figure 4.1 Travel Times per Person



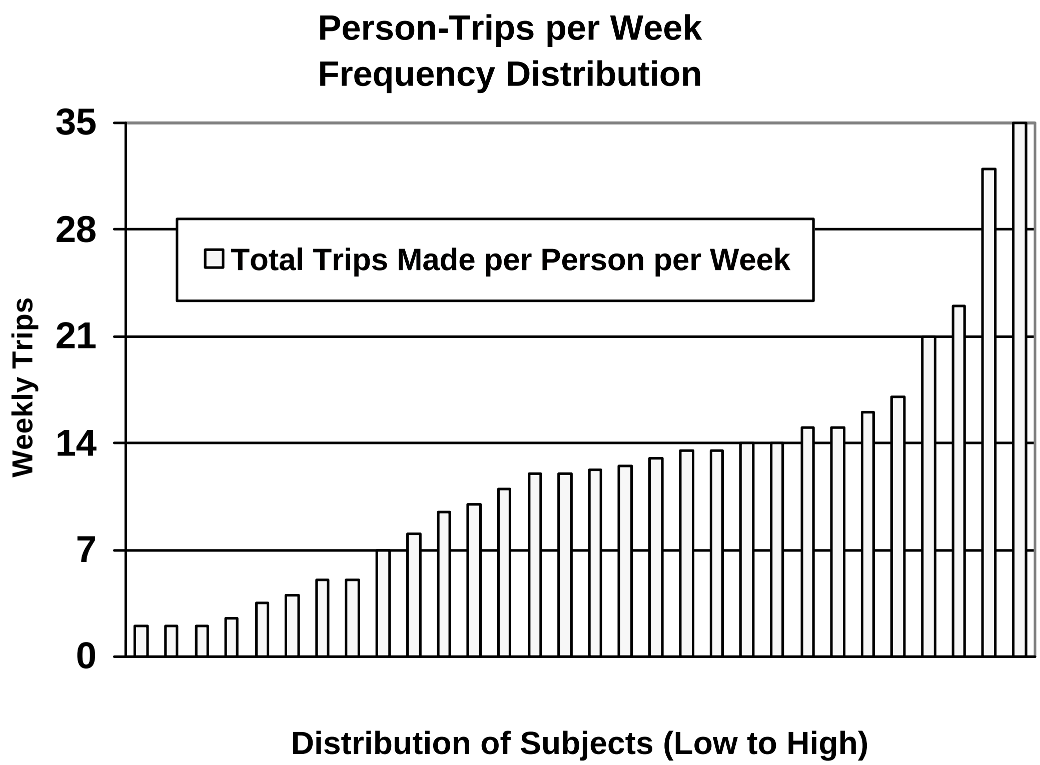
One subject reported travel of only 20 minutes per week, while another traveled 40 minutes per week. Three more traveled between 1.2 and 1.7 hours per week for a total of five who traveled two or fewer hours during the entire week. Ten subjects reported total travel time between 2.5 and 3.8 hours per week. Five traveled between 5.1 and 5.9 hours, while another six reported times between 6.3 and 8.0 hours. Three reported times of 8.8 to 9.4 hours, and one person (a salesman) reported 15.5 hours of weekly travel. To better understand these data, it must be kept in mind that these subjects were not among the estimated 30% of blind people that Clark-Carter, et al. (1986) say never leave the home for independent travel. These subjects had the training, skills, and motivation, to travel to the test site in downtown San Francisco. Most subjects did not live in the City and so many traveled quite a few miles from across the Bay or from South Bay areas. It must, therefore, be expected that mean travel times and the number of trips reported would be even lower when considering the entire population of people with vision restrictions.

4.3.3. Activity Participation and Trip Frequencies

A compelling reason to live in a large urban area, especially for those who do not drive a car, is the large range of activities and urban opportunities that are available and easily accessible through mass transit. When considering all the daily activities a person has to choose from, the following data provide blunt evidence that people with vision restrictions face limitations in their activities and travel, and that there are major restrictions and barriers that affect everyday life activities for this group.

Figure 4.2 displays the number of trips reported by the subjects, sorted from lowest to highest frequency. The mean number of trips reported was 12.1 per week.

Figure 4.2 Total Trips per Person



The activities and trips that subjects reported included any function that took place outside the home. The data on individual activity participation show a wide range, and the variation warrants a closer look at individual behavior. Nine subjects (30%) participated in only seven or less activities in an entire week (one per day.) Three subjects left their home for two activities during a week, one apiece reported 2.5, 3.5, and 4.0 trips, two took five trips and one took seven. Another 13 subjects (43%) reported 14 or fewer activities per week. From the sample of 30 blind subjects who were active and skilled enough to navigate to the test site, fully 73% participated in two or less activities outside their home per day. Another five subjects reported between 15 and 21 trips per week, and one made 23 trips. Two subjects reported high trip and activity participation of 32 and 35 trips per week. These two young adults were part of a residential program, had useful vision, and were very social. They reported many trips to visit friends in adjacent apartments and regarded their many trips to the local "hangout" corner store as either social or shopping.

4.3.3.1. Trip Frequency by Activity

The previous section reported on the number of trips actually made by the test subjects. There is more to understand about trip and activity behavior of the blind than just explanatory statistics and descriptions of actual trip frequency patterns and distribution. Trip frequencies and activity participation data are widely used by marketing professionals, and urban and transportation planners. A major principle in transportation planning is that, by removing barriers to access and increasing throughput, accessibility in the system can be increased, and no one seems to deny that curbs and stairs are major barriers to activities for those using a wheelchair.

Transportation planners can easily compute the effect on accessibility of improvements such as wheelchair accessible buses, a new limited-access highway, a new transit line, an express mode, or the elimination of airport service by comparing trip behavior before and after the change. Urban planners can judge the effects on accessibility in the environment caused by the installation of curb-cuts and ramps, a new pedestrian mall, or a parking structure. They can determine the effect of a big-box mall at the edge of town on downtown business by comparing previous and current trip behavior after the change. Although accessibility models can help estimate these changes, these types of comparisons of trip data can only be made after the change has been implemented.

The ability to make such comparisons in order to understand accessibility for the blind has been limited, if not impossible. If people's sight could be restored, it might be possible to make such comparisons. If RIAS was already fully installed in an urban area, comparisons of the data before and after the installation could easily be made. Some kind of comparison of the blind subjects' data to other data is called for, but a simple comparison to data from the sighted would not uncover much of importance. Since there is no full urban installation of RIAS, hypothetical travel behavior information was collected from the subjects. In order to research the accessibility of this group, some questions were asked that have not been researched before. Prior to subjects' exposure to RIAS but after the actual weekly trip data were collected, it was asked if there were trips that subjects did not make because of problems with their visual impairments' effect on their independent travel and the efficient use of transit. The actual questions asked were:

- "Do you sometimes avoid trips or activities because of your visual impairment and the difficulties of independent travel?"
- "If YES, how often during a week do you avoid these types of trips or activities because of your visual impairment and difficulties of independent travel?"

The questions were worded this way to try and avoid any frivolous or fantasy desires or activities. Of the 30 subjects, 20 (67%) said that they avoid some trips because of travel problems caused by their vision loss. Those who said they avoided some trips reported how many and what types of trips were not taken.

During the field experiment, subjects experienced transfers to different transit modes, including a large terminal and street environments that were rich in RIAS installations. After the experiment, subjects reported how many more trips they would make if RIAS was as richly installed in their environment as they were at the test site. All but one subject (97%) reported they would make additional trips with the addition of RIAS in their daily activity space.

Collecting data on currently desired, but not taken, extra trips and trips they perceived they would make with RIAS installed produced three data sets to examine.

- The actual trip data
- The actual trip data plus the desired but not taken trips (total trips currently desired)

- The actual trips plus those trips they would make if RIAS was installed (total trips they would make with RIAS)

In the discussion, the terms “actual,” “desired,” and “would make with RIAS” are used to identify these three data sets.

The desired trip data when added to the actual trip data gives a type of control group for comparison. These data represent the “best-case” scenario as reported by the subjects if they did not have travel problems relating to their blindness. Comparison of these three data sets reveal which and how many trips vision impairment and transit access currently limit and if the addition of directional and identity cues through a navigation system is estimated to reduce or cancel these limitations. If “would make with RIAS” trips are less than the (control group) desired trips that would show that there were other problems associated with the limitations of navigation without sight. If the “would make with RIAS” trips were higher than the desired trips, it would show that the system was perceived to open up more participation in activities and urban opportunities than the subjects had previously considered possible. If that is the case, it suggests that the lack of spatial cues in the environment is a limiting factor in blind travel. Just like the elimination of physical barriers for those using wheelchairs, this would show that it is the environment and its barriers that limit movement and travel, and not the people and their visual condition. The “desired but denied” data reveals “pent-up” demand that is not currently being met. The “would make with RIAS” data reveals what transportation planners call *hidden demand*. Highway engineers know that after carefully planning the future capacity of a new highway, based on existing travel data, the road is soon at full capacity not long after completion. Thus, there was a *hidden demand* that was not revealed until the new link was available. The demand is *hidden* because people change and increase their use based on the new accessibility offered.

Table 4.6 shows the three data sets. Since all 30 of the subjects did not make all types of trips, the number who reported them is shown as (N=). The different trip types are sorted with the most frequent currently conducted activities first. The average number of actual trips reported was 12.1 trips per week.

Table 4.6 Actual and Desired Trip Making Behavior

N = The # of subjects who reported making this type of trip	**Actual** Trips Made		**Actual** + **Desired** Trips Not Made		**Actual** + **Extra** Trips With RIAS	
	N =	Mean Trips	N =	Mean Trips	N =	Mean Trips
Shopping	30	2.6	30	3.3	30	4.9
Social	25	3.1	28	3.6	27	5.0
Work	17	4.7	17	5.0	24	6.7
Entertainment	16	1.4	20	2.0	25	2.7
Banking	15	1.3	19	1.5	25	1.7
Religious	12	2.2	14	2.6	15	2.6
Recreation	9	2.3	19	2.2	25	3.1
Education	8	3.5	13	2.6	23	3.2
Medical	6	1.3	6	1.3	8	1.2
Other	0	0	1	1	0	0
Total Trips	30	**12.1**	30	**15.8**	30	**25.0**

When the trips that they did not make because of travel limitations were added, the average number of trips they desired rose to 15.8, a 31% increase. This is a realization that the number of trips they do make now is 23% less than what they desire. The subjects' data inform that there are strong limitations on daily activities that are associated with loss of vision, independent travel, and transit use. After using RIAS, subjects perceived that they would make 25.0 trips per week, a 107% increase, or, they estimated they are only making 52% of the trips they would make with RIAS.

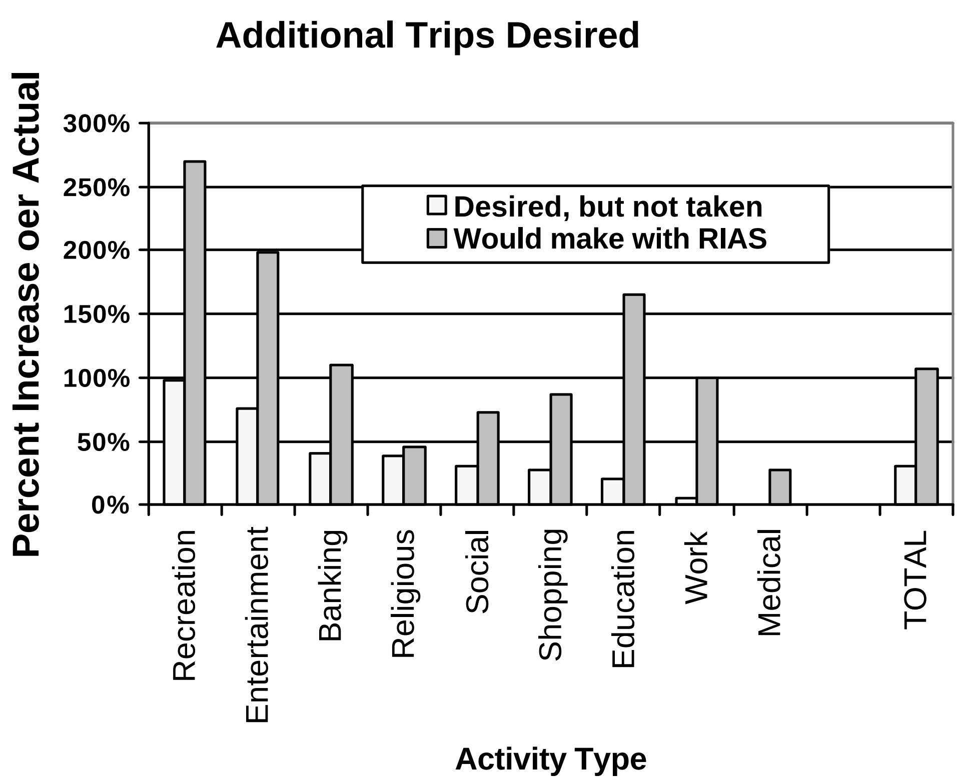
All subjects already made shopping trips, and no subjects thought they were missing any work or medical trips. For all other activities, an increased number of people thought they would participate if it weren't for the problems of independent travel and transit use related to their vision loss. If they could use RIAS, still more people expressed an interest in participating in all activities.

For the currently desired trips, the mean frequency increased for all activities except recreation and education. Both of these activities had high increases in the number of participants, and the total number of trips was higher, but the mean was lower. For the "would make with RIAS" trips, more people desired to participate in activities than they currently did for every activity type, and except for social (with one less person), more people said they would participate than they had expressed in the “desired but denied” question. The total number of trips per activity was higher than the actual and the perceived data in all cases. The frequency mean was slightly lower for medical trips, and it was equal for religious trips. A comparison of the three data sets shows that many activities are denied to these blind subjects in both number and frequency. Even more important, it shows that travelers perceive the lack of simple environmental cues as a major cause of this limitation and that, with the addition of these cues, blind people could make more trips and more could participate in these activities. This is an example of what has been earlier described as **functional barriers** to travel and transit, and the elimination of these barriers should substantially increase accessibility and activity participation. To see how these barriers limit travel for different activities, the percentage change both in the number of people who said they would participate and in the number of trips they said they would make is discussed.

Figure 4.3 shows the increase by percent of the ‘desired” and “would make with RIAS” trips over the actual trips reported. The data are ordered from high to low, based on the desired but denied trip data.

About 2/3 of the subjects were congenitally blind and had never experienced vision. The rest also had no current chance of regaining sight. Their acceptance of the restrictions of vision loss on their everyday travel was quite evident from their rather conservative estimates of the number of trips they thought they were denied because of their vision loss. They expressed a desire to take an additional 99% more trips to recreational events and 79% more trips for entertainment purposes. It could be argued that these two activities are the most discretionary of the group, and, therefore, the ones that are first eliminated because of any problems. Banking, religious, shopping, and education trips were desired from 40% to 21% more than their actual frequency. They only desired to make 6% more work trips, and none desired to make more medical trips

Figure 4.3 Additional Trips Desired and Estimated



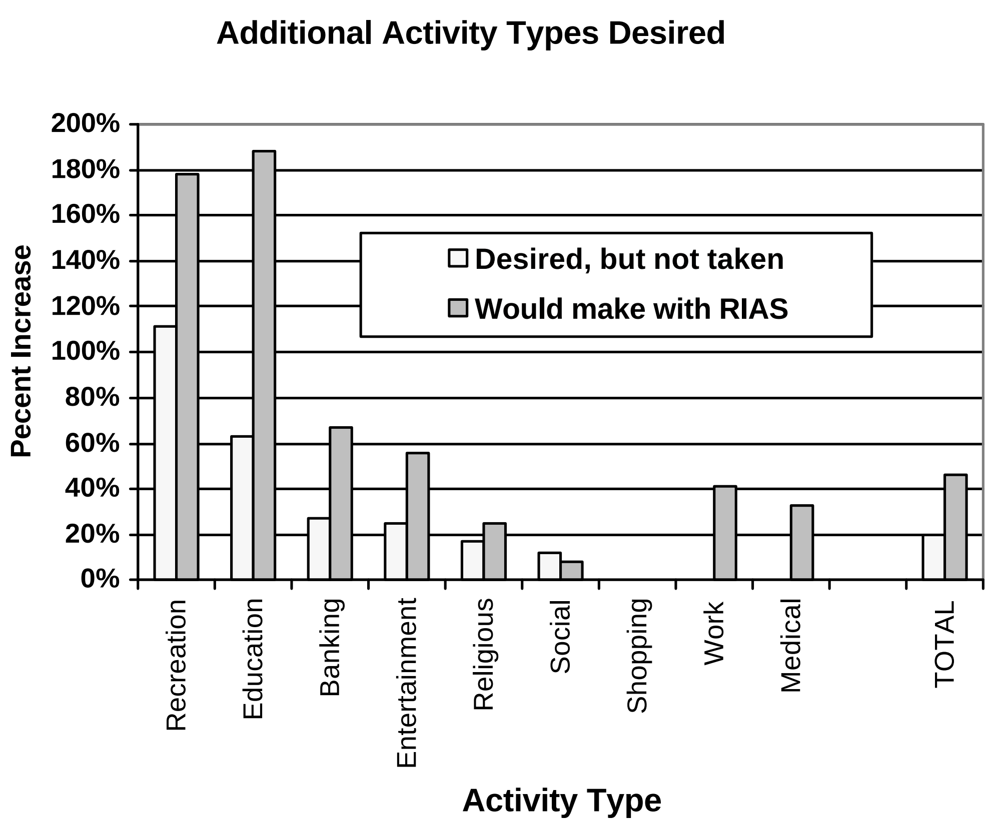
After experiencing RIAS at the experiment site, subjects appear to have learned much about what could be accomplished easily and safely using the additional cues. Before trying the system, only 20 subjects (67%) thought they were missing any trips, but after usage 29 (97%) thought they would make more trips. The number of trips they said they would make with RIAS was much higher than they had originally thought they were missing. Discretionary trips, such as recreation and entertainment, were still the two highest in terms of the increase, but at a much higher rate, 269% and 198% respectively. Estimated education trips increased by 165%, banking trips by 110%, and work trips were perceived as increasing by 100%. Next in decreasing order were shopping (87%), social (73%), religious (45%), and medical trips up 27%.

4.3.3.2. Increased Number of Activities and Trips per Person

This section examines how perceived trip behavior changed for individual subjects. Of the 30 subjects, only one person, who already took 13.5 trips per week, reported she would not make any more trips with RIAS. Five subjects said they would make between 12% and 49% more weekly trips, and another five said they would make between 50% and 99% more trips. Ten subjects said they would make between 100% and 199% more trips, four more between 200% and 299%, two between 300% and 399%, and two reported extra trips between 400% and 499%. One person, who currently made only two trips a week, reported 12 extra trips if using RIAS, for a 600% increase. Clearly there is a *hidden demand* for more activities if travel and transit was made more accessible, a demand for inclusion and participation that has not been previously understood.

Activity participation can also reveal the degree of access. Figure 4.4 shows the increased number of people who said they would attend to new activities The data are again sorted from highest increase to lowest for those that reported activities that they were denied because of transit and travel limitations relating to their blindness.

Figure 4.4 Additional Desired and Estimated Subject Participation



For the desired trips not taken, recreation and education trips had the highest demand by additional participants; a 111% and 63% increase, respectively, over the actual number of current participants. Banking, entertainment, religious, and social trips were estimated to increase, by 27% to 12%, for the number who would participate. No one reported that they did not participate in work strictly because of independent travel limitations. They also felt they were able to meet their medical trip needs, and, since all subjects made current shopping trips, there was no increased desire in that category. These numbers seem to be in line with what one would expect. Except for the first two discretionary activities, the estimate of foregone participation was quite low or non-existent for critical functions like work and medical.

If all 30 subjects participated in each of the nine activities, the total number of person-activities would be 270. The actual trip data showed 138 person-activities. Subjects indicated that they currently wanted access to an additional 28 person-activities for a total desired participation of 166 person-activities, an increase of current unmet demand or desire of 20%.

The possibility of making new activities part of their everyday lives with RIAS was quite evident in the number of people who said they would participate in more and new activities. The total number of person-activities perceived if using RIAS was 202, an increase of 64 from their current level of participation. This is a *hidden* *demand* or desire for 46% more subject- participation in totally new activity types, after exposure to the experimental test site with its auditory cues.

The "desired" data showed that recreation and education activities had the highest percentage of increase of subjects wanting to participate. The same pattern held true for the number of additional people who said they would make those kinds of trips if RIAS was installed. Education was said to attract 188% more people if they could use RIAS. The number of people currently making education trips was eight, and five more thought they were being denied those kinds of trips. But, after using RIAS, 15 additional people stated a desire to attend educational activities. Clearly, this group valued education, but problems of access kept the number of current participants quite small. With RIAS, 178% more subjects desired participation in recreation activities then their current level while 67% and 56% more people reported banking and entertainment activities, respectively. The next two activities that subjects said they would make were not even chosen in the "desired, but denied" question. Originally, there were 17 people who made work trips, and no additional people desired to make them. However, after experiencing RIAS, an additional seven, or a 41% increase, said they would participate in work activities and make those types of trips. In addition, six people reported making current medical trips, and no one expressed that they postponed these kinds of trips because of their inability to travel independently. However, an additional two, or 33%, said they would make that kind of trip if RIAS was installed. An additional 25% said they would attend religious activities, and 8% more said they would make social trips. As everyone already made shopping trips, there were no additional participants noted.

4.3.4. **Summary of Current Activity Participation, Unmet and *Hidden* Demand**

This section has presented data showing travel times, trip frequency, and activity participation. A summary of the basic findings for these blind subjects shows:

- Many subjects do not travel very much, and their trips can be quite short. These people do not often leave home to participate in activities, and their trips appear to be quite close to their home, restricting their activities to familiar areas. They are denied access to opportunities that are available to others in the same area.

- For those who do venture out into the wider environment, their trips are often quite long.

- Activity participation was quite low for many subjects. Three people left home only 2 times during a week, 30% of subjects participated in one or less daily activity outside the home, and 73% of all subjects made 2 or less activity trips per day.

- 67% of subjects reported that they were denied some activities because of visual problems affecting independent travel.

- They reported they would make 31% more trips if they could travel independently.

- After experiencing the additional environmental cues of direction and identity that could be delivered through the use of RIAS, subjects were able to more fully understand that they could gain more access to urban opportunities.

- They reported they would make 107% more trips if RIAS was installed in their environment.

- There was a reported 46% increase in the number of new types of activities that subjects would participate in if RIAS was installed.

- None of the subjects originally thought they did not have access to work because of their lack of independent travel. However, after using RIAS, an additional 41% said they would make work trips.

- Subjects reported trip frequencies for work trips would increase 100% if they could use RIAS.

- Participation in educational activities was desired, after using RIAS, by an additional 15 people over the current level of 8, a 188% increase in the demand for education.

- Estimated trip frequencies increased 165% for education activities if RIAS was available.

Marston & Golledge (1998b) and Marston, et al. (1997) have suggested that one cause of the dismal unemployment level for the severely vision-impaired, 70%, (Kirchner et al., 1999) is the difficulties of independent travel. That includes not just the daily job commute, but, perhaps more importantly, the ability to execute a successful job search strategy when jobs are located in various and scattered urban locations. As non-drivers, the available jobs or educational opportunities for people who are blind that are located in familiar areas must be much less than the aggregate available to the sighted public. That 41% more people thought they would participate in work and 188% more thought they would attend education facilities adds empirical evidence to their argument.

The data in this section about trip behavior indicate that blind people feel they face barriers that limit activities and opportunities because of the lack of environmental cues that restrict independent travel. They often are restricted to local and familiar areas, and many appear to limit their trips and activities to needed functions with a smaller participation in more discretionary activities. Both the number of trips and the types of activities are restricted.

When the environment is made more accessible though the use of additional cues, blind subjects perceived their lives as having many more types of activities and a much higher participation rate in those activities. RIAS appears to reduce the perceived limitation of independent travel by providing a much higher level of accessibility to blind users.

4.4. User Opinion of the Affect of RIAS on Travel Behavior

During the post-test interviews, a series of five open-ended questions was asked. The first three (see Section 3.4, Subject Observations on the Benefits of RIAS) explored specific situations, i.e., street crossings, navigating a terminal, and making transfers. The next question in that series tried to summarize all that had been experienced in the experiment. It was desirable to know how RIAS might affect travel behavior if they were installed city-wide in a manner similar to that in the experiment site.

A post-test question asked "If Talking Signs® were installed citywide on transit, intersections, signs and buildings, how would they affect your travel?" (For all subjects' comments, see APPENDIX 20: Comments about RIAS Affect on Travel Behavior).

4.4.1. Sample of Comments

- "Much less stressful, don't have to ask for assistance, more independent travel, saves time, could make more complicated trips, more trips to new locations."

- "Much easier, safer, more willing to travel, don't need sighted guide, wouldn't have to practice before going, increases self-esteem, travel more often."

- "More frequent trips, go to unfamiliar places, larger range of activities, larger space & further, could comparison shop, rely less on others, could get jobs in wider area, willing to use multiple modes of transit."

- "Wouldn't have to pre-plan as much, more spontaneous, gave me freedom, would know what was around, travel whenever I wanted, travel without assistance, more independently, more confidence, less stress, would be great, independent."

- "Alleviate anxiety of unfamiliar places, more confidence, more self-esteem, independence, enhance my ability to function at maximum, safer travel, reduce my family's fear & anxiety."

4.4.2. User Response Categories

Comments were parsed and sorted based on naturally occurring categories (for this breakdown, see APPENDIX 21: Categorization of RIAS Affect on Travel Behavior).

Table 4.7 Effect of RIAS on Perceived Travel Behavior

"If Talking Signs(R) were installed citywide on transit, intersections, signs and buildings, how would they affect your travel?"

Category	30 subjects
Improves mental state	46
More efficient travel	32
Travel more often	22
Increases independence	20
Travel to more places	20
Increases spatial orientation	12

The 30 subjects made a total of 46 comments that were categorized as “improves mental state.” Little research has been done on the affect of mental attitude on travel for the blind. The present research shows that this is a very strong deterrent to independent living and also strongly supports the installation of RIAS to reduce stress and cognitive overload for the vision-impaired user. Thirteen people used the word “confident” to describe how they felt when using the system. This shows that regular methods of travel for this group contribute to a lack of confidence that can lead to avoiding trips and denying access to urban situations. Safety, security, and feelings of self-esteem were also mentioned many times.

Other comments dealt with feelings of a lack of fear, frustration, anxiety, stress, and inhibitions to travel. One subject said “would have more fun,” and another said RIAS “would make travel much more interesting.” Another person mentioned that the system would “reduce my family's fear & anxiety,” and another said that travel with RIAS was “not boring.” Many subjects mentioned to the researcher how wonderful it was to experience this relaxation in their mental tasks and attitudes. Having this much effect on peoples’ attitude shows the power of added environmental cues, and allows insight into the daily life of this population.

Another 20 comments were made that specified “increased independence.” The words ‘independent’ or ‘independence’ were used 12 times, four people said they “didn’t have to ask,” and four more mentioned they didn’t have to rely on others or sighted guides, need assistance, or “gave me freedom.”

A category called “more efficient travel” had 32 responses. There were many comments that reflected that RIAS reduced travel times and made tasks easier or simpler and more “efficient.” Comments were made to the effect that they didn’t have to remember so much detail and on how the system gave them access to information; one person said “get info in timely fashion,” and another reported, “learn city faster.” One person said, “wouldn't hesitate to travel.” These comments show the hesitation and extra work involved in blind navigation. Even the most independent of blind travelers has to do much pre-planning to effectively travel in new environments. Even more time-consuming is the fact that they also might have to practice a trip before attempting it to arrive at the desired time. People made comments on this aspect by saying, “wouldn't be late so often,” “wouldn't have to preplan as much,” “wouldn't have to practice before going,” and from a blind salesman who made many house calls to new locations, “travel time cut in half.” These 32 comments on how RIAS makes travel efficient show how the addition of identity and direction cues affects their daily life. They also draw attention to travel as it exists today; that it is not efficient and wastes much time and energy, and that accommodations still need to be made to increase access.

A previous section reported on subjects' trip making behavior, and the effects of additional cues were also validated in this question; 22 comments were made to the effect that they would "travel more often." Subjects used the word "more" 18 times, indicating how RIAS would affect their travel. One teacher said "I could be an example for my students to travel more." Several others mentioned how travel would be "more spontaneous," which indicates they would travel more. Another subject said "makes me want to go out much more," and another said "increase desire to travel." These data leave little doubt that vision impairment restricts travel and that auditory spatial cues can greatly help overcome this impedance. How better to achieve the goals of the ADA than by actually making it possible for people to travel more and thereby have more equal access to all that life and the urban environment has to offer?

In addition to those 22 who said they would travel more often, another 20 made comments that were categorized as "travel to more places." They mentioned things like "broaden my horizons" and "could comparison shop," in addition to many general comments about "more places" and new or unfamiliar places. One subject said "could go to 20-30 more places per year." The effect of RIAS on employment was also mentioned here. One person said "could get jobs in wider area," and another said "more options for jobs and housing." Others indicated that their activity space would be "larger" or "wider," and that they could "make more complicated trips" and would be "willing to use multiple modes of transit."

Another 12 comments were made that were categorized as "increase spatial orientation." They mentioned how it helped them know where they were, added certainty to their awareness, and would help them from getting lost, or, if lost, to know how and where to go.

4.4.3. <u>Summary of Subject's Comments on the Effects of RIAS</u>

In Chapter 3, evidence of what respondents said in three open-ended questions about their perception on how the addition of information and directional cues would affect their travel during three specific travel tasks: street crossings, navigating a transit terminal, and making mode transfers was presented. This chapter reported on perceptions of how these cues would affect their travel in general. Their responses to these four questions fall into three major categories: *positive comments on use* at specific tasks and locations, *positive attitudes about how RIAS affects trip behavior*, and comments about a *perceived improved mental state* attributed to the use of these additional environmental cues and information. The summary, Table 4.8, enables one to see how strongly people with vision impairments feel about limits to access that they face whenever they attempt a trip. In addition, their positive comments give strong support to the belief that the environment itself causes many of these problems and that the addition of environmental cues, such as information, location identity, and direction, can overcome current limitations to access caused by lack of vision.

The large number of responses in each of these three categories identifies potential problems and concerns facing independent blind travelers and their access to the built environment.

Table 4.8 Summary of Comments from Four Open-Ended Questions

	Street	Terminal	Transfers	Affect Travel	Total
Tasks and Locations	127	100	90	12	329
Mental Attitude	9	77	51	66	203
Trip Behavior	10	0	35	74	119
Total	146	177	176	152	651

Consider the following points when examining this summary:

- Respondents gave, on average, over five opinions to each question.
- Specific tasks and locations, negative affects, and limited trip behavior currently limit access and quality of life.
- The addition of auditory environmental cues was seen as greatly reducing these functional barriers to increased access in the built environment.
- Positive environmental information and feedback can reduce problems with specific locations and tasks, improve affective states, and thus have positive impact on trip and activity behavior and frequency.

4.5. Reported and Perceived Transfer-Making Behavior

Observation reveals that many vehicle drivers will disobey speed laws, change lanes, run caution lights, go around crossing gates, and certainly change routes in order to save a perceived or actual minute amount of time. Highway traffic engineers are thus very comfortable using "time savings" as the utility function being maximized to best represent typical drivers and their decision to change routes. Recker, Chen, & McNally (2001) state that "travel demand theory, whether derived from consumer demand theory or direct demand principles, is intrinsically rooted in the notion that travel time is a commodity to be saved" (p. 339). They then state that the time-savings would be transformed, by the traveler, into something of intrinsic value; i.e., more time spent on performing activities or increasing the spatial extent of available alternatives for performing activities. These observations on transportation explain automobile use but do little to explain the patterns of transit use and decision-making. In a previous study (Golledge & Marston, 1999), it was noted that some blind people did not mind when the van service took them much longer to get home, as long as they got to their door. Unlike car drivers, it appears that time is not the prime utility to be considered for blind travelers, and any use of the time saved might be transformed into something other than the variables that conventional accessibility and traffic demand models are based on.

Little is known about the motivation or utility that affects decision making when it comes to leaving a transit vehicle in order to make a transfer to a faster route, like an express bus or rail system. Unlike simply changing lanes or turning onto an expressway, this action requires a multitude of actions. Even with perfect knowledge of the system, one must leave the vehicle, walk some distance to the new area, perhaps wait for the new mode, and board the vehicle. Even with a free transfer, one might have to go through a fare gate or access a fare machine. For these reasons, the same type of utility maximization behavior for transit use employed by drivers is not expected. The utility of saving time is confounded by these other necessary actions and efforts. Little is known about what this impedance to making a transit transfer to save time is or what it is based on. The next sections reports on transfer making behavior reported by transit users, both sighted and blind.

4.5.1. **Impedance Considerations while Making a Transfer Decision**

Data were collected in order to understand this impedance to making transfers and to evaluate how it differs for the sighted public and for people with vision restrictions. If the reluctance or impedance to change modes is different between the sighted and people with limited or no vision, these data could be used to measure another restriction to access and allow the computation of another accessibility measurement.

4.5.1.1. Spatial impedance or distance decay

The concept of distance decay stems from Newton's model of planetary attraction or gravity. He discovered that the attraction between two bodies was not only based on the mass of the two bodies, but was affected by the distance between them.

Social gravity models use some form of attraction between places to determine the pull effect and some type of force decay with increased distance (distance decay) to account for the tyranny of distance or other effort. A simple gravity model would be:

$I_{ij}=g(A_1*A_2)/d_{ij}^X$ Where

- Iij is the interaction between two locations, i and j,
- g is a gravitational constant,
- A_1 and A_2 are some measure of the attraction of the two locations,
- d_{ij} is the distance or effort between the two locations, and
- X is an exponent that shows the effort (force) needed to overcome distance.

Calculating a coefficient to model the distance decay is more complicated than a simple exponential function of physical distance. The mode of travel must be considered, but the limitations to travel exhibited by the individual should also be considered. In a previous discussion (see Section 3.1.2.2, Time Penalty Formulation), the need to consider individual constraints on travel was introduced. These constraints include the mode choice and restrictions on an individual's travel abilities and how they both affect the measurement of accessibility will be considered next.

4.5.1.1.1. Effect of Travel Mode Selection

Consider a large employment center located 10 miles across town from a large residential area. Those people using a private car would expend very little personal energy and would be able to make the trip in 15 or so minutes. Without a car, people could take a city bus that might take 40 or more minutes and require some personal energy expenditure for walking to and from the bus stop. Others might ride a bike, which could take an hour and require more energy from the user. Still others might be forced or choose to walk, which could take several hours and much energy output. Thus the resistance to overcome this 10-mile commute is no simple constant and varies greatly depending on which mode of travel is available. Although all these modes would get a person there, the work site is much more “accessible” to a driver than a bus user, a cyclist, or a pedestrian. One cannot calculate an accessibility measure from a job site to the residential area unless the mode of travel is considered.

4.5.1.1.2. Effect of the Person-Mode, or Type of Individual Constraint

Consider now two neighbors who both ride transit to the job site. One is blind and the other is sighted. The field test data previously discussed indicate that it would probably take more time and energy for the blind person to make the exact same trip. In addition, perhaps there is a faster route that requires making a transfer, but one would have to walk an additional several blocks and cross some busy streets. The sighted person might decide to expend the effort to transfer to save travel time, while the blind person might be content to spend more time on the slower bus route rather than deal with extra navigation effort, street crossings, stress, and apprehension. As in the first example, these two people also have different accessibility to the same site, and their resistance or distance impedance is different. Equation 1, on page 94, explains how the variable l is used to designate the person type, i.e., the specific type of access or mode for each individual.

Because of the spatial separation of one vehicle to another vehicle, there is always some effort of distance to overcome when making a mode transfer. The more effort that is needed to overcome this spatial separation, the more impedance there is to overcome and the more reluctance there is to attempt it. The increased impedance for the blind when attempting to make a timesaving transfer is addressed next.

Making a mode transfer can introduce time randomness into the equation for all riders. Will the next vehicle be waiting and ready to go, and will the streets have a WALK or WAIT signal? These and other variables are not controllable by the potential user. This is why timed and coordinated transfer stops are so helpful to users. If not synchronized, a person will wait, on average, at least ½ of the headway time for an incoming vehicle. The experiment question about transfer-making behavior was phrased in order to try and eliminate the effect of this randomness from subject responses.

The subjects were presented with the following scenario:

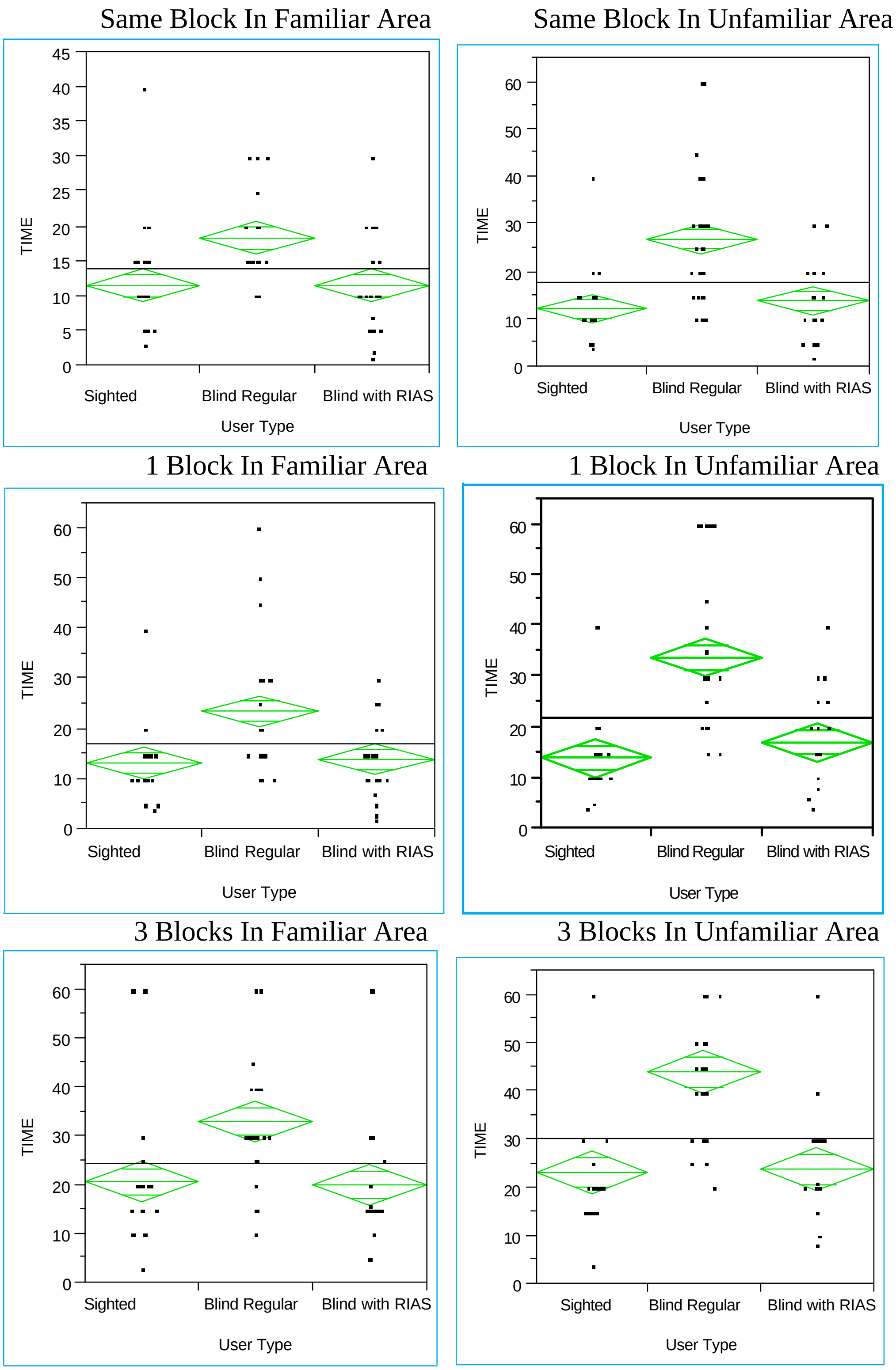
- "For each situation, assume that you are a regular rider of a transit line and your trip home takes you one hour. You find out that a new route such as an express bus or rail service has opened up. You can save some time on your one-hour trip but will have to make a transfer from your regular route to the new route or system. For these situations, assume that there is no waiting time at the transfer site, only the walking and search time and effort. The questions ask about making this new modal transfer in both familiar and unfamiliar areas. How much time would you have to save before you would make a transfer to another mode?"

With this scenario, there is no ambiguity about the time waiting for the new mode vehicle, and, since they were asked how much time they would want to save on a trip to home, the actual walk and search times should not enter into their response. Their estimate should be based strictly on the effort, stress, and apprehensions of the transfer, search, and walk. Each subject responded to this scenario for six different types of transfers: a transfer in the same block, one block away, and three blocks away, in both familiar and unfamiliar areas. Blind subjects were asked this question during the pre-test interview to gauge their current accessibility and also after they had used RIAS in the field test. A group of 30 sighted people, matched by age and sex to the blind subjects, also reported their answers (see Section 1.6.6, Sighted Subjects for Baseline). The sighted group data act as a control for comparison with the two blind data sets.

4.5.2. Transfer Data Analysis

As would be expected from 30 subjects of various ages and sex, there was a wide range of answers to these questions. Figure 4.5 shows the distribution of these data for each subject for each of the six transfer tasks. Table 4.9 shows the number of people in each group, who showed the most reluctance to change vehicles for potential time-savings, and reveals that the utility of saving time is overshadowed by other factors. For the blind using their regular skills and aids, it appears that comfort, secure and known surroundings, uncertainty, apprehension, and fear are affective states or utility functions to be considered. Even for the sighted control group, some people put a very high value on other utilities than saving a small amount of time.

Figure 4.5: Data Points for Six Transfer Scenarios



The horizontal line in the diamond shape on the chart shows the mean of each set of data points, and the diamond shows the 95% confidence level of that mean. At a glance, one can see that the reported time savings required is much higher, in each category of distance and area familiarity, for the blind using their regular methods. The addition of auditory and spatial information makes those estimated data quite similar to that given by sighted respondents. The means diamonds for the sighted and the blind, when they considered RIAS, there is a large overlap, showing that there is no significant difference in their data. P values are discussed later.

Many of the people reported they would require a large amount of timesavings before making a transfer, and Table 4.9 shows the percentage of responses with high amounts (30 to 60 minutes) of time that they would rather stay on a known vehicle than to make a transfer and save that time.

Table 4.9 Percent of Subjects with High Resistance to Transfer Vehicles.

# of Extra Minutes Would Stay on Vehicle	Percent of Subjects		
	Blind Regular	Blind W/ RIAS	Sighted (control)
60 (no transfer)	18%	1%	3%
40 or more	36%	2%	5%
30 or more	71%	16%	7%

The utility function of saving time is clearly not what motivates all transit users, especially for the blind. Fully 18% of the responses to the six transfer scenarios showed that the blind would "waste" 60 minutes rather than change vehicles. Over a third, 36%, would spend an additional 40 or more minutes than attempt a transfer, and almost three out of four (71%) would rather spend an additional 30 minutes or more than make a transfer. That amount of *resistance* to saving time, as compared to the sighted control group, demands closer analysis.

Table 4.10 shows the mean responses from the three subject groups for the six (distance and familiarity) transfer task scenarios. For example, the sighted (control) subjects said they would not make a transfer in the same block in a familiar area unless they could save 11.6 minutes out of the 60-minute trip home. They would walk a block if it could save them 13.1 minutes from the original trip time, but they would need to save 20.8 minutes before they would walk three blocks for a transfer. In contrast, the reported mean times were much higher for blind subjects using their regular skills and aids. These subjects reported that they would have to save 18.3 minutes to make a transfer in the same block, 23.5 minutes to go one block, and a mean of 33 minutes to go three blocks in a familiar area in order to attempt the transfer.

Table 4.10 Mean Responses for Six Transfer Scenarios

		Mean Saved Time To Make a Transfer		
Area	**Subject Type**	**Same Block**	**1 Block**	**3 Blocks**
Familiar	Blind, Regular Method	18.3	23.5	33.0
	Blind, with RIAS	11.5	13.9	20.0
	Sighted	11.6	13.1	20.8
Unfamiliar	Blind, Regular Method	27.0	33.8	44.0
	Blind, with RIAS	13.7	16.9	23.8
	Sighted	12.1	14.0	23.0

The discussion that follows is focused on a set of graphs that show the reported mean times and a linear trend line for different combinations of conditions. Figure 4.6 shows the data for three subject groups making a transfer in a familiar area. In all three cases, the further people had to walk to make the transfer, the more time they wanted to save.

The trend line for the blind subjects using their regular methods of navigation was the steepest and had a much higher initial resistance. The sighted subjects show a flatter linear trend. There was a highly significant difference between transfer behavior reported by the sighted (control) and by the blind subjects using their normal technique ($p<.0001$ or less for all three distances—same block, 1 block and 3 blocks). After the blind subjects used RIAS in the experiment, they changed their transfer-making perception and thus the impedance to accessibility. The estimated means were much lower than what they originally reported as their regular behavior. This difference for the two blind conditions was also highly significant (p<.001 or less for the three distances). In addition, the behavior reported by the RIAS users was almost identical to the responses from the sighted control group. In fact, there was no significant difference between those two groups (P<.95, 0.65, and 0.80 for the same block, 1 block, and 3 blocks, respectively).

Figure 4.6 Transfer Decisions in a Familiar Area

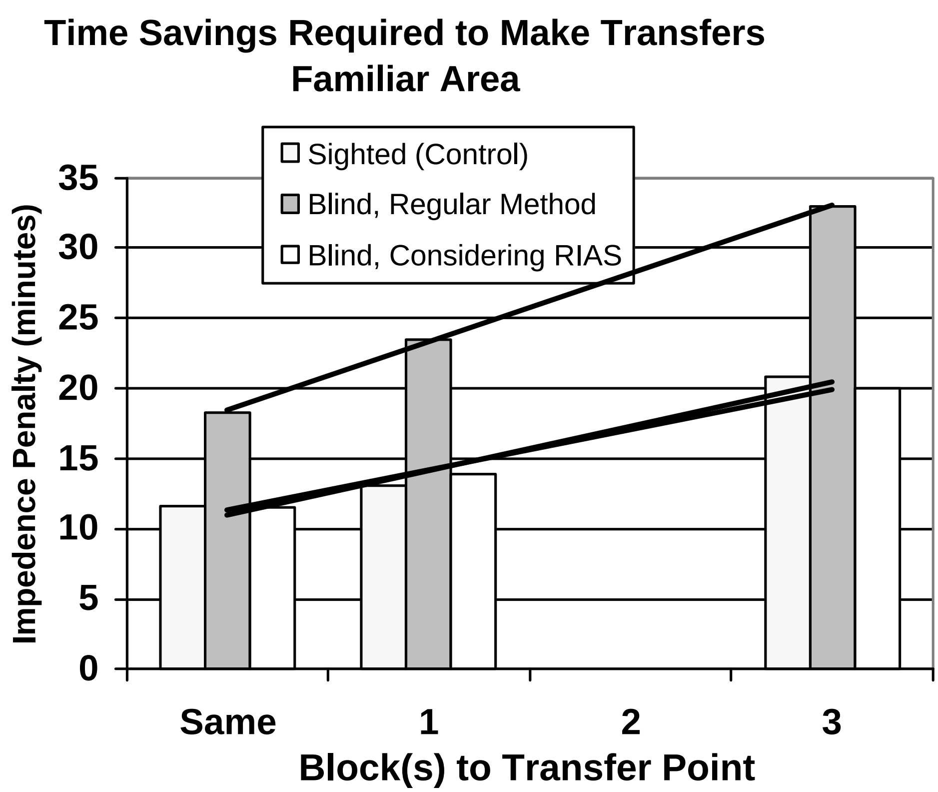
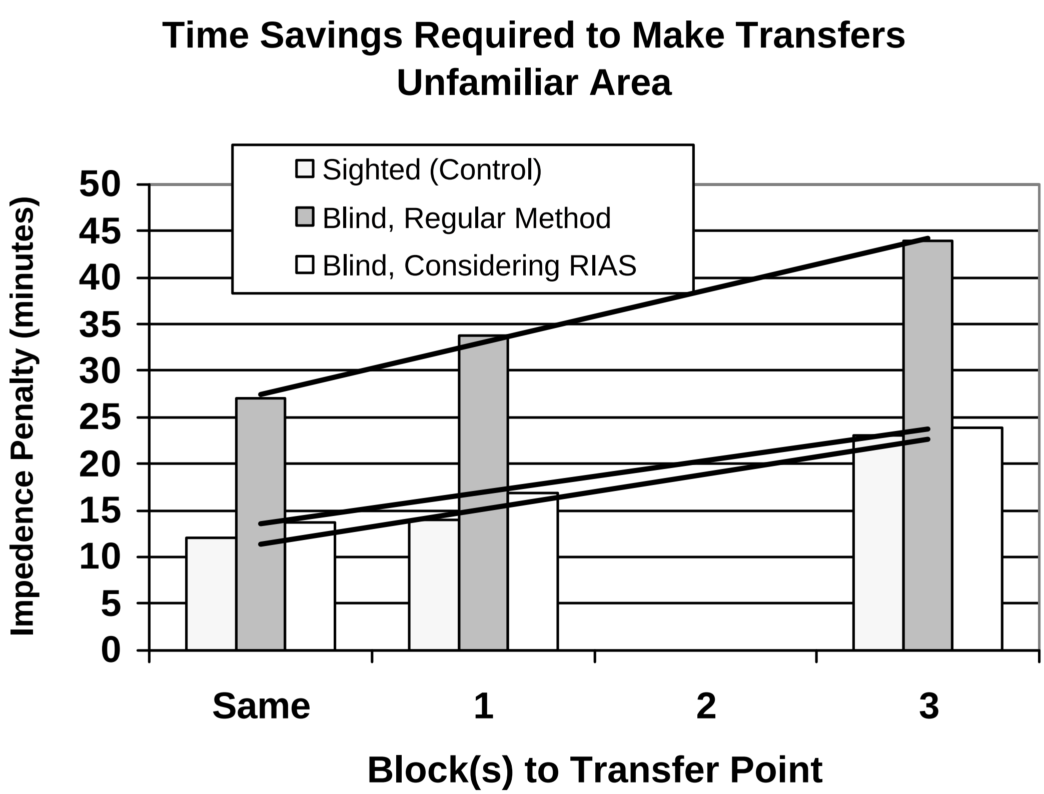


Figure 4.7 shows the data for three subject groups making a transfer in an unfamiliar area. The results look quite similar to the familiar area, although the initial resistance and slope of distance decay is higher for each group. There was a highly significant difference between transfer behavior reported by the sighted and by the blind subjects using their normal technique ($p<.0001$ or less for all three distances). After the blind subjects used RIAS in the experiment, they reported much different perceived transfer-making behavior.

Figure 4.7 Transfer Decisions in an Unfamiliar Area



This difference for the two blind conditions was highly significant (p<.0001 or less for the three distances). In addition, the behavior estimated by the RIAS users was similar to the responses of the sighted control group. There was no significant difference between those two groups (P<.38, 0.12, and 0.79 for the same block, 1 block, and 3 blocks, respectively).

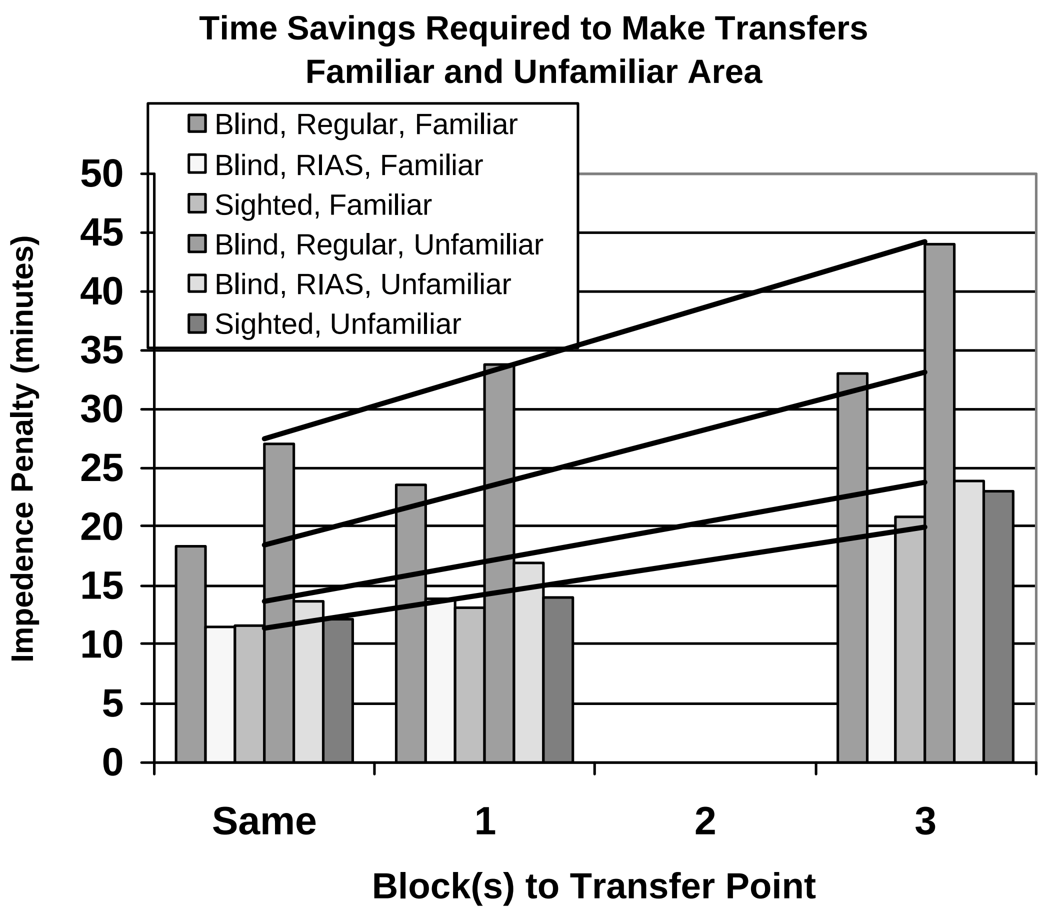
4.5.3. Effect of Area Familiarity on Transfer Making Behavior

Unfamiliar areas present problems when cues, paths, and locations must be learned over time. Figure 4.8 compares the mean reported times for the three groups in both the familiar and unfamiliar areas.

Sighted respondents reported little difference between familiar and unfamiliar areas, and no significant difference was found (p <.16, 0.13, and 0.12, respectively for the same block, 1 block, and 3 blocks). The effect of unfamiliar environments on the people with vision restrictions is strongly shown demonstrated by a comparison of their estimated transfer behavior. Same block times went from 18.3 minutes to 27.0, 1 block times from 23.5 to 33.8, and 3 block times from 33.0 to 44.0 minutes when comparing familiar and unfamiliar transfer areas. The difference in the two familiarity conditions, for the subjects using their regular methods, was highly significant (p <.001 or less for all three distance measures). Even with the vastly lowered estimated time for transfer behavior after using RIAS, the effect of area familiarity was still in effect, although not nearly as strong. Same block times went from 11.5 minutes to 13.7, 1 block times from 13.9 to 16.9, and 3 block times from

20.0 to 23.8 minutes when comparing familiar and unfamiliar transfer areas. The data on area familiarity differences were significant (p <.002 or less for all three distance measures).

Figure 4.8 Effect of Area Familiarity on Perceived Transfer Decisions



4.5.4. Modeling Transfer Making Behavior

Since only three distance data points were measured, an exponential decay function was not used, but, rather, a linear model of the form:

Y = B +A*X or

R = IR + T*D where

- R = Resistance (total time savings needed to attempt a transfer).
- IR = Initial resistance to make a transfer
- T = Time resistance per interval of distance
- D = Distance in blocks

This liinearization simplifies the data so that the initial resistance to make a transfer (IR) and the distance decay in minutes as distance increases (T) can be measured. Table 4.11 shows the initial resistance to travel and the per block resistance for the six test conditions.

Table 4.11 Linear Model for Making Transfers

	Familiar Environment			**Unfamiliar Environment**		
		Intercept	**Slope**		**Intercept**	**Slope**
		Initial Time Resistance	Time per Block		Initial Time Resistance	Time per Block
Blind, Regular	R=	18.5 +	4.9D	R=	27.5 +	5.6D
Blind with RIAS	R=	11.3 +	2.9D	R=	13.7 +	3.4D
Sighted (control)	R=	11.0 +	3.2D	R=	11.3 +	3.7D

The initial resistance to make a transfer in a familiar area for blind travelers using regular methods is 18.5 minutes and 4.9 minutes for each additional block they have to walk. In contrast, the sighted subjects had a mean initial resistance of 11.0 minutes to make a transfer and 3.2 minutes per block traveled. After using RIAS, the perceived initial resistance to make a transfer for the blind dropped to 11.3 minutes and 2.9 minutes per additional block.

When comparing a familiar area to an unfamiliar area, the blind regular group reported their initial resistance to making the transfer increased nine minutes to 27.5, and the resistance or distance decay increased 0.7 minutes to 5.6 minutes per block when navigating in an unfamiliar area. For the sighted, the area effect was minimal with the initial resistance increasing only 0.3 minutes to 11.3, and the decay rate increased 0.5 minutes per block. The RIAS users estimated their initial resistance increasing by 2.4 minute to 13.7, and the per block impedance increased by 0.5 minutes while transferring in an unfamiliar area.

4.5.4.1. Impedance per Block

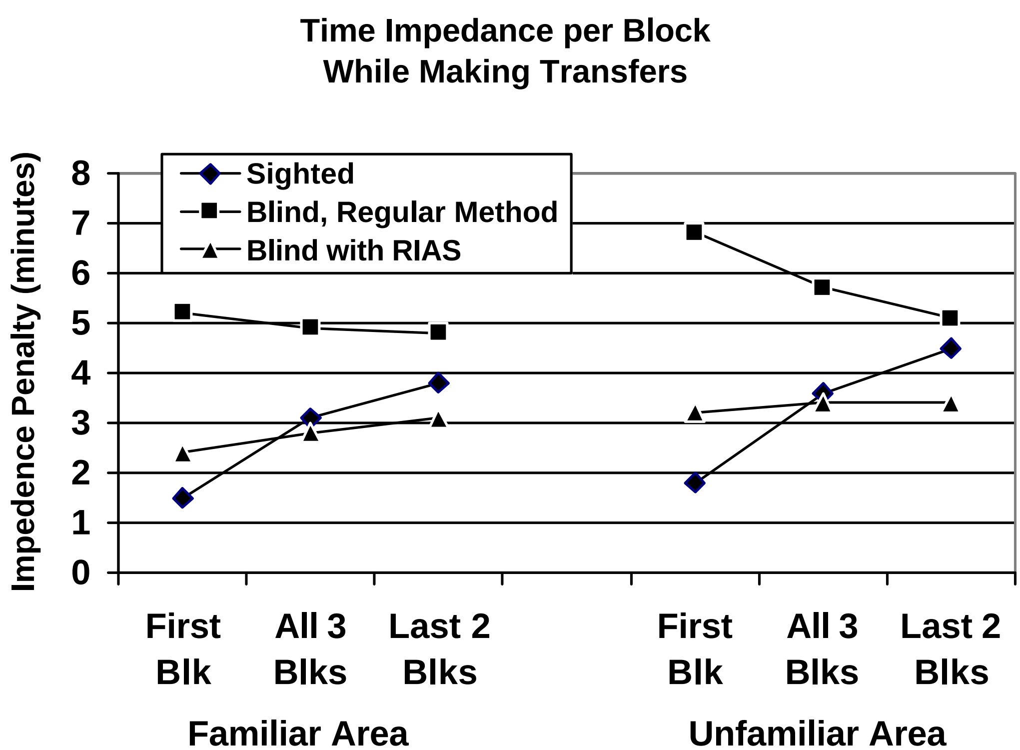
The initial resistance (IR) to transfer in the same block included the inconvenience of leaving the vehicle and finding the next transfer point. Any variation in walking distances further than the same block would strictly measure the effort of the extra distance, since the transfer point search was included in the same block data. Subjects considered a distance of one block (from the same block transfer to the one block transfer), the entire three blocks (the difference between the same block times and the three block times), and the last two blocks (the difference from the one block times and the three block times). Figure 4.9 shows the per-block resistance to walk in minutes for the three groups in both conditions, familiar and unfamiliar areas.

The variation in mean distance resistance between the three groups was previously examined, but there also exists a variation in how increased distance affects their perceived resistance to walk. The graph shows distinct "signatures" or patterns of the perceived effort of walking. These patterns hold for both familiarity conditions. For the sighted subjects, their smallest resistance per block was for the first block walked. The "effort" of walking three blocks resulted in a much higher resistance per block. Walking the last two blocks had the highest resistance to overcome. Of the three groups, it was the sighted that had the most reluctance to walk as the distance increased.

The pattern was reversed for the blind people using their regular methods. Their highest resistance was in walking the first block and crossing a street. The per-block resistance decreased for the three-block distance and further decreased for the last two blocks. This group seemed to not be bothered by extra walking effort as much as the sighted. A blind person, well trained in Orientation and Mobility procedures, may not seem to consider the walk tasks to be very difficult, rather, it is the task of finding vehicles, signs, boarding areas, or stations that pose the bigger problem.

After using RIAS, subjects estimated their transfer times, and the resulting resistance trend was more like a combination of the other two groups. The graph shows an almost flat line because they estimated a more constant time resistance for each block traveled. The possibility of using RIAS changed their resistance signature from a decreasing trend line in their regular method to a slightly increasing line, more like the pattern the sighted exhibited.

Figure 4.9 Distance Impedance per Block



4.5.5. <u>Summary of Impedance to Make Transfers</u>

- Saving time is not the only factor when people consider making a transfer of transit vehicles.

- Sighted transit users reported resistance to transfer probably based on affective attitudes such as less personal effort, comfort, and accepting a "sure thing," rather than adding any more uncertainty to the trip.

- Blind subjects reported a much higher resistance to making transfers, as their resistance to uncertainty would be much higher without the benefits of visual cues.

- Sighted users reported little difference in resistance to transfer based on the familiarity of the area, but unfamiliar areas elicited much higher resistance data than familiar areas for the blind users.

- Blind users showed a higher resistance to overcome the walking and search effort to find a transfer point.

- After using RIAS, blind subjects reported transfer making behavior that was very similar to that reported by the sighted users.

Time penalties, difficulties, and uncertainty of navigation during transit tasks were examined in Chapter 3. Those timed trials, and previous field tests on finding vehicles and making transfers (Golledge & Marston, 1999; Golledge et al., 1998b), help confirm the perceptions reported here. The lack of full information on where the transfer point is, what route or vehicle is served, finding the vehicle, crossing streets, and navigating the walk appears to markedly increase the resistance to transfer much more than it does for the sighted.

Uncertainty is increased during navigation without sight, more mistakes can be made, and there are more barriers to overcome. This uncertainty is increased in unfamiliar areas, and, by staying on a known route or vehicle, transit users assure their seating and do not have to confront situations that might cause uncertainty, new decision tasks, or obstacles. At each decision point, a person without vision might make an error or not reach their goal, and as the number of decision points increases along a route, the probability of making a path or even trip-altering mistake increases rapidly.

The difference in the times reported by the sighted and those from the blind indicate another restriction to access for people with vision restrictions in the built and transit environment. The perceived reduction in blind users' resistance, when considering RIAS, was similar to that of the sighted and indicates that the paucity of accessible identity and directional cues in the environment helps cause the increased resistance for that group, when using their regular methods.

These data show that the impedance to efficiently make transfers directly affects the ability of a blind traveler to take full advantage of a transit system and achieve the degree of accessibility that the system was designed to provide. The lack of information and environmental cues directly and negatively impacts the ability of those with vision restrictions. These data on transfer decision making measures another barrier to, and constraint on, transit and travel accessibility for those people with vision restrictions and the models quantify the initial and distance impedance.

4.6. Spatial Knowledge Acquisition and Cognitive Maps

In this section, two experimental tasks that attempted to measure the amount of spatial knowledge that had been acquired while performing the field test are examined. Much has been written about spatial knowledge acquisition and the creation and use of mental or cognitive maps regarding people with severe visual limitations. For a review, see such authors as Dodds, Howarth, & Carter (1982), Foulke (1983), Golledge (2001), Golledge, Blades, Kitchin, & Jacobson (1999), Golledge, Kitchin, Blades, & Jacobson (2001), Golledge, Klatzky, & Loomis (1996), Jacobson (1993), Kitchin (1994), Kitchin & Jacobson (1997), Lockman, Rieser, & Pick (1981), Long, Rieser, & Hill (1990), Passini (1986), Rieser, Guth, & Hill (1986), Strelow (1985), and Thinus-Blanc & Gaunet (1997).

Despite these reviews and many experiments, there is still little agreement on how blind people perceive, learn, understand, and internalize geographic spatial information. However, these research reports do uncover information about knowledge structure and content and allows for measurement of some kind of "accuracy" compared to the real environment. Results from the following two experiments demonstrate the lack of agreement about the skills of people with various degrees of visual experience. An elegantly crafted experiment showed the effect of specific visual knowledge (blindfolded sighted), previous general visual experience (adventitious) and no visual experience (congenital). Subject made comparative distance judgments between groups of three named locations (choosing the two that were closest and the two that were furthest apart). The data showed that, when making distance judgments through walls (as the crow flies), those with no previous vision experience had the most error, those with specific visual knowledge of the layout had the fewest errors, and those with previous visual experience, before losing their sight, fell between those other two groups (Rieser, Lockman, & Pick, 1980). Another group of researchers also tested blindfolded sighted, adventitious and congenitally blind people. Those subjects performed various physical tasks, such as retracing a multi-segment route in reverse, returning to the origin after being led around linear segments, and pointing to targets after locomotion (Loomis et al., 1993). In contrast, they found little indication that prior visual experience influences spatial competency. These differing results can be explained, at least partially, through a closer examination of the subjects and methods. Rieser et al. tested four subjects in each group, they were all very familiar with the layout, the blind subjects were in the process of receiving blind skills training, and the test was a non-physical recollection of previous knowledge. In the Loomis et al. experiment, 12 subjects were in each category, they were more independent as travelers, they had no previous knowledge of the environment, and the layout was physically experienced during the test. This brief summary of two well conducted experiments show some of the reason for differences in theories relating to the skills of people with blindness. These different theories are discussed later (see Section 7.2.1, Relevance of this Work to Spatial Organization Theories of the Blind).

The intent of the present research is not to add to the wealth of literature about how spatial information is processed and stored into the cognitive map of the blind user. Rather, the focus is on examining what can be learned about the source of restrictions that affect travel and accessibility for the blind. At its core, spatial knowledge acquisition and cognitive map accuracy is a primary concern because these have some utility to the user; the more accurate an individual's spatial knowledge and mental map, the easier it would be for a person to navigate an environment and gain access from one location to another. In this section, how the utility of the subject's knowledge is shown through active field tasks in navigating a new environment is examined.

In the field tests, the blind subjects using RIAS were significantly faster and more efficient in navigating and finding their destination goal than without the system. To navigate in a new environment, people must actively orient themselves to an object or location destination and proceed toward it. But, just as a sighted person might be able to complete many path segments and still not acquire a good spatial representation of the area, the navigation accuracy and efficiency, exhibited by RIAS users, does not necessarily mean that spatial knowledge has been acquired, processed, and stored.

Sholl (1996) argues that there are two processes used for successful acquisition and understanding of spatial layouts. People must understand not only the dynamic person-to-object relationships that occur when navigating a route, but also the stable object-to-object relationships that are anchored in the environment. Object-to-object relationships can be quite difficult for the blind because there are no visual cues or distal vistas providing knowledge of the spatial arrangement between objects. In addition, optic flow cannot be accessed to monitor the changing relationships of objects while in motion. This is why some blind people, though well trained to follow a path, might not easily understand the environment's spatial arrangement - the relationship between all objects - and might be ignorant of entire sections of space. For some blind people, any deviation off a known route is "terra incognitae," and sticking to a known route is the safest, most secure, and, therefore, "optimum" option. This means that one might have learned and be able to walk a path from A to B and then to C but have little idea how to go from C to A without retracing the route, back through B. People with limited or no vision might not have a good idea of the object-to-object relationship between C and A, and this task of making "shortcuts" is made even harder because a blind person might have no idea of what type of environment or terrain lies between C and A. Therefore, potential barriers, obstacles, unsafe surfaces, and general fear and apprehension about new environments restrict some blind people to known routes and locations.

Since cognitive maps are an internal process, there is no way, as yet, to access and analyze them except through measurement of surrogate and externalized methods. There appears to be no precise and accurate correspondence between internal spatial knowledge and what can be discovered through the use of these externalized measurements or *spatial products*. For more information on externalized *spatial products*, see Golledge (2001) and Kitchin & Jacobson (1997). The use of various spatial products can lead to different observations about an individual's cognitive map. This problem is evident in the wide range of theories regarding spatial knowledge acquisition for people with vision restrictions. When different results are found using different spatial products, it makes it difficult to know which measure is "correct." This produces weak convergent validity, but, when several spatial products reveal similar results, stronger convergent validity is evident.

To increase this methodological validity, subjects' *cognitive maps* and *spatial knowledge* (using two different kinds of *spatial products*) were examined. A wayfinding and navigation product was used when subjects were given the opportunity to make several shortcuts in the field test. The other method used was to examine cognitive maps by asking questions about object-to-object spatial relationships, with a verbal description product, using a simple *sentence framing* technique. The verbal description experiment is discussed later in this section.

Every attempt to uncover the internalized map knowledge by an *external product* has correlation problems. Using navigation tasks is no exception, and they also add confounding factors. Subjects might use environmental cues, in addition to their spatial knowledge, to guide their action. On the other hand, well-controlled laboratory experiments might have less noise, but they can raise questions of external validity. For example, is the relationship between objects on a tabletop experiment actually relevant to the person or theory being studied? Can those results be extrapolated to real-world or geographic spaces? When considering the important tasks of understanding how the blind perceive, learn, and, especially, use real-world space, much can be said for tests that reveal spatial knowledge that exhibits a high degree of usefulness or utility to the people being studied.

4.6.1. Spatial Knowledge Revealed by Navigation and Wayfinding Tasks

Chapter 3 discussed two of the field transfer tasks where subjects were allowed to take any route they chose to locate the next task destination. Figure 3.5 shows the routes taken for transfer task 3 and the location of the RIAS transmitters. There was occasional construction activity , and therefore subjects were guided by the researcher out the front door of the terminal and turned left toward Townsend Street. They turned left again and walked down Townsend to a cabstand on the street. No information was given about street names or turn direction; subjects just walked along with, and were guided by, the researcher. Subjects were then told to find the water fountain in the terminal. No additional path information was given. The terminal had side doors facing Townsend Street that led into the station, and these doors were labeled with RIAS transmitters. No mention had been made of these doors.

To eliminate variance and noise in the data, only those subjects who had no residual vision are reported on. None of those could see shapes, or objects up close. There were 20 such subjects in the sample of 30; 11 subjects used their regular method for their first trial at the terminal, and nine used RIAS for their first trial.

Air currents and crowd noise might have been available as cues for the blind to enable them to notice or locate the doors to the street. For the 11 blind subjects that used their regular methods first, only three (27%) made the shortcut through the side doors. The rest retraced the longer path they had previously taken to the cabstand. In contrast, all nine (100%) of the blind subjects using RIAS on their first trial used the shortcut. Although they had not been looking for the door, they appear to have learned about it while scanning around during the previous or current tasks. No formal data was collected, but the researcher noticed that some subjects heard the side door message while they were looking for Track #2 (in the previous sub-task), after leaving the track door on the guided walk, or from the outside while going to the cabstand. It was also possible to hear the message while starting to retrace the original path if they were scanning in that direction. Table 4.12 shows the data for both possible shortcut trials (subjects using *NRIAS* 2nd did not perform these tasks).

It also shows the results for the *within subject* condition where subjects tried RIAS on their second trial. Results for the subjects who reported they could see shapes and objects up close are also shown, along with the total for all 30 subjects.

The second route where a shortcut was possible occurred after subjects visited Track Door #11 at the far end of the terminal. See Figure 3.7 for the diagram of that route. From that door, they were told to go to the street corner that had first been visited, but to prepare to cross the other street. Again, no street names or directions were given. There was a series of doors across from the track doors that led to a plaza opening up to the street. This is the kind of situation where, even if a blind person knew there were doors available, they would not know what was outside the doors, or whether they could get to the corner without barriers or obstacles in the way. Only two (18%) of the eleven blind subjects, in the first condition, used the shortcut through the doors leading to the outside plaza; the others all walked back down the hall in the opposite direction and went out the main exit that they had learned in the first task. For the nine blind subjects that used RIAS first, eight (89%) used the door opposite the track door to directly access the corner. The RIAS transmitter above the door had the message, "Exit to 4th and King plaza." They must have found this message while scanning around the environment (either while walking to Track #11 or when starting the trip to the corner). The message, giving the direction and identity of the doors, appeared to provide them with enough information to attempt navigation in a totally new area of the environment (the plaza area).

Table 4.12 Ability to Make Shortcuts

	Cab-stand to Water Fountain			Track Door #11 to Corner of King and 4th		
	Regular Method 1st	Using RIAS 2nd	Using RIAS 1st	Regular Method 1st	Using RIAS 2nd	Using RIAS 1st
No Vision	N = 11	N = 11	N = 9	N = 11	N = 11	N = 9
	27%	91%	100%	18%	64%	89%
Some Shape	N = 2	N = 2	N = 4	N = 2	N = 2	N = 4
	100%	100%	100%	0%	50%	100%
Some Objects	N = 2	N = 2	N = 2	N = 2	N = 2	N = 2
	50%	100%	100%	50%	100%	100%
All Subjects	N = 15	N = 15	N = 15	N = 15	N = 15	N = 15
	40%	93%	100%	20%	67%	93%

The propensity to make shortcuts and the spatial knowledge awareness exhibited here is a true measure of the utility of their cognitive map. Being able to make shortcuts shows an understanding of the object-to-object spatial arrangement and the ability to make efficient route choices, which is the goal or utility of a good mental representation of an environment. The literature (see above citations) and statements from blind people state that making shortcuts is difficult, and that some people retrace their steps rather then try to figure out if it is possible to take a new route through the environment. As in the case of a vision-impaired person's impedance to making transit transfers (see Section 4.5.1, Impedance Considerations while Making a Transfer Decision), they would rather stay with a known environment rather then risk obstacles and barriers in a new environment, thus avoiding apprehension and stress. This inability to access the “best” path is a major restriction to access in new environments and limits independent travel and learning spatial arrangements efficiently. Instead of being taught a new path by a friend, stranger, or O&M instructor, blind people using RIAS appear to learn an environment on their own and access the environment in the way that it was designed. An additional benefit of using a system like RIAS is that a person can learn about locations they were not even looking for. The existence of the doors that were used for the shortcuts appear to have been learned while performing previous, unrelated tasks. Subjects did not actively search for a shortcut when presented with the next destination; rather, they had already learned and stored that information while doing other tasks. User comments reported during the experiment also verify how important this ability to discover new knowledge is to the blind. They are able to learn new environments and locations without having to stick to a known path, follow other people, or ask for help. Subjects often mentioned “independence” in their comments, and the ability to learn new environments without help and the ability to make shortcuts are major sources of this feeling.

For the two shortcut tests, blind people using their regular method on their first attempt had 22 chances to make a shortcut, and only five times (23%) were subjects able to take full advantage of the potential accessibility in the environment and use the shortest path. When using RIAS, first time subjects had 18 chances to use a shorter path, and all but one (95%) did so. As an objective measure of accuracy in navigation, the ability to reduce distance by making correct spatial decisions is fundamental. RIAS demonstrated its ability to save distance and time for subjects in new environments, making it easier to gain access to more activities.

4.6.2. Spatial Knowledge Revealed Through Verbal Statements

Another way to measure cognitive map knowledge is to examine spatial products revealed by verbal or written descriptions. A type of *sentence framing* technique was used where subjects were asked to give the answers to a series of 20 questions that dealt with both spatial arrangements and knowledge of the environment. Questions that dealt directly with spatial relationships between concession stands and the ticket window and with relationships between amenities in the waiting room area were used. Other questions dealt with the spatial arrangement of the track doors, information about the traffic lane configuration of the streets they crossed, names of the streets, and other more general spatial relationships in the terminal environment. To reduce variance and increase validity, only the subjects who had no useful vision are reported on.

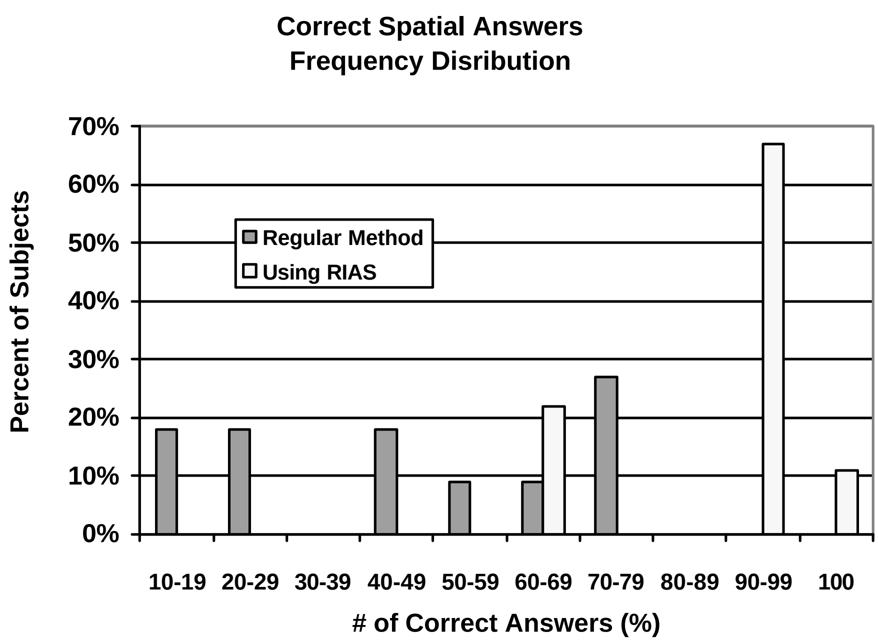
The spatial questions were asked after five transfer tasks were completed, in the *NRIAS* 1st, *NRIAS* 2nd, and *RIAS* 1st conditions. Subjects were walked outside the station and rested on a bench facing away from the station to eliminate any cues about the questions that followed. Subjects had not been told that any spatial questions would be asked and so had no way to cognitively prepare for a spatial test.

The questions were given in such an order that no previous question could give the answer to any further question (see APPENDIX 4: Subject Questionnaire for San Francisco RIAS Experiment). Of the 20 questions asked of the 11 subjects with no useful vision using their regular method on the first trial, 44% were answered correctly. When these same subjects used RIAS on their second trail, the mean number correct rose to 84%. In comparison, the nine subjects who used RIAS for their first attempt in the field test got 88% correct. The use of RIAS was highly significant; the difference between the blind group using their regular method and using *RIAS* on the second try was ($p<.0001$) and, when compared to the *RIAS* first condition, was ($p<.0002$). Those using *RIAS* first actually had better results than the group who used it second, but the order of the condition had no significance ($p<.56$).

4.6.2.1. Frequency Distribution of Spatial Knowledge Performance

The frequency distribution of each person's correct scores in their first trial, between the two groups, was highly skewed in favor of those using RIAS. The worst scores per subject, out of 20 questions, for those using their regular methods, were two twos, a four, and a five. The best scores for that group were a 13, two 14's and a 15. In contrast, the worse scoring two subjects using RIAS in their first attempt got 12 correct. Six subjects missed only one question (19 correct), and one person got all 20 questions right. What made this even more remarkable was that the control, the first time sighted user (FTSU; see Section 1.6.6, Sighted Subjects for Baseline) got just 16 (80%) correct. RIAS gave so much information that seven of the nine blind subjects using *RIAS* first scored higher on these questions than the first time sighted user. Figure 4.10 shows the frequency distribution of each subject's correct answers on their first trial, a measure of their spatial awareness.

Figure 4.10 Frequency Distribution of Spatial Awareness



4.6.2.2. Frequency Distribution of Answers to Spatial Questions

The distribution of how well each question was answered was highly skewed toward the RIAS condition. The three "easiest" questions were answered correctly in the regular method condition by 73, 73, and 82 percent of the subjects. In contrast, the three hardest questions for RIAS users, after their first field trial, were answered correctly by 67% of the subjects. Eight of the questions were answered correctly by 100% of the subjects, and another five questions were missed by just one subject when using RIAS. In the *within-subject condition,* all regular users scored better after using RIAS. One person answered an additional 13 questions correctly, another 10; three got nine, and two more got eight more correct on their second trail with RIAS. For each of the 20 questions, those who used *RIAS* first scored higher than those who used their regular method first. Table 4.13 shows the questions numbered and ranked from hardest to easiest in the blind regular condition.

A variety of different questions was asked, and the next section will discuss these various groups of spatial and information questions. It is difficult to use externalized spatial products to accurately measure the internal cognitive map. The main interest here is how that map has real utility for blind travelers, which information is the hardest to learn without vision, and how these gaps in the cognitive map can affect independent travel and accessibility. Using a mixture of question types removes bias caused by the researcher's choice of the "correct" way to measure the internalized map and lets the subjects more clearly speak to the contents of their cognitive map and reveal which tasks are difficult to master.

Table 4.13 Spatial Question Analysis

Spatial Questions	Trial #1 Regular Method	Trial #1 Using RIAS	Type	Q #
	Percent Correct			
Which track # did we first start at?	9	78	BI	1
Where do the doors across from tracks 9-12 lead?	18	78	BI	2
What street is the taxi stand on?	27	67	SN	3
What street did you cross to get to the Muni rail platform?	27	100	SN	4
What street is in front of the train station?	27	100	SN	5
How many train tracks serve the Caltrain station?	27	100	BI	6
Which tracks are closest to the waiting room?	27	67	TS	7
How many lanes and what direction (one way / two way) is this street [to the Muni rail platform]?	27	89	SI	8
Which tracks are closest to the main entrance?	36	67	TS	9
How many lanes and what direction (one way / two way) is this street [in front of the train station]?	45	78	SI	10
Which track door # is closest to track door 7?	45	100	TA	11
Which track door # is closest to track door 6?	55	100	TA	12
What concession counter is closest to the train area?	55	89	CS	13
Which concession counter is closest to or across from the ticket window?	55	100	CS	14
What amenity is closest to the phone?	55	100	AS	15
What amenity is furthest from the phone?	55	89	AS	16
The highest track # is closest to which of the other transit modes we visited	64	78	GS	17
Which amenity is closest to the water fountain?	73	89	AS	18
Which concession counter is closest to the front street?	73	89	CS	19
What concession counter is closest to the Candy counter?	82	100	CS	20
Mean correct spatial questions	**44**	**88**		

4.6.2.3. Cognitive Map Knowledge And Spatial Awareness In A New Environment. The question types and answers in the general order they appear on the table, sorted from hardest to easiest to learn, are discussed. The order was determined by the answers of the people using their regular methods of navigation.

4.6.2.3.1. Building Information (BI) Questions #1, 2 and 6

Only one blind subject answered the hardest question (#1) using regular methods of orientation. Even our FTSU (control) did not know the answer. Subjects were walked to the beginning location of the test with their eyes closed and started with their back to the door. There was little utility in knowing where they started from and few cues available to gain this knowledge. With RIAS, subjects got this question right 78% of the time. The next hardest question (#2) asked about the doors across from tracks 9-12 and where they led. Only two (18%) subjects knew the answer without RIAS. Since most of the regular method subjects did not even use these doors (for the shortcut) they had little knowledge that the doors even existed. With RIAS, 78% knew the correct answer. The other question put in this general building information group was #6, asking for the total number of tracks at the station. The highest track number actually visited was #11 and, without knowledge of the track layout and extent of the hallway, there were few ways to know the correct answer. For the regular orientation group, three people (27%) knew there were actually 12 track doors. All subjects using RIAS got that question correct. These three questions asked about information that was not directly needed to complete the field test, and the results show that this information was not learned by most of the regular method subjects. Those using RIAS picked up this information quite well, even though it was not critical to the task and they were not required to navigate to those locations. This ability to pick up information about locations while doing other tasks is often impossible without sight, unless an active and physical search is undertaken. To be able to learn about the environment while simply walking through it is what vision allows, and this ability to easily gather spatial information helps make sighted navigation so much more efficient.

4.6.2.3.2. Street Names (SN) Questions #3,4, and 5

The names of the streets were never mentioned during the experiment, although some subjects certainly learned them before making the trip to the Caltrain station. Street names are also not necessary to make successful locomotion but can add enormously to general spatial understanding and the ability to make crucial spatial decisions. Questions 3, 4, and 5 all dealt with the names of the three streets, and, for these questions, only three people (27%) got them right without the orientation and identity help provided by RIAS. The control (FTSU) also did not know the names of the three streets. For the street they did not cross (Townsend), 67% of the subjects got that question correct after using RIAS. They likely learned that name while scanning toward the side (shortcut) doors. Subjects crossed 4th and also King Street, and, with RIAS, they heard the name of the street being crossed while they waited for the "WALK" message. All subjects using RIAS knew the correct answers for those two questions. There is little doubt that, although not necessary for successful locomotion, knowing the names of streets in the environment helps spatial decision-making and spatial orientation and adds to general knowledge and peace of mind.

4.6.2.3.3. Tracks, Spatial (TS) Questions #7 and 9

Two questions, 7 and 9, asked about the relationship between track doors and other locations in the terminal building. Of those using their regular orientation skills of orientation, only three (27%) knew which tracks were across from the waiting room, and four (36%) knew which tracks were closest to the main entrance hallway. When using RIAS, subjects got both of those questions right 67% of the time. Again, this knowledge was relevant, but not critical, for the navigation task, but the higher scores show that the use of auditory cues gave better spatial knowledge of the environment. It is quite difficult for blind people to get enough distal cues to understand the relationships between locations in a large open space. With no visual cues to spatial arrangements, blind travelers must often go to a wall and search along it until finding a location. Later, they might be at the opposite wall to find other locations. If the open space between these two locations is an area that is too large to comprehend without vision, they might have little or no knowledge of the spatial relationship between the two locations. The two locations might even be directly across from each other, but this knowledge can be hard or impossible to acquire, at least without much physical activity.

4.6.2.3.4. <u>Street and Lane Information (SI) Questions #8 and 10</u>

Crossing streets safely and successfully requires gaining information from various modalities. One listens to traffic sounds and tries to determine the shape of the intersection, traffic flow and speed, lane direction, and turn lane cycle information. Two questions (8 and 10) asked about the two streets that were crossed in the experiment. They asked about how many lanes the subjects had crossed and whether they were one-way or two-way streets. The regular users got 27% and 45% of these two questions correct, even though they crossed each of the streets twice. RIAS users got 87% and 78% correct on the same two streets. This information is not mandatory for successful locomotion, but the knowledge certainly adds to the safety and success of a street crossing. For instance, not knowing that a street is one or two ways or has an extra turn lane could lead to serious accidents or death. It also helps to know lane and direction information in advance so that one can know what to listen for while waiting to cross the street.

4.6.2.3.5. <u>Track Arrangement (TA) Questions #11 and 12</u>

Figure 1.1 shows the twelve tracks serving the Caltrain terminal. Tracks 1 and 2 are separated by a wide concrete shared boarding platform, and this pattern is repeated up to the final shared boarding platform for tracks 11 and 12. There are two sets of double doors that open from the terminal onto each shared platform. Thus, doors for track 1 and track 2 are directly next to each other, while track 3 is quite a distance away (where it is next to the door for track 4). The spatial arrangement of the doors and tracks is not easily discernable without sight. Two questions were asked to determine if the subjects had learned the spatial arrangement of the track layout. Questions 11 and 12 asked subjects to state which track door # was closest to another. The people using their regular skills got 45% and 55% of these two questions correct. Even after visiting various track doors three times, about half still did not show knowledge that the doors were arranged in groups of two (with the odd number door on the right and the even one on the left). This is critical information needed to make efficient navigation and full use and access of a train terminal. With the use of the information provided by the auditory and directional cues, 100% of the subjects knew that the doors were arranged in groups of two, so that track #8 was closest to #7 and track #5 was closest to #6. There is a high utility associated with having this type of information. Since there was no Braille or tactile information on the doors, it could have taken quite a while for a blind person to understand this arrangement and extrapolatethis arrangement to all platform doors in the current environment.

Concessions, Spatial (CS) Questions #13,14,19, and 20

During the field test, subjects visited all three concession stands and the ticket window (twice) in the main hallway. The person-to-object information they acquired while walking to these locations appears to have been formed into a better object-to-object understanding than other types of locations. For questions 13 and 14, subjects using normal orientation skills got 55% of those questions correct. In contrast, with

RIAS, one of the questions was answered correctly by 100% of the subjects, and the other question had one incorrect answer (89%.) Regular users answered 73% and 82% of the other two questions about the spatial arrangement of the concession stands correctly, and, with RIAS, they scored 89 and 100% respectively. Clearly, the active search and navigation allowed subjects to understand these types of spatial relationships better than some of the other types of locations. The area between the four locations was quite small and fairly easy to understand.

4.6.2.3.6. Amenity, Spatial (AS) Questions #15,16, and 18

Each of the subjects visited three amenities in the waiting room during the field test. They found the “correct” bathroom, the phones, and the water fountain. This was a very small area; the locations were just a few feet away from each other, although they were on three different (90 degree separation) walls. Although these locations were almost touching each other, only 55% of the normal orientation subjects were able to identify what was closest to the phone and also what was furthest from the phone. RIAS users scored 100 and 89% on those 2 questions respectively. Regular navigation subjects scored 73% when asked what was closest to the water fountain, and RIAS users scored 89% on that question.

4.6.2.3.7. General Spatial (GS) Question #17

There was one question that did not fit any of the groups. It dealt with not just the terminal but with the entire area that had been navigated, including the cab stand, the bus shelter across 4th Street, and the Muni rail station across King Street. The question asked subjects to identify which transit mode was closest to the highest track # at the terminal. The Muni rail station was directly across one sidewalk and two lanes of traffic from the highest track number. The cab stand and bus shelter were much further away. RIAS users got this general spatial question correct 78% of the time, and, without the system, subjects got this correct 64% of the time. Results on this question were probably confounded by some subjects not considering closest to mean "as the crow flies" distance."

4.6.3. Summary of Spatial Knowledge Acquisition and Cognitive Maps

A researcher using some type of externalized means of measurement must extract the information stored in a person's cognitive map. Different spatial products are likely to reveal differing amounts and types of information. Two methods were used to gain more convergent validity and concentrated on testing if these observed internalized spatial representations had utility for the user.

- Except for one trial, all subjects using RIAS (95.5 correct) were able to identify unvisited doors and make a successful shortcut to the next destination.
- With their normal methods, all but 3 attempts (23% correct) led to making the longer (retrace) path, not having the knowledge to make a shortcut.
- RIAS allowed users to find information they were not actively searching for and use it later to affect more efficient travel.
- All 20 spatial and knowledge questions were answered correctly by more people when using RIAS. There were many incorrect answers for the regular

users; and most RIAS users scored exceedingly well. In fact, 78% of the RIAS users scored better than the fully sighted first time visitor (control).

- Regular navigation skills led to higher correct scores for spatial locations that they had visited quite often. The best results were those associated with the relationships between concession stands and the ticket window, the amenities in the waiting room, and the general layout of the entire site. All these types of places were visited multiple times, and this helped increase their accuracy.

- Subjects that used their regular orientation skills had little success incorporating knowledge about places that they did not actively visit. They had difficulty knowing the names of the streets that they had used and also the information about the streets' characteristics.

- Subjects without RIAS also had trouble understanding the arrangement of the track doors, even after 3 visits.

Cognitive mapping research concerned with blind travel provides information on what restrictions exist and what cues are missing. It allows the testing of assistive devices against known behavior and spatial awareness. These two experiments, assessing subjects' ability to make shortcuts and spatial knowledge, provide information about how hard it is to learn spatial information without vision, unless the area is accessed repeatedly. Blind users trying to navigate unknown spaces can be at a great disadvantage, and that affects their ability to have ready access to many new environments. Many cannot easily, efficiently, or independently learn new environments without much effort or training. This incomplete spatial knowledge affects the ability to gain reasonable access and could be a reason why many blind people report very limited travel behavior or never venture out alone. Even with multiple visits, spatial relationships remain elusive for some. The ability to increase one's spatial knowledge with auditory signs, by providing easy access to missing directional and identity cues, allows for independent and dignified wayfinding. These auditory cues allow blind users to gain some of the critical spatial information that a sighted person can access, and they allow for efficient behavior such as the ability to make shortcuts and learn the layout of an environment.

By comparing cognitive mapping results of an assistive aid such as RIAS to the regular method baseline, much needed knowledge is gained about what cues are needed and how to best present these navigation cues to a user. These two tests provide evidence that, with the availability of additional cues giving direction and location identity, blind people can form an accurate cognitive knowledge of an area just as well as a sighted person. They can learn locations without visiting them and are able to use this knowledge (utility) to take advantage of the access potential of an environment, something that has previously been denied to them. This empirical evidence should put to rest the notion that there are inherent flaws in the ability to acquire spatial knowledge without sight. Blind people appear to have the processing ability required to understand geographic space, and it is the lack of accessible cues that can cause inferior spatial knowledge. It appears that RIAS provided essential spatial information that was mostly lacking, thus allowing blind travelers to use spatial skills that are otherwise suppressed.

4.7. Chapter Summary

- Self-reported feelings of confidence in independent travel, sense of direction and in new environments were much higher after using RIAS.

- Subjects reported they would learn new routes or go to new environments much more often if they used RIAS,

- About half of the subjects said they would not be able to make a hypothetical trip to a job or a one-time event independently. If RIAS was installed, they reported they would make those same trips independently.

- Fully 73% of the subjects participated in 2 or fewer daily activities outside their homes. Travel time data showed that many subjects were quite restricted in their activity space. For those who did travel further, their times were often quite long.

- Two-thirds of respondents said there were some trips they did not make because of their vision problem and problems of independent travel. On average, they reported that they would like to make 30% more trips then they currently make.

- If RIAS was installed in their environment, 97% of the subjects said they would make more trips, with an average increase of over 100%.

- Subjects revealed a high *hidden demand* for more activity participation, especially for more discretionary activities like recreation and education.

- The number of people who said they would travel to education activities, using RIAS, increased from the current level of eight to 23.

- The number of people who said they would travel to work, using RIAS, increased from the current level of 17 to 24.

- Subjects reported that RIAS greatly improved their mental state and made for more efficient travel. They reported they would travel more often and to more places, and that the use of RIAS would increase their independence and spatial awareness.

- Lack of vision caused high levels of resistance when considering making a transfer to save time. This resistance was even higher in an unfamiliar area. If using RIAS, subjects perceived that their resistance would be much lower, similar to that reported by the sighted control group.

- Subjects exhibited increased spatial awareness in the field test by making shortcuts. When using normal methods of navigation, 23% made shortcuts, while 95% of those using RIAS made shortcuts.

- Spatial awareness was also revealed by spatial arrangement questions. For those using their regular methods, 44% got the correct arrangement, while when using RIAS, they got 88% correct.

Lack of visual cues, a paucity of spatial information, and increased stress and apprehension can have a direct and strongly negative effect on the ability to travel and participate in a wide range of activities. There is little that can be done by the blind to quickly master travel in new environments. The ability to access environmental cues through the use of RIAS, was perceived to vastly increase access to urban opportunities and participation in more, and more novel, activities. There is a large pent-up demand for increased travel and activities, rarely investigated, which shows the limitations to access caused by a lack of vision. Further access restrictions were also shown by the high resistance to making mode transfers.

Whether considering travel confidence, the ease of exploring new environments, the ability to make independent trips, reported travel and activity behavior, the pent-up demand and *hidden demand* for more activity participation, transfer making behavior, or how limited environmental cues restrict spatial awareness and updating, this chapter has shown how the lack of vision translates into an often limited and restricted activity space and the inability to travel freely. These restrictions can affect all aspects of the quality of life, social equity, and access to opportunities, including financial independence through access to education and the job environment. In all these test scenarios, the use of RIAS was perceived by the users to greatly mitigate these hidden barriers to access and equality.

5. Effects of Vision Loss and RIAS on Quality Of Life and Traveler's Attitudes

- **Hypothesis 3**: Travel and access limitations negatively impact the quality of life for those with vision loss. When using RIAS, subjects will report a wide range of positive influences on their quality of life.

5.1. Summary of Previous Quality of Life Statements

Table 4.8 showed a summary of the first four open-ended questions. Subjects were quite verbose regarding how RIAS would positively affect their ability to travel and participate in activities. All these comments were categorized into three major groups: the ability to gain specific information about locations and tasks, positive changes in affective states, and the ability to generally make trips more frequently and efficiently. These comments can be interpreted to reveal the negative impact on mobility, accessibility, and overall quality of life issues caused by loss of vision. Each of these 651 positive comments about RIAS and its affect on increasing travel options is also a negative statement about the current, limited state of blind navigation. The impact of all these difficulties surely has a high negative effect on the quality of life for many people with vision loss.

It appears that every question asked in this experiment revealed strong limitations on the freedom to fully participate in life activities faced by those with vision loss, especially in a new environment. The reported desire to travel to many more activities and to participate in new activities, shown in the section on travel behavior (see Section 4.3.4, Summary of Current Activity Participation, Unmet and Hidden Demand), confirms the inability of some blind people to fully embrace an active lifestyle. This chapter examines the impact of vision loss and travel restrictions and the mitigating effect of increased environmental spatial cues in greater detail.

5.2. Subject's Opinion and Evaluation of Talking Signs(R)

The fifth open-ended question was of a more general nature and was not limited to specific tasks or travel behavior. It was important to see what people felt about the overall impact of the additional auditory cues that they had just used in the field experiment. At the end of the field test, subjects were asked "What is your overall opinion of Talking Signs® ?" (For all subjects' comments, see APPENDIX 22: Comments about Opinion of RIAS).

5.2.1. Sample of Comments

- "Very helpful for independent travel, non-intrusive device to provide visual info for blind & vision-impaired, safer, confident, independent, financial benefits, less accidents & fatalities."
- "Should be installed everywhere, they are cool, they make travel easier, more independent, don't have to rely on others, don't get lost."
- "Simple & eloquent solution to the problems of blind, independence, important to have more TS installed, should be in malls."
- "Increases independence dramatically, provides new info about unfamiliar locations, can find out about things you wouldn't normally find, saves time locating hard to find places, not asking for help."

- “Awesome, provides equality, provides safety, confidence, hell of a lot less stress.”

- “Great if installed all over, greatly enhances vision-impaired to become productive.”

5.2.2. User response categories

The comments were parsed and broken down by type of response (to see each response, and its assigned category, see APPENDIX 23: Categorization of Opinion of RIAS). These responses confirm and summarize what had been learned in the field tests and other questions.

Table 5.1 Opinion of Talking Signs®

“What is your overall opinion of Talking Signs(R)?”

Category	30 Subjects
General Superlatives	45
Should be installed	15
Improves mental state	14
Spatial orientation aid	12
Increases independence	9
Specific places	6
Suggestions	3

Many of the responses were superlatives like “great,” “helpful,” “important,” or “wonderful.” There were 45 such statements by the 30 subjects. Half (15) of the subjects commented that RIAS should be installed. Comments made included “hope they are installed universally,” “should be installed everywhere,” “should be installed where there are signs," "should be involved per ADA," and "endorse city-wide installation." This was a strong endorsement of the benefit of this kind of spatial enhancement for the blind.

Fourteen comments directly mentioned that the system improved their mental state. Some comments in this category were: "hell of a lot less stress," "makes life a lot easier," "make you socially able to live like a sighted person," "provides equality," and "confident." Other comments mentioned that they made travel safer, easier and more efficient. Twelve comments dealt with the use of RIAS as a spatial awareness aid. Some comments were: "can find out about things you wouldn't normally find," "know where you are," "needed wayfinding tool," "provides new info about unfamiliar locations," and "never would get lost."

Nine comments were made that were categorized as "increases independence." They either used a form of the word "independent" or mentioned that they didn't have to ask for help. As discussed earlier, many blind people do not like to complain about the lack of independence and their forced reliance on others; but, after experiencing the freedom allowed with RIAS, many people mentioned this fact freely. Six comments were made about the help received from RIAS at specific places. They mentioned the street information, block numbers, the angle of intersections, bus stops and bathrooms. One person commented that the system needed "fine tuning," and two said that more input was needed from users.

5.3. User Response to Talking Signs®

After completion of the field experiment, all 30 subjects were asked to rate their opinion on the usefulness and their desire to have Remote Infrared Audible Signage installed. The scale ranged from strongly agree (1) to strongly disagree (5)

Table 5.2 Perceived Usefulness and Locational Suggestions for RIAS

"Please rate if you agree or disagree with the following statements (5-point scale)
1=Strongly Agree, 2=Agree, 3=Neutral, 4=Disagree, 5=Strongly Disagree"

Talking Signs(R) Installations	Rating
TS are helpful and should be installed at transit platforms	1.1
TS are helpful and should be installed at street intersections	1.1
TS are helpful and should be installed at terminals	1.2
TS are helpful and should be installed at bus stops	1.2
TS give vital spatial information at intersections, should be installed	1.2
TS are helpful and should be installed in buildings	1.3
TS are helpful and should be installed where printed signs are located	1.3
A city-wide TS system would allow me to travel to more places	1.4
From what I experienced in this test, I feel that the TS system helped me use unfamiliar transit and make transfers	1.4
TS makes transit transfers easier and safer	1.4
TS at intersection crosswalks make crossings safer	1.6
TS are helpful and should be installed at transit vehicle boarding doors	1.8
A city-wide TS system would help me financially	1.9

The results were highly skewed toward the "strongly agree" category, and even the lowest rated question returned a rating higher than "agree." The above results were very similar to the strong endorsements obtained from the previous experiment at the downtown Santa Barbara, CA, MTD bus terminal (Golledge & Marston, 1999; Marston & Golledge, 1998b; see Table 2.5 for those user evaluations).

Not much discussion is called for here. The subjects overwhelmingly supported the additional environmental cues provided by RIAS and its benefit to their daily lives. Previous research (Golledge & Marston, 1999; Marston & Golledge, 1998b) investigated certain daily navigation tasks that were stressful and difficult. The perceived stress and difficulty reported with normal blind navigation almost completely disappeared after subjects experienced RIAS. Little research has been done on the effect of stress and fear on travel by this group, but it certainly must negatively affect travel success, access, and the overall quality of life available to an independent traveler.

5.4. Subject's Employment Characteristics

Before presenting monetary valuations placed on independent travel and freedom to participate in all that life and the urban environment has to offer, the employment status of the subjects is briefly explained. Nationwide, about 70% of blind people are unemployed (Kirchner et al., 1999). The subjects that are reported on here differed from the norm in that they had to be active travelers to get to the site for the experiment. Out of 30 subjects, nine were employed full-time and two were employed part-time. No students were in the regular education system, but two went to a blind skills center and were also employed part-time, while another eight went to skills centers and were not employed. The majority of those who went to the centers were recent high school graduates who were learning how to live on their own. Another five of the subjects were self-employed: four in assistive or computer technologies and one as a masseuse. No one reported being a volunteer, and three were unemployed because of their disability. One person was retired.

One difficulty with the oft-touted higher figures (70%) for unemployment is that they include all blind people of working age, including many without good health. A national survey by the National Center for Health Statistics in 1994-95 (data released in 1998) showed that legally blind people less than 55 years old and in "excellent" health, were 40% unemployed (AFB, 2000). The subjects in this experiment were more similar to the National Center for Health Statistics (NCHS) data.

Sixteen subjects were happy with their current employment status. Of the others, 12 wanted to be employed full-time and two wanted to be employed part-time. Eighteen subjects reported being employed an average of 12.2 years. Of the five people who were working when they became blind, three said that vision loss led to their being under-employed and two said it did not. In addition, one subject who was blind before starting work said that he was under-employed because of the blindness.

These six subjects reported earning on average $11,500 less because of their blindness, with ranges between $5,000 and $20,000.

Of the 18 people who had jobs, nine (half) said that they felt they were under-employed. Eight of these nine people (90%) thought that they were under-employed because of transit and access problems.

For the nine people who were unemployed, six had never had a job and three had lost their job because of the disability. Of the three formerly sighted and employed, one made $38,000 less, one made $18,000 less, and one person on a disability pension made $2500 less than when employed, for an average loss of $19,500 for the three unemployed subjects. Three of the nine (33%) respondents who said they were unemployed thought their unemployment was a result of transit and access problems. The other six said their unemployment was not due to these limitations; these were mostly the young adults from the living skills centers who were not yet looking for employment.

5.5. Lost Earnings and Additional Expenses Due to Inaccessible Transit

A national unemployment rate of over 7% in the United States is considered an indicator of economic distress. This figures pales in comparison to the 70% unemployment rate for the blind reported by Kirchner et al. (1999) of the 40% by

NCHS. In addition, under-employment can also affect the ability of a blind person to fully realize their potential, and it affects their quality of life.

5.5.1. **Reduced Earnings and Inaccessible Employment**

The estimates reported in the previous section dealt with all aspects of vision loss and its affect on employment. To determine if transit access affected employment potential and earnings, subjects were asked a more specific question about how much more money they could make if they had independent access to transit in the pre-test interview: "If I was able to use unfamiliar transit and make transfers independently and with less difficulty, I could probably make $----more per year."

Some people were students, retired, or felt they were fully employed. For the 20 people who said this question applied to them, they thought they could make, on average, over $16,750 more per year. The average for all 30 subjects was $11,167 per year of perceived earnings lost due to inaccessible transit.

After using RIAS in the experiment, subjects were asked: "If Talking Signs® were installed citywide on all transit, intersections, signs, and buildings, I could probably make $-----more per year." Again, there were some subjects who were not concerned with gaining or changing employment, but 20 subjects reported they could earn an average of $12,385 more per year, if RIAS was installed. The more conservative amount, the average of all 30 subjects ($8,257 per year in increased earnings) will hereafter be used. These estimates are quite substantial, indicating how much this population felt that earning potential was denied by the lack of independent travel opportunities.

There was no significant difference between the pre-test estimated benefit for increased earnings through "independent access" and the amount given for the effects of using RIAS. Individual data points and the *means diamonds* are shown (see APPENDIX 24: Data Plot of Estimated Additional Earnings). These numbers are not intended to be interpreted as what would actually happen in the real world. What is important is to realize that these are the amounts that people place on the denied income caused by vision loss and its effect on the inability to travel independently, showing a benefit derived from increased access to transit and travel. These data highlight how access to transit is perceived to affect employment opportunities and lends support to the idea that it is the lack of access to travel that is one of the causes of the extremely high unemployment rate among this group.

5.5.2. Reduced Spending for Travel Assistance

The inability to travel independently also can have a direct monetary cost. People with restricted vision might have to pay for expensive cab rides, pay a friend, hire a sighted guide, or pay someone to do errands at locations that they can't access easily. One might even have a paid driver or assistant for employment. Blind people with discretionary income might find it very worthwhile to have a paid personal aide or chauffeur to maintain a high quality of life. To discover the additional cost incurred by this dependency on others (the inability to travel independently), subjects were asked how much less they would spend on assistance if travel could be made independently. The specific question was: “If I was able to use unfamiliar transit and make transfers independently and with less difficulty, I could reduce my spending for assistance by $-----per year.” This question was asked in the pre-test interview, and 24 subjects reported they paid for assistance, with an average expenditure of $1,620 per year. One subject paid $20,000 per year for a driver because of lack of access to transit. If that is removed from the data, there still is an average expense of $821 per person for all those who reported this expense. This is a large amount to pay in order to gain access to activities, an amount that is not paid by other people for travel assistance. Using the more conservative estimation, the average cost reported by all 30 subjects is $1,296 per year.

After the field test, subjects were asked if RIAS could help them reduce their expenditures for assistance in travel caused by their lack of vision and independent travel. The question was: “If Talking Signs® were installed citywide on all transit, intersections, and buildings, I could reduce my spending for assistance by $-----per year.” Most of the subjects reported that RIAS could save money that they currently spent on travel assistance, and 26 subjects reported an average savings of $1,462 per year. Removing the one subject with the driver, the average was $720. The average for all 30 subjects was a reported yearly savings of $1,267.

There was no significant difference between the pre-test estimations on the cost of assistance, due to limited access to transit, and what they reported they could save if RIAS was installed citywide. Individual data points are shown (see APPENDIX 24: Data Plot of Estimated Additional Earnings). These expenses often come directly out-of-pocket, and it is highly likely that this group gave a good estimation of their real expenses.

5.5.3. Summation of Lost Income and Expense Due to Restricted Travel

The next table summarizes the perceived benefits placed on RIAS as it relates to earnings potential from increased transit and travel access to employment opportunities and the expenses associated with having to depend on others for some travel needs. For easier comparison, the daily amount for these benefits are shown.

Table 5.3 Estimated Benefit of Using RIAS

Perceived Benefits of the Ability to Travel Independently using RIAS	$ Per Year	$ Per Day
Extra Income from Employment	8,257	22.50
Money Saved on Travel Assistance	1,267	3.50
Total Benefit of Using RIAS	9,523	26.00

The average benefit placed on the use of RIAS, for the entire sample size, was a positive change of $26 per day. That is a sizeable amount to place on the limitations and restrictions caused by the lack of access to independent travel.

5.6. Monetary Benefit of Independent Travel

By placing a monetary benefit on different scenarios, people can express the quality and extent of their desire for changes in behavior. A change in a perceived quality of a life adjustment can thus be compared between people and scenarios. Two scenarios were previously discussed (see Section 4.2, Perceived Travel Behavior while Making Transfers) that dealt with mode choice in making a ten-mile transit trip and mode change to a one-time event or a daily job. A series of questions was asked about the benefit subjects put on perceived and actual possible changes to their life. Those benefits are explained in this section. The methodology and validity of these kinds of willingness to pay data are discussed in the next chapter. For each of the two scenarios, the following question was asked.

- Pre-test: "How much would you be willing to pay for a sighted guide to get you to and from the event (or job)?"

Many did not want to pay a sighted guide or ask for that type of assistance.

- For the one-time event, 18 people said they would pay an average of $16 for a sighted guide. The average for the 30 subjects was $10 per event.

- For the daily job scenario, 13 people said they would pay an average of $7 for a sighted guide. The average for the 30 subjects was $3 per day

5.6.1. <u>Independent Travel to A One-Time Event</u>

Table 5.4 shows the benefits placed on independent travel for this scenario. These questions did not apply to some individuals; therefore, the mean is shown for both those who gave an amount and for the 30 subjects.

Table 5.4 Monetary Benefit of Independently Travel to a One-Time Event

Willingness-To-Pay Scenarios	N=	Mean $
Pre-test: "How much money would you be willing to pay if you were able to **independently travel** the new route and **make the transfer yourself**?"	30	16
	28	17
Pre-test: "How much extra money would you be willing to pay for this event if you were able to have the **same access to the information** on signs, at streets intersections, on transit and in buildings **that the sighed public enjoys**?"	30	25
	27	28
Post-test: "How much money would you be willing to pay to be able to **use Talking Signs®** for this trip if they were installed on transit, intersections, signs and buildings?"	30	19
	29	19

The more conservative amount of the overall mean will be used later. These benefits placed on the ability to travel independently are quite high and show the importance this group places on the ability to freely access urban opportunities. All but one subject said they would pay to use Talking Signs®. That one person adamantly stated that she would pay nothing, because sighted people don't pay for signs and, mentioning the ADA, said it would not be fair if she had to pay. The other 29 subjects said they would pay between $1 and $80, with an average of $19 per day, for a special event (see APPENDIX 26 for the individual data points for the three questions).

The pre-test questions required subjects to self-generate how this hypothetical access to independent travel would become available. Those questions attempted to capture the benefit of this increased mobility without any specific components being given to them. The last question concerned a specific device that they had just used in the experiment. If RIAS had been valued much lower, it would indicate that the system did not fully meet their expectations for an environmental enhancement. However, there was no significant difference between the two non-specific and heretofore unattainable goals and the specific scenarios of using RIAS. An analysis of variance (ANOVA) showed $F(2,87) = 0.77$, $P>.05$. It appears that RIAS met much of their criteria for the desired access that they previously envisioned.

5.6.2. <u>Independent Travel to a Daily Job</u>

Table 5.5 shows the benefits given for the second 10-mile scenario. As expected, the amount they would pay for access to a daily job is less than a one-time special event.

Table 5.5 Monetary Benefits of Independently Travel to a Daily Job

<table>
<tr><th>Willingness-To-Pay Scenarios</th><th>N=</th><th>AVG</th></tr>
<tr><td rowspan="2">Pre-test: “How much money would you be willing to pay if you were able to independently travel the new route and make the transfer yourself?”</td><td>30</td><td>6</td></tr>
<tr><td>27</td><td>7</td></tr>
<tr><td rowspan="2">Pre-test: “How much extra money would you be willing to pay for this event if you were able to have the same access to the information on signs, at streets intersections, on transit and in buildings that the sighed public enjoys?”</td><td>30</td><td>8</td></tr>
<tr><td>27</td><td>9</td></tr>
<tr><td rowspan="2">Post-test: “How much money would you be willing to pay to be able to use Talking Signs® for this trip if they were installed on transit, intersections, signs and buildings?”</td><td>30</td><td>10</td></tr>
<tr><td>29</td><td>11</td></tr>
</table>

These benefits measure the demand for increased access to travel, transit, and employment. They show a large daily expense that people said they would pay for "equal access" which is currently mandated by the ADA (as its underlying principal) but which is currently specified in a limited fashion.

The same subject firmly stated that it would be unfair for any blind person to have to pay for access and appropriate signage. Again, there was no significant difference between the two self-generated, non-specific, and heretofore-unattainable goals and the specific scenarios of using RIAS. ANOVA resulted in $F(2.87) = 2.24$, $P>.05$.

These two sets of monetary valuations show that this blind population placed a high amount of importance on the ability to travel independently. This offer to pay is an indication of how independent travel is an enhancement to their quality of life. The current inability to have this kind of access, especially in unfamiliar places, is seen as something that is worth paying money for in order to overcome these limitations.

These benefit amounts appear to be much higher than public agencies use in their calculations for aid to travelers with vision impairments, indicating that the amounts offered as disabilities subsidies do not match the perceived worth of making the trip independently and, thus, probably do little to encourage extra travel.

5.6.3. <u>Offer to Pay for Daily Use of RIAS</u>

The final question about monetary trade-offs to use RIAS was a direct question asked at the end of the experiment. The question asked was: "I would be willing to pay $------per day to be able to use Talking Signs® if they were installed citywide and gave me the same access to signs as the sighted public." The same subject objected to paying for signage.

The question was asked to determine the benefit placed on this type of spatial information, and the remaining 29 subjects all offered a payment amount for their use and gave an average response of $5 per day (see **APPENDIX 26** for individual data points).

5.7. Summary of Benefits from Increased Access and Independent Travel

The data collected from these five monetary valuation questions show that there is a large pent-up desire for easy and independent travel, and that subjects thought accessible transit would help them make more money and also save money on assistance. Using the more conservative approach (the benefit placed on these scenarios by the entire subject group), these estimated benefits of using RIAS to gain more independence access to travel are summarized as:

- $19 for a one time special event
- $10 for a daily job trip

- $22.50 increased daily employment earnings
- $3.50 daily savings in out-of-pocket assistance expense
- = A total change in discretionary income of $26.00 per day
- $5 per day to use on a regular basis

It must be made perfectly clear that reporting these data in no way means that the vision-impaired individuals should pay extra to enable their independent use of public transit through accessible signs and environmental cues. Providing access for all is an equity issue, and these data are offered only to inform about the <u>magnitude of the benefits</u> that this population places on achieving this illusive goal.

This population should not have to pay individually for their own signage, but it is enlightening that most of these people value independence so highly that they offered to pay for something that is provided at no direct cost to individual members of the general public. These costs are spread throughout the total population by way of taxes and/or are folded into the prices of products and services. Limiting signage to that which specifically excludes a class of people who cannot use them (blind people who cannot read them) also is a civil rights issue.

These financial tradeoff questions also indicate that planners and social agencies might be putting their resources into programs that do not provide access to transportation, as has been mandated by the ADA since 1990. It is interesting to note that several respondents reported that they would be willing to abandon their discount transit fare and pay full price if they had access to RIAS. They felt that the discount was more to placate them, when all they really wanted was increased access to transit. This was especially true of those who had good jobs. It wasn't a discount they wanted or needed, but, rather, to be treated as equals and to have the same access as the general public.

The monetary benefits examined in this section demand further public policy consideration and analysis to determine if providing better access to transportation would increase tax and transportation revenues while promoting meaningful employment opportunities. Such improvements would lead to dignity and self-worth, in contrast to the current system of subsidized unemployment, which, to some, is a restricted and unfulfilling life. The benefits of environmental signage for the blind and the cost of not providing these cues are more fully examined in the next chapter.

6. Benefits Summary and Cost Comparison

- **Hypothesis 4:** The field test data and subject's observations, ratings, and opinions will demonstrate a wide variety of benefits that accrue to the user of RIAS.

6.1. Summary of Benefits from Field Tests and Questions

- Field tests showed that additional environmental cues led to faster, safer, and more efficient travel, with greater independence to the user.
- Transit tasks were perceived as much less difficult when using RIAS.
- Subjects reported they would travel more often and to new places.
- They perceived they could use transit in a much more efficient manner.
- Overall mental states were improved when using the enhanced travel aid.
- Subjects highly supported additional installations.
- Strong positive opinions were offered about the effect on quality of life issues.
- Substantial monetary benefits were placed on the effectiveness of these enhancements for travel and access to urban opportunities.

6.2. Monetary Valuations from Subjects

Data solicited from respondents about estimations of values placed on non-monetary costs associated with travel have long been analyzed. Economists have developed tools such as the *contingent valuation method* (CV) to value environmental amenities or changes (Clarke, 2000). These types of monetary valuations can reveal much about how people value different kinds of tasks. For example, most people value their time driving a car as being less than the value placed on their work time. People put an even lower cost on a drive to a recreational spot. Thus, this discount reveals a utility inherent in the purpose of the journey (McFadden, 1988). The empirical data collected in this experiment using various forms of monetary valuations are discussed here. These values were used to analyze the benefits that severely vision-impaired people place on their ability to reduce travel time, stress, apprehension, or fear, and to gain the ability to travel independently. This chapter offers a brief review of problems that can reduce validity in the types of questions about monetary valuations discussed in Chapter 5.

6.2.1. <u>Techniques of Monetary Valuation</u>

Contingent Valuation (CV)are survey methods designed to elicit *Willingness To Pay* (WTP) amounts to ascertain what monetary benefit people place on goods or services. These tests ask people to consider certain situations or preferences and respond with a monetary amount that they would pay to be able to receive those goods or services. It is assumed that choices can accurately reflect well-formed and stable preferences, insofar as these techniques are based on classic *economic rationality* (McFadden, 1988, p. 339). If this is true, it should be possible to deduce from direct questions the social desirability of public policy initiatives such as transportation improvements. However, people do not always act according to assumptions on which these neo-classical economic models are built. One must also consider behavior and attitudes due to the wide range of beliefs and perceptions of humankind. People are more complex and fallible than assumed in the "economically rational man" model. In addition, the psychological model is dynamic—a process model where the emphasis is on how beliefs or preferences are formed and how information is acquired.

Accurate measurement of a value placed on specific goods or services requires that the subject understands the scenario or task, that it can be preformed, and that all sorts of possible bias and misunderstanding be attended to (Bateman et al., 1999). Four barriers that might restrict the subject from giving the information the experimenter is truly seeking are summarized from Sudman & Bradbury (1982):

- Memory: the respondent may have forgotten or remembered incorrectly;
- Motivation: the respondent may be afraid to tell the truth, want to present themselves in a positive manner, support the questioner's implicit position (experimenter effect), or not care enough to respond accurately;
- Communication: they may not understand what they are being asked;
- Knowledge: they may not know the answer.

To accomplish these tasks from a psychological perspective and increase validity, a study from NOAA (1993) suggests attention to the following:

- Convey meanings exactly to the respondent;
- Avoid incorporating implicit theory
- Begin with the needs and perceptions of the percipients;
- Enable the respondent to learn what his or her preferences are in the course of the experiment.

McFadden (1988) states that preference tests should strive to elicit core preferences and avoid strategic behavior or cognitive illusions, as when a person is confronted with unfamiliar tasks and looks instead for “cues from context to shape an appropriate response” (p. 355). He states that the more realistic the hypothetical setting, the more likely it is that stated choice behavior will look like real choice behavior. In some research, such as assessing the desirability of transportation modes not yet in service (such as high-speed rail not familiar to most respondents in the United States), descriptions tend to be highly stylized and the results biased. In reality, “inexperienced consumers confronted with incomplete information on a commodity may make a biased imputation of unobserved attributes, and may make mistakes in weighting these attributes in comparison with observed attributes” (McFadden, 1988, p. 360). Green & Tunstall (1999) suggest that good experimental design must direct respondents’ attention to the issue, enable them to form preferences, and practice their *willingness-to-pay.*

6.2.2. Design Method and Results

The focus of most of the field experiment was on determining the extra time and effort needed to make successful independent travel with limited or no sight. Along with measurements of time costs and success, safety concerns, and the degree of difficulty of various tasks were researched. The CV and WTP literature emphasizes that a valid research question should be important to the subjects and be one about which they have great interest. The scenario should be simple and explicit, with little chance of misinterpretation. There can be little doubt that safe and independent travel is an important concern for this population. Their quality of life is defined daily by the efforts of mobility and navigation without sight. The questions were as straightforward as possible: what would they pay to independently travel to types of activities, how much more could they earn, and how much less would they spend on assistance.

6.2.2.1. Pre-test questions

The pre-test questions were asked with no reference as to how this equal access would be gained. It was up to the individual to imagine that kind of scenario. These questions helped to open up cognitive processing about a heretofore-unattainable goal and gave a baseline against which to test their WTP response after using the RIAS. These were conducted by telephone, before the subject and interviewer had met. The interviewer did not previously know these subjects, and so there were no known reasons or motivation to give slanted answers. The pre-test questions had nothing to do with any technology being studied; they simply asked for values to be put on equal access. When there is no consumption or purchase involved, WTP data are considered more valid because there is no reason to give false answers (McFadden, 1988). Their perceptions of worth come directly from their experiences as travelers using their normal skills. At the time of the interview, the subjects were comfortably at home, not dealing with the difficulties of travel. Most people offered amounts for these scenarios, thus adding to their real-world validity.

6.2.2.2. Post-test questions

The same questions were asked after a long and demanding field experiment, and, in that case, subjects evaluated the WTP for a very concrete and specific technology. They had just spent up to several hours using the system while making many trips in a crowded and complicated urban transit terminal. They had been asked to independently perform many tasks and had a very vivid memory of that situation and of what they had just experienced. In this way, the respondents were self-aware of the effects of the system and how vision loss affects their travel choice and activities, without the researcher having to describe any scenario or perceived benefits. The perceptions of the worth came directly from their experiences during the experiment. There was no need for a mental search for facts or experience on which to base their answers. All subjects had the same experience on which to judge their answers. They were also highly aware of the trips they do not make and other restrictions on their personal activity space and behavior. Without the pre-test questions, doubt could be raised about the accuracy of the post-test *RIAS* condition question. By including the hypothetical pre-test questions as a control, subjects could be tested as to whether they were affected by attitudes toward the researcher and if the effects of primacy and recency apply. If they did, there should have been a difference between the field test and the telephone question results. However, there was no significant difference in monetary valuation between a self-generated scenario (with equal access and independence) in the pre-test questions and the very real world they experienced in the transfer tasks using a specific technology. By asking such simple and relevant questions and being assured that subjects had the vital information they needed to make a value judgment, the concerns and caveats mentioned above have been addressed.

6.2.2.3. *Willingness-to-Pay* Versus Perceived Benefits

It was important to establish a monetary amount that subjects placed on the benefit of independent travel and equal access to transit. The pre-test question dealt with a concept only: what is independent access worth, and what is it worth to have the same access to signs as the sighted public. However, the true “benefit” of this access is most likely incalculable; perhaps no amount of money can truly capture the benefit of access to all signs and the ability to travel independently. Although it is the widely held opinion of people with vision impairments that they should not have to pay for access that the general public gets at no extra charge, the question based on what they would pay was asked. This put the valuation on the level of what they would actually be willing to forgo in order to achieve these goals. This procedure also made it easier to compare the answers from the concept question to those answers derived from the experiences of an existing technology that they had just experienced. By asking what they would pay for equal access, a baseline was established for this ideal self-generated manifestation, which, hopefully, revealed the cost of limited access and dependency.

6.2.2.4. Saliency and Importance of the Scenarios

WTP data, to be valid, must relate to scenarios that are well understood by the subjects. They must have full knowledge of the material and how it would affect their lives. It could be argued that there is little, or nothing, more important to a person with a vision impairment than the ability to independently move through the urban environment and to have equal access to activities and travel. They are faced daily with restrictions on travel and are acutely aware of what it would be worth to "turn off" these limitations. There is little reason to doubt that the subjects did not fully understand the question, have complete and current knowledge of the situation, and know what the cost of those limitations meant to them.

6.2.2.5. Cognitive Illusions

Subjects fully understood that the University of California and the California Department of Transportation were conducting this research. No product sale or market analysis was involved. Cognitive illusions are highly sensitive to context, and they are stronger with unfamiliar tasks. For a monetary study to have a reasonable probability of success, the "consumer" must be fully informed about the attributes of the commodity and be experienced in making decisions about it or trained in a manner that provides a context that resembles historical experience (McFadden, 1988).

6.3. Benefit Analysis

Data were gathered on perceived monetary benefits of using RIAS and also on how many people can be helped by the addition of environmental cues. Combining those two sets of data and looking at the vision-impaired population in San Francisco and the surrounding Bay Area may answer some necessary questions about the feasibility and benefits of this system. There are three main reasons why a typical cost/benefit analysis is not warranted for this discussion of benefits: issues of social equity, changing product cost and features, and a wide variation in installation costs. These three reasons are summarized next, then population estimates are discussed with regards to those with vision loss, and a section is presented which applies the personal benefits uncovered in this research to the population of the test area, and current government assistance and unemployment for this group are examined. Finally, a brief estimate is shown for the cost to equip buses with this technology.

6.3.1. Issue of Equity

When a society desires to make life more equitable for all members, it does not determine the virtue or benefit of that equality in monetary terms as if full public participation by its citizens is a *zero sum game*. When it was deemed desirable to make transit buses accessible for those using wheelchairs, no cost study was called for. Making public services available for people who had been excluded was the "right" thing to do. When cities and agencies were charged with making curb cuts to allow for more equal access to public areas, again no cost/benefit analysis was called for. If public tax money is spent on public areas or infrastructure, it is desirable to make them accessible to all members of society. Over and above this rationale, a strict dollar cost analysis would also have been unrealistic. Kneeling buses and, especially, curb cuts and elimination of steps with ramps have made areas, buildings, and transit vehicles accessible to many more people than just those using wheelchairs. People with various ambulatory problems and those with bicycles, baby strollers, skateboards, wheeled luggage, and delivery or shopping carts also benefit when public funds remove physical barriers. The benefits of these modifications affected a much larger segment of the population than they were originally targeted or designed for. Like those access modifications to buses, curbs and stairs, perhaps a type of signage that provided location-based information, in a non-printed format, would also help many more people than just those with a vision impairment or print-reading disability. When other ADA mandates such as accessible parking spots are considered, again, no cost/benefit analysis is called for. A specified number of parking spots are required without regard to the number of people in the area who might use them. In fact, these modifications look toward the future, with the idea that "if we build it, they will come." These types of required modifications for persons with ambulatory disabilities provide needed access to opportunities and are not required only if financial benefits for that excluded group outweigh the cost.

6.3.2. <u>Changing Technology</u>

Additional features have been added to RIAS since the Caltrain installation. The new model, manufactured by Mitsubishi Precision Products, offers the same features that were tested in this experiment and is fully backward compatible. It offers additional information channels (see Section 7.8.1 Talking Signs® Enhancements). This new feature, allowing for even more information, has a different cost than the units tested at Caltrain, and, therefore, it would be misleading to offer a standard cost benefit analysis.

6.3.3. <u>Installation Costs</u>

RIAS transmitters need to be installed at locations and the costs vary considerably depending on whether they are planned for new or excising structures. Furthermore, planning and placement costs depend on the type of building construction and architecture. Electrical power is needed, and providing that service requires costs to be estimated by electricians and designers on a case-by case basis. With the wide range of building designs and functions, variations in access to nearby electrical wiring, and a wide range in construction costs, no meaningful costs can be generalized.

6.3.4. <u>Visually Impaired Population of San Francisco and the Bay Area</u>

Although this type of auditory signage might benefit many types of print-handicapped people and those with developmental disabilities (Crandall, Bentzen, &

Myers, 1999), the following section discusses only vision impairment. Table 6.1 shows 1999 data compiled by the San Francisco Lighthouse for the Blind. These statistics are based on percentages, developed by Lighthouse International, applied to the general population.

Table 6.1 Vision Impairment in the San Francisco Area

Statistics on Vision Impairment in the San Francisco Bay Area				
County	Population	Total Visually Impaired	Total Severe Visual Impairment	Total Legally Blind
Alameda	1,415,582	100,766	24,065	6,370
Contra Costa	933,141	66,424	15,863	4,199
Marin	236,768	16,854	4,025	1,065
Napa	120,962	8,610	2,056	544
San Francisco	746,777	53,158	12,695	3,360
San Mateo	702,102	49,978	11,936	3,159
Solano	385,723	27,457	6,557	1,736
Sonoma	439,970	31,318	7,479	1,980
TOTAL	4,981,025	354,565	84,677	22,415

Source: San Francisco Lighthouse for the Blind (July 99 data)

These data show about 3,360 totally blind people in the city of San Francisco and about 12,700 who have severe vision impairments. For the eight-county area, more than 22,400 are totally blind and more than 84,600 have severe impairments. These data show a total of about 53,100 in San Francisco that have some sort of vision problem that is not correctable by glasses and a total population for the Bay Area of about 354,500 with some type of vision impairment.

No matter how well crafted the experiment and how careful the analysis, it is not always possible to attribute the findings from a sample to an entire population, especially one as varied in characteristics as those with vision loss (see Section 7.7, Possible Methodological Confounds). Some data are given in this report that attribute findings from the sample to the entire population, in order to estimate the impact and magnitude for this group. These estimations do not imply that the researcher claims that the sample tested was representative of the entire population of those with severe vision loss, or are legally blind.

How many people in these estimates might benefit from RIAS? The experiment contained several questions that point to an answer. The travel task experiment showed that all people could save travel time and travel with more independence, and all subjects rated the system highly. But this does not necessarily mean that the installation of RIAS would help them make more trips or actually give them a benefit beyond easier and more efficient travel. However, an earlier discussion (see Section 4.3, Activity Participation, Trip Behavior, and Travel Times), noted that many people said they would participate in more activities and with more frequency with these additional spatial cues present in the environment. Some of the questions that elicited how many people would be positively affected by their installation are briefly summarized.

- 97% said they would make more trips if transit was made more accessible with additional spatial cues but, before using RIAS, 67% thought they were missing additional tips.
- All subjects said they could travel to a daily job independently with RIAS, up from 53% at their current level.
- 97% said they would travel independently to a one-time event, up from 40% without RIAS.
- 97% said that the system would help with unfamiliar transit and transfers.
- 87% said they would travel to more places if these cues were available.

All these different findings show a high agreement that this type of information would directly affect the lives of these subjects. The percentage of those people who stated that travel with RIAS was faster, easier, or safer is not dealt with in this section, but, rather, only the percentage of those who said that RIAS would increase their travel frequency or ability to travel independently. In the following estimations, the smallest agreement rate (87%) is used to measure how many people would be positively affected. If it is assumed that only 87% of blind travelers will actually make more trips, that leaves a target audience of people who would directly benefit from the additional cues.

- 11,050 severely vision-impaired in the City of San Francisco and
- 73,602 severely vision-impaired in the San Francisco Bay Area

There are many ways to look at benefits for this group using RIAS. The following table shows the total dollar benefit placed on this kind of information, first by three estimations by the subjects (WTP for daily use, savings for travel assistance, and the subsidy for a single round trip bus fare). Then two low estimates of 25 cents and 10 cents per day are shown. These figures are a yearly estimate of this benefit, and all monetary estimates are shown in 1,000's of dollars. A later discussion examines the problem of extrapolating the experimental results to the entire population of people who are legally blind (see Section 7.7.1 Subjects), but no statistics are available to determine how many of this population are, or could be, independent travelers. These monetary benefits should be considered with that caveat in mind.

Table 6.2 Estimated Benefit of RIAS Installation

			Severe Vision Impairment		Vision Impairment	
			San Fran.	Bay Area	San Fran.	Bay Area
		Pop.	12,700	84,600	53,100	354,500
		87 %	11,049	73,602	11,049	308,415
		$ Benefits of Independent Travel and Transit Use				
	Daily	Yearly	Amount (in 1000's)			
WTP Value	$5.00	$1,825	$20,164	$134,323	$84,309	$562,857
Expenses Saved	$3.50	$1,267	$13,999	$93,253	$58,531	$390,761
RT Subsidy	$1.30	$475	$5,242,	$34,924	$21,920	$146,342
Low Estimate	$0.25	$91	$1,008,	$6,716	$4,215	$28,142
Lowest Estimate	$0.10	$37	$403	$2,686	$1,686	$11,257

What does this mean for the City of San Francisco and the entire Bay Area? The WTP estimate of $5 per day, if applied to those with severe vision impairment, shows a yearly dollar benefit of over 20 million dollars to San Francisco residents and over

134 million dollars for the entire Bay Area. This benefit, for those with some type of vision limitation, would be over 562 million dollars for the entire Bay Area.

Using the amount subjects said they could save in their actual, direct travel expense for assistance resulted in a dollar benefit for this type of information of almost 14 million dollars a year for San Francisco residents with severe vision restrictions and over 93 million dollars for the Bay Area residents with severe vision restrictions. If all residents with vision impairments are included, the dollar amount for the entire area is about 390 million. Even a low benefit estimate of 25 cents a day gives a total yearly benefit of 28 million dollars for all vision-impaired residents of the entire area. The benefits estimated by individuals for less travel assistance did not include a benefit from the reduction of paratransit service use that is sometimes paid by public or private agencies. In this experiment, subjects clearly stated they would not need to use the expensive paratransit service if the auditory spatial cues and information was widely available.

6.3.5. Employment, Education, and Government Assistance

With an unemployment rate of at least 70%, financial independence can be a significant problem for this group. Many of the blind and vision-impaired population are receiving Supplemental Security Income benefits (SSI) and other supplemental income, along with other types of government subsidies. This research has shown how the lack of access to transit affects activity participation, including job search and travel. The sample population reported that they could earn on average $8250 more per year if RIAS was installed in their area (the 20 subjects who said that lack of access to transit affected their earnings gave an amount of $12,385). Some of the subjects were not in the job market, and some had well paying jobs and said that they would save on expenses and make more trips, but that RIAS would not change their income. For the 20 who did answer this question, it was quite a different story. Two subjects, who both sold and installed adaptive computer equipment for the blind, explained that they had to devote one day to making a practice trip to a new client's house in order to be able to ensure that they arrived on time and with ease while carrying the equipment. These two thought they could almost double their sales income if they did not have to make a preliminary practice trip by using RIAS. Practice trips can also slow down job search activities for this population. Since limited access to work and education directly impact low employment for this group, those findings are examined next.

Of the 30 subjects, 17 currently made work trips (see Section 4.3.3, Activity Participation and Trip Frequencies for further discussion of those data). One subject was retired, so there were 12 working age subjects who did not make work trips. After using RIAS, fully 50% of those who did not work said they would make work trips if this kind of spatial information were available. The findings for education trips were even more robust. Eight subjects currently made trips for educational activities, leaving 22 people who did not attend any educational functions. After the field test of these auditory navigation cues, 15 more subjects (68%) reported they would travel to and attend educational activities.

What might this increase in work and education activities mean for reducing public expenditures? According to the Blindness Alliance For Rehabilitation Change (BARC, 2000, p. 1), “the unemployment of blind Californians yearly costs government well in excess of $1 billion in cash outlays, Medi-Cal, Section 8 housing and other forms of assistance.” This figure does not include all the federal aid to this group; people who are disabled and meet minimum income and asset levels are also eligible for federal SSI and Social Security Disability benefits (SSD) payments of up to about $700 per month. The sample data showed that half of the unemployed said they could work if additional spatial and environmental cues were available. That estimate would probably not apply to the target populations as a whole, but it extrapolates to a savings of 500 million dollars. Even if a much lower figure of just 10% being able to independently use transit to get to employment is used, that would save the state 100 million dollars a year.

Current state efforts to increase employment for blind people in California are coordinated by the California Department of Rehabilitation. They provide education, assistive technology, and other services to promote employment. However, over 83% of closed cases are classed as “homemaker” which means they are not employed. The Department spends about 25 million dollars a year for blind services, and, over the last five years, they have placed about 300 people a year in "competitive" employment. Dividing the budget by the number of jobs placed reveals that the state pays $85,000 for each job, with an average weekly starting pay of $353 (BARC, 2000, p. 1).

6.3.6. Cost to Equip Bus Fleet In San Francisco

Many transit buses are accessible to people who use wheelchairs, through massive efforts to comply with ADA requirements. Problems faced by travelers with limited vision trying to identify, find, or transfer buses were discussed earlier (see Sections 2.5.3 and 2.6.3) and Table 3.1 shows that these problems are some of the most difficult transit tasks, as rated by the subjects. This section offers a brief "back-of-the-envelope" estimation of the cost to install RIAS on all San Francisco Muni buses. Unlike other types of installations, the total installation has a known cost, and therefore is examined here. Talking Signs® for buses are available from Luminator, a company that also makes route and destination header signs for transit vehicles. One RIAS transmitter is used to transmit an infrared beam forward to identify the bus and also to the side to identify the doorway. The current price for this transmitter was quoted as $1650, without installation, or $2100 with installation, which is the cost used in this example (Luminator, 2002).

The San Francisco Municipal Railway (Muni) has 454 diesel buses that carry over 96 million passengers per year and 331 trolley buses that carry almost 81 million passengers (San Francisco Municipal Railway, 2002). The estimate that follows calculates the cost of installing a Talking Signs® transmitter on all of these two vehicle types (diesel and trolley), a total of 785 vehicles that carry almost 177 million passengers per year. The cost to equip those 785 vehicles would be 1.65 million dollars ($1,648,500). Using a 15-year useful-like for vehicles yields a yearly cost of $110,000, which represents 0.029% of their reported operating budget for 1999-2000, $380.9 million (San Francisco Municipal Railway, 2002). Table 6.3 shows the estimated yearly cost divided by population estimates and by ridership numbers. Because people with severe vision impairments are *captive* transit users, it would be expected that they actually use transit at a higher percentage than the general populations, many of whom drive cars. However, for this estimate, equity of use is assumed and the number of riders per year is based on the National Lighthouse estimates of 1.7% of the population having severe vision impairment and 0.45 % being legally blind. Currently, Talking Signs® receivers are available to qualified users in San Francisco at no cost, but it is assumed that other sources would be needed to provide receivers if buses were equipped with RIAS. Transit providers are best able to estimate the number of blind users that they serve, through information from disability discount applications or transit statistics on discount fare usage, in order to estimate the number of receivers needed. The installation cost and distributions over people and riders were made with information available and further study by transit providers is needed to determine the number of people who would use transit and could benefit from these installations. The cost is well below that needed to make a vehicle accessible for wheelchair use and compare favorably with current discount programs.

Table 6.3 Talking Signs[(R)] Installation Cost for San Francisco Muni Buses

Cost per Person			
Cost per Year	Total Population	Severe Vision Impairment	Legally Blind
$110,000	746,777	12,695	3,360
Yearly Cost per Person	$0.15	$8.66	$32.74
Cost per Ride			
Cost per Year	Total Ridership	Severe Vision Impairment	Legally Blind
$110,000	177 Million	3,009,000	796,500
Cost per Ride	$0.0006	$0.037	$0.14

6.4. Chapter Summary

The *estimated benefits* and *WTP* data were collected in a manner that followed the advice offered in the literature about increasing validity for such types of questions. According to this experiment, blind subjects are well aware that restricted access to transit and independent travel is a major factor in finding and holding employment. They strongly agreed that the addition of environmental cues, such as RIAS, would greatly increase their access to public transportation, buildings, and the urban environment and its opportunities. The high number of people that reported they were willing to work indicates that more attention should be paid to the causes of unemployment for this population and that new policies should be considered to ensure more robust employment than is delivered by the current system of government subsidies. Public expenditures to ensure more equal access to transit might save many millions of dollars in direct subsidies and assistance payments and also could make taxpayers out of some people who now are dependent on tax money for their basic needs. The population numbers and estimates offered here were only for those with vision-impairments. Further research could reveal that other people who have difficulties accessing printed or environmental cues, such as those persons who are illiterate, dyslexic, or cognitively disabled, might also benefit from these additional cues. One of the goals of ITS has been to attract more transit users through more efficient information and use, and these kinds of auditory environmental cues are one way that the information could be delivered to the general public.

A wide range of benefits was discussed and a cost estimate given for a bus fleet installation. It is important that these numbers not be used as exact estimates, or generalized to the entire population of those with severe vision restrictions, but used as a guide to better understand the magnitude of perceived dis-benefits due to limits on independnent travel.

7. Making Environments More Accessible for the Blind: What Has Been Learned?

7.1. Introduction

Much research on environmental perception and cognition gathers empirical data from subjects and compares it to a "true" or "real" environment to test for any differences. Deviations from the norm are considered subjective cognitive views, based on the subject's information processing. A statement like "Campbell Hall is the big round building with the curved concrete roof" is considered a "true" statement. However, this information might not help a visitor who does not have sight. The physical world is understood through perceptual filtering, and the lack of vision might hinder the acquisition of necessary spatial knowledge.

It appears that people with a sensory disability inhabit some kind of transformed space, one conceived of and used differently than the conceived and used world of "objective" reality experienced by those with the full array of perceptual senses. Barriers and obstacles are multiplied in both number and scale for blind and visually impaired travelers. Many cues are not available, and space itself can become highly confusing and "wildly distorted…by incomplete knowledge" (Golledge, 1993, p. 64). These "deviations' from the objective world are what makes the study of spatial awareness and navigation by those with vision impairments a distinct area of geographic analysis.

Freedom of movement, accessibility, and, in fact, a major component of people's "quality of life" depends on the ability to make spatial decisions. These decisions are made at different scales and in environments of different complexity. People without full vision can find it very difficult to access information about the world in which they must travel.

In this chapter, the new types of cues that blind people gain when using RIAS are identified. Then some of the previous research findings on blind navigation and spatial knowledge acquisition are highlighted, and what has been learned from this experiment that adds to our understanding of the role of vision in daily navigation tasks is discussed. The experimental design and procedures are discussed and a summary of the results and hypotheses is given. Next, any confounds of this design are examined and, finally, future research that might add to our understanding is examined.

7.2. Missing Spatial Cues Provided by RIAS

Figure 2.5 Transit Terminal Installation shows a person using RIAS at the experiment site and illustrates four types of information or cues that are missing without vision, but that are provided to the user of auditory signage.

- **Specific Information and Positive Identification at Locations:** Even when a blind person finds a location, such as a door, bus stop, or counter, it can be difficult to be positive of its identification. In the experiment, without RIAS, some people found counters, train track doors, or a bus stop but did not know if they were at the correct location. RIAS allows a person to get direct and positive identification of any signed location. This type of information is especially valuable in a new environment, before one has had the time to learn spatial arrangements or locations. This type of assurance reduces the cognitive load caused by extracting information from memory (if it exists) or having to ask others for information or clarification.

- **Spatial Information Accessed From a Distance:** As shown in the illustration, a RIAS user can get spatial information from distant locations instead of being limited to the area of the body or reach. Blind people, finally, do not have to actively search along walls and spaces for cues; they can scan around and hear what locations are nearby. This information can help one find a specific location being searched for or get an overall idea of the function and structure of an unknown environment.

- **Directional Cues to Distant Locations:** In addition to learning the names of distant objects, RIAS gives the user the direction to those locations. Even in a totally new environment, a user can identify and proceed to a location without having to learn and memorize a path or sequence of spatial arrangements. A user can stand in one location and receive spatial information that can assist in understanding the spatial arrangements of the area.

- **Self-orientation and Location:** Without vision, it is quite easy to lose track of where one is in a space and even which way one is facing. Blind people might need to walk to a wall, familiar location, or curb to orient their position. With the ability to scan and find directions and identity of other locations, a blind person has another cue usually only available to the sighted; they know which way they are facing in relationship to objects and roughly where they are located and orientated in an open space.

These cues combine to help form an **integrated model of the space.** The ability to preview space is noticeably absent without vision and appears to be a major cause of inferior spatial performance exhibited by some blind travelers. Accessing spatial information from a distance gives blind people the ability to preview space and gain information without moving from place to place in active searching. The four environmental cues and spatial abilities (to identify objects up close, to identify objects from a distance, to get directional cues to objects, and to orient the body to the surroundings) give the blind traveler much of the same information available through vision and indicate why this type of system produces such efficient, safe, and less-stressful travel.

The "vision-like" cues made available through location-specific auditory prompts allow a user to get more complex information about the locomotion path and more spatial information about the environment. Instead of being limited to path knowledge, adjacent landmarks can be easily picked up and stored in memory. In this experiment, this additional information appeared to help users to structure their mental maps with more relevant and accurate knowledge. The ability to preview a large space and receive direction and identity cues appears to greatly increase the speed of compilation of an accurate mental image of the environment. In addition, the test subjects strongly expressed the view that the cues received from RIAS gave them much more independence, and, according to Casey (1978), independent travel leads to superior mental representations.

7.2.1. Relevance of this Work to Spatial Organization Theories of the Blind

There is little agreement about the spatial cognition, mobility, and orientation abilities of blind people in large scale or geographic space. In fact, three different theories have been postulated to explain the limited spatial skills exhibited by blind subjects concerning the comprehension of space (Fletcher, 1980). The *deficiency* *theory* holds that congenitally blind people do not possess the ability to process spatial relationships, and that the lack of a schema is caused by the absence of visual experience of large and small scale locational properties. This view also holds that some adventitiously blind people have not had time to develop a full spatial relationship understanding and are also unable to develop one.

Another theory is that of *inefficiency*. It explains that congenitally and early blind people might have the ability to process spatial information, but that they have to use auditory and haptic senses; the spatial system was designed for vision, thus leading to ineffective use of these skills. A blind person might interpret a gently curving path as a straight line or not be able to recognize patterns in the environment.

The third theory, that of *difference*, states that all spatial concepts are available to all people, but that quantitative and qualitative differences are introduced based on visual experience. Blind people may use different structures to acquire and process spatial information, and they may take much longer to acquire this knowledge. This theory also says that lack of sight may hinder the ability to store, retrieve, manipulate, and use pieces of spatial data stored in the mind (Golledge et al., 1988). Research, using eight different but supportive approaches to measure spatial knowledge, showed that the blind exhibited the same spatial understanding as the sighted, and that any difference could be due to visual cues that were not available (Passini & Proulx, 1988; Passini, Proulx, & Rainville, 1990). However, if these visual cues could be substituted for, perhaps there would be no difference in the processing schema

This leads to a fourth possibility, that of an *amodal representation* (Carreiras & Codina, 1992), which postulates that the blind are able to store and process spatial relationships in a manner similar to the sighted, but that it might take them longer. The authors say that the blind can acquire configurational spatial knowledge and solve spatial problems with strategies similar to those used by the sighted, and that mental spatial representations are not limited to any particular sensory modality. Although this experiment was not designed to fully answer which theory is most valid, the amodal theory best explains the present findings. Some of the reasons for the disparities between these different theories and how the chosen experiment was designed to avoid many of these confounds will be discussed next.

7.2.1.1. Issues of validity

There appear to be many reasons why there is such disagreement among researchers about the capacity and abilities of blind people to input, process, store, and use spatial and configurational relationships. Reviews of many experiments and the issue of validity have been covered in great detail in other papers (Golledge et al., 1999; Jacobson, Kitchin, Golledge, & Blades, 2002; Kitchin, Blades, & Golledge, 1997; Kitchin, 1994; Strelow, 1985; Thinus-Blanc & Gaunet, 1997).

7.2.1.1.1. Small and diverse sample size

It is not an easy task to recruit a large number of research subjects with severe vision impairments. Much of the research reported in the literature mirrors this difficulty by the use of quite small sample sizes. Many experiments had sample sizes of eight or less per group, and such small samples make it difficult to draw generalizations about the abilities of other blind or vision-impaired people. This research was based on 30 subjects: 17 were congenitally blind, 20 had no useful vision, and another six could only see some shapes. Compared to most experiments of blind navigational skills, this was a large sample size, with a high percentage of totally blind subjects. The subjects were also more homogeneous than some other sample test-groups. They all reported having undergone Orientation and Mobility training, and they were adults who all exhibited independent travel skills by traveling to the test site without assistance. They were a fairly active group, with over half holding jobs and most of the rest receiving training or education.

7.2.1.1.2. Scale transformation

Much research on spatial abilities without vision is conducted in small scale or even laboratory spaces, yet these results have been treated as if they applied to large scale and naturalistic spaces. These range from tabletop experiments, to room-size (Hill et al., 1993), to buildings (Passini & Proulx, 1988), and to artificial mazes (Passini et al., 1990). Some experiments in larger scale spaces only use several choice points (Dodds et al., 1982). Only a few have used environmental and natural spaces (Golledge et al., 1999; Jacobson, Kitchin, Gärling, Golledge, & Blades, 1998). A large-scale environment, as in this experiment, might offer additional cues such as sounds, breezes, and smells that can be controlled in a small-scale experiment. However, uncontrolled environments can be complicated by the presence of people, obstacles, and other distractions.

Skilled blind travelers process and use many non-visual cues during their daily navigation, yet some large-scale tests are conducted in a featureless and cue-less open field, with irregular turns being required at non-distinct choice points, causing concerns about ecological validity. Strong evidence of the spatial skills of the blind (Golledge et al., 1999; Jacobson et al., 1998) is due in part to an experiment design that allowed blind people to use cues at choice points that were familiar, typical, and memorable, instead of being abstract or featureless locations. The experiment reported here was also conducted in the type of built environment familiar to blind travelers; they were tested in a large interior space of a transit terminal, along city streets, and crossing streets to other transit modes. No scale transformation of these findings is claimed; the results are attributed to these everyday environmental spaces. This is where the blind labor to achieve independent navigation; they do not do so in small scale or laboratory space.

7.2.1.1.3. Spatial products, construct and ecological validity

Mental map information and *configurational knowledge* must be extracted by using *external products* that attempt to portray the internal knowledge stored in the mind. While sketch maps might be adequate to capture this internal knowledge for the sighted, lack of vision and familiarity with drawing make this type of spatial product invalid for blind research. This is well understood, but other products are also not familiar or accessible to the blind. Pointing to landmarks in the environment might be flawed if the person has rotated their position (such as a turn toward the experimenter's voice) or otherwise is not sure (during the pointing task) of their alignment to the path they are on, and these errors in orientation might produce results that do not reveal their true mental representation. Even 3-D models, while far superior to sketch maps, can be flawed because people must search for, identify, and scale different segments or pieces without the use of vision. Some people have a poor understanding of metric distances, and a product that uses distance estimations can result in an "impossible" map when using typical multi-dimensional scaling techniques. Even spatial relationship questions might be biased toward vision, or prior visual experience. If these tests or spatial products do not measure what they are intended to, without error, there are *construct validity* issues that might affect the different theories about spatial abilities. In this experiment, two spatial products were used to reveal spatial and relational knowledge: the ability to understand and use shortcuts and the relationships between objects that they had recently visited.

7.2.1.1.4. Utility of tasks

The experimental design that stressed the utility of tasks and tests was discussed earlier (see Section 4.6, Spatial Knowledge Acquisition and Cognitive Maps). The utility to get from one point to another in a complex real world environment tells more about a person's spatial skills than does comparing revealed spatial knowledge to objective, often Euclidean, reality (Kitchin & Jacobson, 1997). Mentally intensive estimations of distance or directions might fail to reveal the internal map as well as might the use of a more real-world and high-utility approach.

7.2.1.1.5. Convergent validity

Different tests designed to measure distance cognition have been found to yield different results (Montello, 1991). With so many imperfect ways to elicit internal spatial knowledge, it is quite important to test blind people's knowledge with more than one method. If two or more methods or tests are used, and they do not agree, then one or both of those methods is suspect or invalid. Some of the research that is cited as supporting these differing theories of spatial organization uses only one method to measure spatial skills. If only one is used, there is no way of knowing if it is a valid choice. Kitchin & Jacobson (1997) believe that each spatial test introduces some bias into the analysis, and that multiple and mutually supportive tests must be used to more completely assess configurational knowledge. This lack of *methodological convergence* (Campbell & Fiske, 1959) makes much of the cited literature suspect as to the validity of the different theories. The experiment presented here was not designed to fully investigate spatial skills, but two methods were used to estimate spatial knowledge, and both methods converged to show that RIAS users had superior spatial awareness. In addition, many people in the *RIAS* condition had perfect or near perfect results, which were not seen in those who used their regular methods. In addition, the field test showed that path travel times, error production, and request for assistance were all superior in the *RIAS* condition.

7.3. Measuring Accessibility for Special Populations

Access measures must not only include physical mobility, but also a person's ability to interpret, recognize, and understand key landmarks and choice points and the layout and function of environments (Golledge, Loomis, & Klatzky, 1997). Since individuals with disability might conceive and use objective space in subjective ways, standard distance or network accessibility models do not capture the world as used by many in this group.

7.3.1. <u>Group or Person-Based Measures</u>

Many measures of accessibility were reviewed in Chapter 2. Throughout this paper, a variety of access measurements have been used to document limitations on travel caused by vision loss. Since network and distance-based measures do not capture individual differences, it is important to look at group or person-based measures and use methods to explain various constraints and barriers to access that are not revealed in conventional measures. Chapter 4 dealt with measures and models comparing accessibility of blind people to a base-line sighted person's performance, and also between the control group and those in the test condition. To better understand the access limitations of the blind, or other disabled groups, it is necessary to know more than the fact that it takes them longer to travel; one should compare those travel times and efforts to the typical sighted and ambulatory user to empirically determine what and where these limitations are. In addition, measuring results from mitigating techniques can be done to determine any positive changes to accessibility. In this report, comparing the actions of the blind to the sighted revealed locations that served to block or delay travel, revealing that there was not an overall "penalty" to blind travel, but, rather, that specific areas of the environment caused more restrictions than others. In addition, comparing regular blind travel to technology-aided travel also demonstrated which areas of travel are most restricted by lack of vision and how technologies could mitigate these limitations. Whether travel times, activity participation rates, independent travel, ability to make transfers, or reported difficulty of tasks were examined, this method of comparison revealed specific areas for further research and mitigation. Techniques that reveal access differences, whether between conditions (Clark-Carter et al., 1986; Golledge & Marston, 1999), or between the typical user and a person or group with a disability (Church & Marston, in press; Golledge et al., 1999; Okunuki et al., 1998), define accessibility much better than conventional measures.

7.3.2. <u>Activity Based Measures</u>

Access measures must also be activity-based, as people with environmental limitations exhibit different limitations for different activities. By using a "person-based" variable, existing measures can be adjusted to reveal specific restrictions for individuals and groups with disability.

7.3.2.1. Distance Decay

The use of a *distance decay* formulation helps identify specific problems faced by people with particular disabilities. Comparisons of the impedance coefficients can empirically measure the degree of restrictions and the effect of any corrective improvements. For the blind, the path distance might be the same, but the travel effort can be increased by the lack of cues. For those using wheelchairs, the distance is often longer, due to barriers in the environment. By using impedance coefficients, quantitative measures can be produced for comparison and possible remediation purposes. This technique was used to produce a "penalty" measurement to empirically determine the restrictions to access and how limitations directly affect travel time and effort.

In addition to impedance, the distance decay model also considers the magnitude of attractions. Higher levels of a location's attraction theoretically induce more travel. Since some blind people report very few trips, this could imply that the blind give different salience to locations than the typical user, and a lower attraction coefficient must therefore be used to model their trip-making frequencies. On the other hand, prior knowledge of a location might well make that place much more attractive as compared to an equal and closer alternative that is unfamiliar. Ease of orientation and navigation, safety concerns, closeness to known transit, or even a familiar layout or menu can affect the attractiveness, and these differences should be considered when using this type of model.

7.3.2.2. Constraints

Accessibility can also be studied by looking at constraints put on the task of participating and traveling (Hägerstrand, 1970). Hägerstrand offered three such constraints, those of *coupling*, *capacity*, and *authority*. These have been used to explain disability access problems such as vision loss (Marston et al., 1997) and ambulatory limitation caused by MS (Thapar, 1999; Thapar, Bhardwaj, & Bhardwaj, 2001). The loss of independence associated with many disabilities increases many kinds of capacity and coupling constraints. Waiting for travel assistance or helpers affects access, and, for those who cannot drive a car, the dependence on transit adds further to these constraints. Missing a transit vehicle by a few seconds might delay access and travel for an hour or more, and the coupling required at the other end of the trip might also be constrained.

7.3.2.3. Utility

Typical *utility measures* can also be used to evaluate access for the disabled, but, again, these are not always the same for this population. It has been noted that the desire to save time is overshadowed by other concerns. For the many in this group who are unemployed, the standard measures of money and time valuations might need to be adjusted. Utilities such as safety, comfort, and familiarity appear to be much stronger for this group.

7.4. Applied Disability Geography

There appear to be two types of geographical inquiry that relate to the disabled. There is a geography <u>of</u> the disabled that examines their unique social and spatial distributions as a group of disenfranchised individuals. The other is a spatial geography <u>for</u> the disabled, one in which analysis is focused on understanding and improving this groups' relationship with the world that they travel and live in (Golledge, 1993). The research presented here follows the contextual framework of applying geographic analysis to the spatial problems faced by people with disabilities. This type of research goes well beyond the paradigm of social theory or Marxist critique. While it shares the desire to be emancipatory (seeking increased social and material equity) and empowering (seeking positive individual change through participation) (Kitchin, 2001), it focuses on empirical data about how the use and understanding of space is transformed by sensory deprivation (Golledge, 1994). Not content to simply identify and discuss "exclusion" and other social inequalities, it attempts to clearly identify the factors that transform and limit this conception and use of space and then to identify how applied techniques, including technologies and innovations, can decrease these spatial inequalities and lead to more inclusion and participation and to positively affect the quality of life for this group.

This type of approach is relevant when "the human-environment interaction mode is constrained-as when disability places a filter between people and the world in which they live" (Golledge et al., 1997). Their research also reported that loss of independence is a major and humbling disadvantage of life without vision, and that any device that can reduce dependency would be "of the utmost importance to increasing the quality of life for the blind or vision-impaired individual." Therefore, research that leads to more independence, easier travel, and a more active lifestyle makes applying geographic and spatial analysis to disability issues a worthwhile and much-needed endeavor.

Research by Golledge et al. (1999), Jacobson et al. (1998), and Kitchin et al. (1997) showed that blind people could learn the spatial arrangement of complex routes as easily as the sighted and could retrace those routes as well as the sighted, given a few more trials. This was achieved by using methods such as having subjects point back at landmarks as they traveled or by building models to learn the routes. That research has potential impact on how blind people should be taught orientation and navigation skills and holds promise for making the environment more accessible for this group. Applying this type of spatial geographic analysis and techniques to environments riddled with barriers to wheelchair travel can also help emancipate those using wheelchairs from the tyranny of the built environment (Church & Marston, in press; Golledge et al., 1997; Okunuki et al., 1998).

The research reported here can also add to the understanding of the effects of spatial restrictions on this group. Previous research on RIAS (see Chapter 2) showed that blind people said the additional spatial cues would increase their independence and help them travel more often. In addition to those findings, this dissertation reports that these cues would facilitate increased participation in otherwise denied activities. Subjects strongly agreed that RIAS would help them lead a more active life, increase their access to urban opportunities, and help increase their quality of life. Two models derived from this type of analysis are summarized next.

7.4.1. <u>Modeling Travel for the Disabled</u>

In order to model travel for certain groups with disabilities, empirical data on impedance and other spatial limitations faced by people with disabilities should be collected to pinpoint what the specific problems are, what barriers exist, and what cues or information are missing. Once this is known, techniques to reduce these limitations can be researched and evaluated. Chapters 3 and 4 examined these data for the vision-impaired.

7.4.1.1. Impedance to Making Transfers

People with vision impairments willingly traded time to avoid the problems of making a transfer (see Section 4.5, Reported and Perceived Transfer-Making

Behavior). This shows the restrictions on travel faced by this group, and indicates that reasonable access has not been achieved for them. This is clearly a social equity issue that demands more attention. This group's initial impedance to make the transfer was much higher than for the sighted group, and their impedance for walking to a transfer point was also higher. After using the RIAS, subjects estimated that their times would be much lower, quite similar to the sighted control group.

7.4.1.2. Location Based Differences of Cues and Legibility

It was shown that there was not a uniform search and travel impedance faced by blind people, but that the type and placement of locations affected the degree of extra time and effort needed to travel without vision (see Section 3.5.3, Modeling Transit Task Difficulty and Mitigation). Therefore, it is not the effect of blindness per se, but the structure and layout of built environments that can so strongly affect accessibility to public services. Social theorists hold that it is the social context that has a disabling effect on people, and this research offers a way to measure spatial limitations inherent in the environment. Hopefully, this information can lead to better designed spaces. Accessible signage greatly reduced this disabling effect, and its adoption could prove an effective way to use political and social resources to increase the ease of travel and quality of daily life for this group. A more logical placement of environmental features, or the addition of a few more cues, could also lead to a much more equitable world for those without vision.

These examples of applying spatial geographic analysis to disability issues show how this technique can lead to a greater understanding and identification of where and how to commit resources. Foulke (1982) pointed out that we still do not know what spatial information to display for the blind, where to display it, and what manner that display should take, and Golledge (1993) says these are viable research problems for geographers. It is hoped that this research has helped to answer those and other questions.

7.5. Survey Design and Methodology

In this section, the design and methodology of the experiment is summarized. Possible confounds caused by those design decisions and how those decisions might have impacted the validity of results are discussed in Section 7.7.

7.5.1. Subject Recruitment

Legally blind adult subjects were recruited from a list solicited from two Orientation and Mobility instructors who worked in the area. A full description of the process was reported (see Section 1.6.1, Subject Recruitment and Procedures).

7.5.2. Design

The concepts tested and the questions asked were largely taken from what had been learned from earlier experiments, from other researchers, and from discussions with blind travelers, as reported in the second chapter. A large battery of questions was asked to take full advantage of the subjects' knowledge and input.

7.5.3. Methodology

A field test was used to acquaint the subjects with Remote Infrared Audible Signage. Subjects were tested in two conditions, with and without RIAS. Most questions were asked before the test and then after the test. Some questions were asked after each of the two field trials and some questions were asked only after the test.

7.6. Summary of Results and Hypotheses Testing

This research collected many data, using various collection techniques, to measure functional barriers to transit use, by those with a vision impairment, and to determine if RIAS could mitigate those barriers. Four hypotheses were tested in multiple ways and the results are briefly summarized here. The efficacy of these additional environmental cues and their ability to provide increased access to transit and the urban environment were both strongly supported by these data.

Hypothesis 1: Experiment data will show that, for those with limited vision, specific locations and tasks cause difficulty when using transit. The use of auditory signage will mitigate much of the difficulty. This hypothesis was tested in Chapter 3 in the following sections.

Section 3.1: Caltrain Field Test

- Blind people had slower times and more errors without RIAS.
- Limited cues at some locations caused people to have to ask for help from others when using their regular methods.
- Street crossings were much quicker and made more safely when using RIAS. With the normal techniques, many subjects started to make unsafe street crossings and a few would not even attempt the crossing.
- Limited cues or inconsistent placement at some locations caused higher travel time penalties than other locations.

Section 3.2: User Rated Difficulty of Transit Tasks

- Transit tasks were rated as having a high degree of difficulty.
- After using RIAS, many tasks were rated as having little or no difficulty.

Section 3.4: Subject Observations on the Benefits of RIAS

- Positive effects were reported when using RIAS at street crossings, to navigate in terminals, or when making transfers.
- Difficulties and negative effects were implied, when using regular methods.

Section 3.5: Modeling Impedance of Different Transit Tasks

- Specific tasks and locations such as unmarked doors, busy streets, and inconsistent locations were associated with large time penalties.
- Other tasks and locations such as those with good cues, walking to a corner, or less busy streets had much smaller time penalties.

Hypothesis 2: Difficulties of transit tasks will affect travel activity and behavior, and reduce trips and accessibility. Subjects will estimate they would make more trips and access more places if RIAS was installed. This hypothesis was tested in Chapter 4 in the following sections.

Section 4.1: Travel Confidence and Frequency of Visiting New Environments

- User ratings of their confidence in independent travel, sense of direction, and in new environments were much higher in the post-test condition.
- Users reported they would make more trips to new places if RIAS was installed.

Section 4.2: Perceived Travel Behavior while Making Transfers

Two questions were asked about making a 10-mile transit trip that included a transfer in an unfamiliar area.

- For a one-time event, 40% using their regular methods and 97% considering RIAS said they would make the trip independently.
- For a daily job, 53% using their regular methods and 100% considering RIAS said they would make the trip independently.

Section 4.3: Activity Participation, Trip Behavior, and Travel Times

- Actual activity and trip behavior showed that many people made few trips to participate in outside activities. 73% of subjects participated in only two or less outside activities per day.
- If RIAS was installed, 97% said they would make more trips to more activities.
- Subjects reported making 12.1 trips per week, if RIAS was available, they estimated they would make 25 trips per week.
- Work, education, and recreational trips had a high *hidden demand* that they said could be meet by RIAS.

Section 4.4: User Opinion of the Affect of RIAS on Travel Behavior

- They reported on the difference of their travel behavior with RIAS and said that travel would be more efficient, they would have better spatial orientation, make more trips, go to more places, with better affective states, and more independence.
- Implied were the many difficulties and limitations of travel using their regular methods.

Section 4.5: Reported and Perceived Transfer-Making Behavior

- Blind travelers willingly spent time to avoid difficulties in making transfers. 71% said they would spend 30 or more minutes (on a 60 minute trip home) on a slower vehicle to avoid making a transfer. With RIAS, only 16% thought they would waste that much time.
- Blind respondents showed much higher resistance to make transfers then the general public.
- Resistance was even higher in unfamiliar areas.
- After using RIAS, the blind estimated their resistance to transfer as being similar to those times reported by the sighted public.

Section 4.6: Spatial Knowledge Acquisition and Cognitive Maps

- Subjects using their regular methods made 23% of possible shortcuts. Those using RIAS made 95% of possible shortcuts.
- Subjects using their regular methods answered 44% of the spatial knowledge questions correctly. Those using RIAS answered 88% correctly.
- Some types of spatial knowledge were very hard to acquire using regular methods.

Hypothesis 3: Travel and access limitations negatively impact the quality of life for those with vision loss. When using RIAS, subjects will report a wide range of positive influences on their quality of life. This hypothesis was tested in Chapter 5 in the following sections.

Section 5.1: Summary of Previous Quality of Life Statements

- Many difficulties and limitations were reported and exhibited with regular blind travel. Subjects reported that RIAS greatly reduced transit difficulties, and gave them more confidence, more efficient travel, the ability to participate in more activities, and to feel independent.

Section 5.2: Subject’s Opinion and Evaluation of Talking Signs(R)

- Users stressed how RIAS was a spatial orientation aid that improved their mental state and led to more independence.

Section 5.3: User Response to Talking Signs®

- Users agreed that RIAS would help them travel more often, make travel easier and safer, increase their use of unfamiliar transit and transfers, and help them financially.

Section 5.5: Lost Earnings and Additional Expenses Due to Inaccessible Transit

- Limited transit access to employment was perceived to diminish their earning potential. Respondents thought they could earn an additional $8,257 yearly if RIAS was installed. For those in the job market, that amount was $12,385.
- Limited transit access required them to pay for travel assistance. They reported they could save $1,267 yearly if RIAS was installed.

Section 5.6: Monetary Benefit of Independent Travel

- Respondents stated a benefit of $17 to use RIAS to travel independently to a one-time event.
- They offered $10 as the benefit to use RIAS to travel independently to a daily job.
- They offered a benefit of $5 per day to use RIAS.

Hypothesis 4: The field test data and subject's observations, ratings, and opinions will demonstrate a wide variety of benefits that accrue to the user of RIAS. This hypothesis was tested in Chapter 6 in the following sections.

Section 6.1: Summary of Benefits from Field Tests and Questions

- These benefits have been discussed earlier. In addition to the monetary amount they placed on being able to use these additional cues, they reported that this would give them much more access to transit and urban opportunities.

Section 6.3: Benefit Analysis

- The monetary amounts offered for the use of additional cues demonstrate a very large benefit when applied to an entire metropolitan area.
- The amount of lost income and additional travel expenses puts a large total burden on area blind residents.
- Currently, unemployment for blind people is around 70%, and, in this experiment, half of those not working thought they could find new employment. Increased employment would provide to society benefits of lower welfare and assistance payments and new employment opportunities might increase the tax base.

These results show that the addition of auditory information makes a great difference in efficient performance, safety, and attitudes about independent travel. With specific location identity labels and directional cues, legally blind subjects can greatly increase their ability to travel without assistance and to have access to more urban opportunities, including better access to job search and employment possibilities. The tests summarized here, as well as others from this paper, all showed positive changes in perceived or actual behavior when people with lgal blindness had access to additional auditory cues. The use of so many different tests to measure the same condition effect enhances *convergent* or *methodological validity* (Campbell & Fiske, 1959).

7.7. Possible Methodological Confounds

7.7.1. <u>Subjects</u>

The sample was not representative of the total blind population. The percentage of people with disabilities, including blindness, increases with age. Many people with vision impairments are quite advanced in age, and they also might have other physical disabilities that would have made this type of testing impossible to conduct. Not included in this sample were those types of people who do not make independent trips, such as reported by Clark-Carter et al. (1986). As has been made clear, the sample population required active and independent travelers to get to the test site, and, thus, they were not representative of all blind people. A true representative sample, even if condoned by human subject protocol and restrictions, would have probably not been able to complete many of the tasks using their regular methods. Fatigue and stress would also have taken their toll on subjects.

It is doubtful that this type of sample had any negative impacts on the validity of this study. This research was designed to be a "real world" experiment, and the group tested was likely to be representative of active blind travelers who make independent trips into new environments. It is assumed that, if a more representative sample had been used, the control group, using their regular methods, would have made many more mistakes and not been able to complete many more tasks than was the case with these people. It is expected that the results would have been even stronger for the efficacy of the auditory signs if the elderly and more dependent blind people had been included.

7.7.2. <u>Time Constraints</u>

When asking blind subjects to locate and find 20 locations in a new environment, there would be many times when the goal could not be found in a reasonable amount of time. In addition, a valid experiment must keep stress, fatigue, frustration, and other negative feelings at a low level. For those reasons, some type of time constraint must be placed on these tasks. A four-minute limit was used on each of the 20 tasks. As many more people “timed out” when using their regular method, the effect of this limit was to actually reduce the time difference between the two conditions. A higher limit would have made the differences in the results even more robust but would have led to other problems. In a *route learning experiment* at the UCSB campus (Golledge, Marston, & Costanzo, 1998a), it was noticed that, blindfolded, sighted subjects did not hesitate to give up on a task when they could not easily locate a target, whereas the blind subjects were very reluctant to ever give up before the time limit. In the Santa Barbara MTD experiment, (Golledge & Marston, 1999), many subjects kept searching even when totally disoriented and were also very reluctant to stop their task. This is a vital and necessary search tactic for an independent blind person, and it was felt that this tenaciousness in terms of completing a task and not being seen to "fail" would have made the test much longer, stressful, and frustrating if more time had been allowed.

One problem with using the same limit for all tasks is that the performance differences were constrained by the upper bound of four minutes, although all routes were not of equal length. Thus, a route that would take a sighted subject or RIAS user two minutes could, at the best, be only twice as "effective" when compared to a subject who timed out at four minutes. In contrast, a shorter route, such as crossing a street or walking to a nearby location, could have a much higher effectiveness rating. One way to solve this problem would be to have each limit based on a multiple of the actual sighted control walking time. However, this could cause other problems. A walk that would take two minutes might need to have a limit of 20 minutes to make it comparable with another shorter control trip of 24 seconds and having an upper limit of four minutes. If the purpose of this experiment was strictly to measure the relative difference between conditions at different locations, then all distances should have been made equal to avoid this confound. However, the real world motivation demanded that people navigate though an environment and learn routes that did not consist of artificially equal distances.

7.7.3. <u>Requests for Assistance</u>

In most blind research, subjects are not allowed to ask for any help from others. However, previous research (Golledge & Marston, 1999) showed that having to rely on others was a major frustration in blind navigation and a very common tactic that sometimes must be used. Again, it seemed that not allowing people to use this everyday and normal technique to transverse this complicated environment would have added to stress and frustration and not been representative of how the blind travelers actually explore new spaces. The principal researcher did not give any help to locate destinations, but subjects were allowed to ask others for verbal information to help locate objects, although they were not allowed to be led or guided to the location. This technique influenced the results in two ways, both of which actually reduced the time and performance difference between the two conditions, and, as such, actually subtracted from the relative performance advantage of RIAS. First of all, no one using RIAS for the first trial ever asked for help, and so, in that condition, subjects actually had less input than available to those using their regular (*NRIAS*) method. Secondly, without the ability to ask for help, many more of the disoriented people using their regular method would have failed to complete the task in the allotted time. When searching for locations like concession counters, track doors, or the bus stop, many of the regular method (*NRIAS*) subjects got very close but, without asking for help or identification, would not have been able to complete the task. If subjects had not been able to ask for information, the results would have been much more robust for the RIAS condition.

7.7.4. <u>Actual versus Anticipated Changes</u>

At the present time, there are no urban areas that are fully equipped with RIAS. If there were, comparisons between actual travel data from blind people with and without the system could be made. In order to gather data about travel behavior and activity participation with RIAS, estimations of how they thought their actions would change were used. After using the RIAS in the field test, they were asked to estimate future travel activities if the environment had the same kind of coverage as did the test area. When these data were compared to pre-test responses of current behavior, the differences in increased activity participation and travel were very large. As explained in Chapter 6, there is little that is more important to a blind person than achieving access to independent travel and activity participation. For most blind people, it is assumed that there are daily affirmations of the negative impact of vision loss on independent travel and access to opportunities, so it was fully expected that they would be able to give well-informed opinions on how this system could affect their quality of life.

This methodology might raise questions of ecological validity; i.e., did their estimations accurately measure how RIAS would affect their travel behavior? All but one subject thought they would make more trips with RIAS, and all subjects thought they would waste less time on transit trips by using cues from RIAS to help them make transfers. These strong results leave little doubt about the perceived effect that

RIAS would have on increasing access, activity participation, and travel efficiency and comfort. Actual trip data using RIAS, if and when possible to collect, would simply better quantify the magnitude of these effects.

Such a strong indication of missed and desired trips might be considered a desire to please the researcher. There is also a tendency for respondents to give “socially desirable” answers that has been well documented in the literature, especially those concerning environmentally friendly or political actions. More people report voting in an election or buying environmentally favorable products than the actual participation data can support (Lam & Cheng, 2002). However, this desire by some to impress upon others that they make socially desirable actions has little to do with the questions asked in this experiment. There is nothing socially desirable about admitting that activities are denied by the difficulty caused by one’s vision limitations. Likewise, there is no social reason to exaggerate one’s willingness to stay on a vehicle for long periods of time to avoid making a transfer. Keeping in mind the strong sense of independence and self-worth exhibited by most active blind people, it is just as easy to think that they would be hesitant to admit how “restricted” their current lives were, or how much they missed, by not having access to all that urban life has to offer. The fact that they admit to so many missed opportunities is a strong indication of how difficult travel without vision can be and how it affects every aspect of daily living. However, in any survey, there always exists the possibility that respondents try to influence the overall results by exaggeration.

7.8. Future Research

The field test data reported here and in the many RIAS studies reviewed in Chapter 2 reveal that auditory signage provides many of the missing cues of travel without vision and makes locating objects from a distance a simple and easy to learn task. The addition of location based identity and directional cues clearly aid in travel efficiency. Indoor and outdoor environments have been tested with both static and dynamic messages; even moving buses have been evaluated. There is little need for future research on how well the technology itself works. For example, when airports are equipped with the system, there is no compelling need for more testing of that kind of environment, as other indoor spaces have already been evaluated.

What is called for is more research on how auditory signage affects spatial knowledge acquisition and awareness. Two such experiments to determine how spatial configurational knowledge is affected by use of RIAS are briefly discussed.

In this research, subjects were given a series of locations to find, with no previous walkthrough of the environment. The location of transmitters was not known before starting the test, and, so, subjects were learning a route with no human input as they searched for specific locations. This procedure was used because it was desired to measure independent performance in an unfamiliar environment.

Subjects did not have the opportunity to try the routes more than once with RIAS, so learning curve data about what can be learned with repeated exposure to an equipped environment were not collected. Feedback obtained from users indicated that they would like to try the test again as they would then do much better, because of knowing so much more after one trial. Others mentioned that they would be able to learn a new environment on their own, without hiring a sighted guide or O & M instructor. These two comments strongly suggest new research directions. Personal use and observations of other blind RIAS users showed that, with exposure to an environment, a person without sight can navigate a large space directly and efficiently. As reported in Chapter 3, 60% of the subjects, who learned the route with their regular methods first and tried it again with RIAS, were able to complete the tasks at less then twice the time of the first time sighted user (FTSU). To date, however, there have been no tests to determine how much exposure is needed to approach the efficiency and travel time of a sighted person, as experiments have focused more on testing people in unfamiliar locations.

The proposed experiments should take place in an area where no subjects have any previous knowledge. To eliminate any variance of vision acuity, subjects with residual vision should be blindfolded. To determine the type and length of exposure needed to mimic the spatial awareness of a sighted user, several subject conditions should be examined.

- Control Group: Subjects are led to the door of a large, interior area and given a period of time to explore the area on their own, using their regular methods of orientation and navigation.

- Trained Regular User: Subjects are taught the interior space by an Orientation and Mobility instructor and then given time to explore on their own.

- Untrained Independent RIAS User: Subjects explore the environment on their own, using RIAS.

- Trained RIAS User: Subjects walk the area with a guide who “shows” them all the signed locations and how to scan for spatial relationship cues.

Spatial products such as 3-D models, labeling tactile maps with names, or spatial relationship questions could be used to test the amount of spatial information learned in these conditions. In addition, routes to walk, using the major landmarks, could be assigned as timed tests. The ability to travel efficiently through the environment should have a high utility to the user. These tests could be repeated until subjects reached a criterion level determined to be an acceptable time in which to complete a specific travel task. This experiment would quantify how much exposure is needed, in various conditions, to learn a space at an acceptable level.

Another experiment could be conducted to simply determine how much and what kind of exposure is needed to mimic the time and directness of sighted travel. In that test, subjects would be taught routes using RIAS. After several practice trials, subjects would be timed and errors noted as they walked the route on their own. Subjects would repeat the trials until they reached the criterion minimum time threshold. Based on previous observations, people should be able to learn to walk the route with no error and close to the speed of sighted people once they have learned the route with RIAS. The data from the guided training should be compared to those who learned the RIAS environment on their own with no guided training. Can people learn to walk with direct efficiency without being taught anything by a guide and relying only on RIAS? Would a minimum guided walk noticeably speed up that learning process?

Those two kinds of experiments would shed light on how long it takes a blind person to efficiently travel through a new environment. If they are able to do so without any assistance, except the use of RIAS, it could radically change how blind people are trained to navigate in new spaces. For example, airlines have employees whose job it is to escort disabled people to and from their boarding areas. In addition, much time and money is spent to ensure that students can find their classrooms and buildings at the beginning of every new term. Research to date has already shown how much more independence is available through RIAS, but experiments that confirm that the blind can fully learn new areas independently and travel at nearly the speed of the sighted could reduce the need for assistance and greatly increase their freedom to travel and explore new environments. Orientation and Mobility instructors could thus concentrate on teaching safe and efficient travel instead of simply teaching new routes to people each time they need to learn a new area or path.

7.8.1. Talking Signs® Enhancements

Since this field test was conducted, a new transmitter (compatible with the existing RIAS system) has been developed by Talking Signs®. The new feature is called PointLink® and augments the standard RIAS labeling and message system using a wireless connection to link the receiver to a server by transmitting a sign-specific code to the receiver. The receiver then sends a request for information about that particular sign to a local server through a wireless connection (such as 802.11b).

Unlike current GPS based services that give information about a broad area, this system is truly location-based. The information is stored and retrieved for the specific transmitter to which one points. In addition to the original spatial cues that have been discussed in this report, this system also allows a user to get detailed information about a particular location. Even when a store or building is closed, a person can access detailed information about the location. The information available is unlimited in scope, and a few examples of how this additional information could be used are offered:

- Bus Stops: A user could point at a specific bus stop and hear route and schedule information about buses that serve that stop, including the wait-time until the next bus arrives.
- Building Entrances: The user could get detailed information about the interior arrangement of the building, the functions that take place there, hours of service, important phone numbers, a list of stores, or a building directory of offices.
- Interior Doors: Users could find out what functions take place at each door, the function of the office, or names of staff members. Bathroom doors might

give information about the spatial arrangement of the interior space, saving much search time while trying to use the facilities.

- Stores and Services: Information could include hours of service, sales or specials, location of departments, or where to go for personal assistance. Restaurants could have their menu available, including daily specials. Other locations could give detailed information about what services or items they offer.

This information could be downloaded in the person's preferred language, making it an invaluable tool for travel in foreign countries. Unlike the original RIAS, which is mostly valuable for those who have a vision or print handicap, this system is also quite valuable for the sighted traveler. Being able to get specific location-based information about building functions and services, in one's own language, makes this feature a powerful tool for learning about the environment.

7.9. Conclusion

Vision is by far the supreme sensory modality that benefits wayfinding and navigation, the spatial sense par excellence (Foulke, 1983). The tasks and questions reported on in this study would have probably produced little difference in performance if applied to those with full vision. When applied to those with vision loss, however, large differences were evident, because, in the absence of vision, other cues must be used to inform people about the environment. RIAS was used in this study, because it gives the user two missing pieces of spatial information about an environment: a spoken label or identity of the signed location and a directional beam to that object. Comparisons could therefore be made between active and skilled blind people when using their regular skills and when using the increased environmental cues. This technique revealed large differences within and between blind subjects that are attributed to the increased number of accessible cues that were available. The increased efficiency of travel with RIAS implies that the difficulties exhibited by many blind travelers in new environments are caused by a lack of accessible cues and not necessarily by some inherent disadvantage in the spatial processing abilities of this group.

The results of this experiment show that, for those with vision loss, lack of information is a major barrier to independent access to urban opportunities, and that the addition of auditory cues to an urban environment can greatly reduce or eliminate these barriers. Without the use of accessible information of some sort, blind people will continue to still not have the access that they are entitled to and might continue to find it difficult to be fully functioning members of society. The empirical data and models presented here quantify the degree of limitation (or penalty) faced by vision-impaired transit users. Many of these penalties are quite large and show that many barriers still exist that restrict access to public facilities.

This experiment demonstrated that if a blind person cannot find a transit stop, navigate through a complex transfer station, or find fare machines, amenities, and doorways, they face barriers, every bit as daunting as structural barriers to equal access to transit and buildings. Freedom to travel and use of transit and other public facilities is an ongoing equity concern for planners and public agencies. Thus, since 1990, the Americans with Disabilities Act has mandated equal access to transit and public buildings for all populations. Much improvement has been made in removing **structural** or **physical barriers.** However, little progress has been made in bringing better access to urban opportunities to those who have vision impairments, who face the **functional barriers** to access that have been identified here.

The test site examined herein had a large number of accessible cues that allowed first-time blind users to travel independently and locate necessary facilities. An accessible city would provide accessible cues to those with vision loss so that they could access public transit, buildings, and infrastructures on an area-wide scale, similar to the amount of information available at the test site. Vision-impaired people would finally be able to access all the employment, educational, recreational, cultural, and social aspects of a city while maintaining their freedom, independence, and sense of self-worth. Integrating these accessible cues and signs into a seamless and almost transparent network would allow residents and visitors to easily identify their location, safely cross streets, take public transit, make necessary transfers or mode changes, and access public buildings independently. The accessible city concept would enable blind and vision-impaired people to freely travel in the environment, even allowing independent exploration for first-time visitors to a city. Accessible cues would free a blind pedestrian from having to be taught each new route, having to count steps or blocks, and having to remember where they are at all times. As one test subject mentioned, “I finally can day dream and still know which block I am approaching, instead of keeping track of my location.”

Those concerned with access and equity issues, such as blind advocacy groups, social or transit activists, architects, planners, transit providers, and city public works departments, should be able to find many data here that support the use of accessible signage as a way to remove barriers to transit use that are faced daily by the vision-impaired and to help increase accessibility to urban opportunities.

References

AFB. (2000). *The Impact of Age and Health on the Employment of People who are Blind or Visually Impaired*. American Foundation for the Blind. Available: http://www.afb.org/info_document_view.asp?documentid=1212.

BARC. (2000). *Blindness Alliance For Rehabilitation Change.* Available: http://www.ccbnet.org/points.htm.

Bateman, I. J., Langford, I. H., & Rasbash, J. (1999). Willingness-to-Pay Question Format Effects in Contingent Valuation Studies. In I. J. Bateman & K. G. Willis (Eds.), *Valuing Environmental Preferences* (pp. 511-539). Oxford: Oxford University Press.

Ben-Akiva, M., & Lerman, S. R. (1979). Disaggregate travel and mobility-choice models and measures of accessibility. In D. A. Hensher & P. R. Storper (Eds.), *Behavioural Travel Modelling* (pp. 654-679). London: Croom-Helm.

Bentzen, B. L., Crandall, W. F., & Myers, L. (1999). Wayfinding system for transportation services: Remote infrared audible signage for transit stations, surface transit, and intersections. *Transportation Research Record, 1671*, 19-26.

Bentzen, B. L., & Mitchell, P. A. (1995). Audible Signage as a Wayfinding Aid - Verbal Landmark versus Talking Signs. *Journal of Visual Impairment & Blindness, 89*(6), 494-505.

Bentzen, B. L., Myers, L., & Crandall, W. F. (1995). *Talking Signs® System: Guide For Trainers* (Easter Seals Project ACTION/NIAT Doc. #95-0052). Washington, DC: The Smith-Kettlewell Eye Research Institute.

Brabyn, J. A. (1985). A review of mobility aids and means of assessment. In D. H. Warren & E. R. Strelow (Eds.), *Electronic Spatial Sensing For the Blind--Contributions From Perception, Rehabilitation, and Computer Vision* (pp. 13-27). Boston, MA: Martinus Nijhoff Publishers.

Brabyn, L. A., & Brabyn, J. A. (1983). An evaluation of "Talking Signs" for the blind. *Human Factors, 25*(1), 49-53.

Campbell, D. T., & Fiske, D. W. (1959). Convergent and discriminant validation by the multitrait-multimethod matrix. *Psychological Bulletin, 56*, 81-105.

Carreiras, M., & Codina, B. (1992). Spatial cognition of the blind and sighted: Visual and amodel hypotheses. *Cahiers de Psychologie Cognitive, 12*, 51-78.

Casey, S. M. (1978). Cognitive mapping by the blind. *Journal of Vision Impairment and Blindness, 72*(8), 297-301.

Church, R. L., & Marston, J. R. (in press). Measuring Accessibility for People with a Physical Disability. *Submitted for Publication, Geographical Analysis.*

Clark-Carter, D. D., Heyes, A. D., & Howarth, C. I. (1986). The efficiency and walking speed of visually impaired pedestrians. *Ergonomics, 29*(3), 779-789.

Clarke, P. M. (2000). Valuing the benefits of mobile mammographic screening units using the contingent valuation method. *Applied Economics, 32*, 1647-1655.

Commerce Clearing House Editorial Staff (Ed.). (1990). *Americans with Disabilities Act of 1990: Law and Explanation*. Chicago, IL: Commerce Clearing House, Inc.

Corn, A. L., & Sacks, S. Z. (1994). The impact of nondriving on adults with visual impairments. *Journal of Visual Impairment & Blindness, Jan-Feb*, 53-68.

Crandall, W., Bentzen, B. L., & Myers, L. (1999). *Smith-Kettlewell research on the use of Talking Signs for use by people with developmental disabilities* (15). San Francisco, CA: Smith-Kettlewell Rehabilitation Engineering Research Center.

Crandall, W., Bentzen, B., & Myers, L. (1996). Remote Infrared Signage for People who are Blind or Print Disabled: A Surface Transit Accessibility Study: Project ACTION, FTA.

Crandall, W., Bentzen, B., Rosen, S., & Mitchell, P. (1994). *Infrared Remote Signage for the Blind and Print-handicapped: An Orientation and Mobility Study*: Final Report, National Easter Seal Research Program.

Crandall, W., Bentzen, B. L., & Meyers, L. (1998). Talking Signs®: Remote infrared auditory signage for transit, intersections and ATMS, *Proceedings of the California State University Northridge Conference on Technology and Disability*. Los Angeles, CA.

Crandall, W., Bentzen, B. L., & Myers, L. (1995). *Talking Signs® remote infrared signage: A guide for transit managers*: The Smith-Kettlewell Eye Institute, Rehabilitation Engineering Research Center, San Francisco, CA., Project Action, FTA

Crandall, W., Bentzen, B. L., & Myers, L. (1999). *Smith-Kettlewell research on the use of Talking Signs® at light controlled street crossings* (30). San Francisco, CA: The Smith-Kettlewell Eye Research Institute. NIDRR

Crandall, W., Bentzen, B. L., Myers, L., & Easton, R. (1999). *Emergency information for people with visual impairments: Evaluation of five accessible formats* (40). San Francisco, CA: Smith-Kettlewell Rehabilitation Engineering Research Center. FTA

Crandall, W., Bentzen, B. L., Myers, L., & Mitchell, P. (1995). *Transit accessibility improvement through Talking Signs® remote infrared signage: A demonstration and evaluation* (Easter Seals - Project ACTION Doc #95-0050, FTA, Washington, DC, Project ACTION/NIAT). San Francisco, CA: The Smith-Kettlewell Eye Research Institute, Rehabilitation Engineering Research Center.

Crandall, W., Brabyn, J., Bentzen, B., & Myers, L. (1999). Remote infrared signage evaluation for transit stations and intersections. *Journal of Rehabilitation Research and Development, 36*(4), 341-355.

Crandall, W., & Geary, W. (1993). Remote signage and its implications to print-handicapped travelers: Functional and technical specifications, *Proceedings: Rehabilitation Engineering Society of North America (RESNA) Annual Conference, Las Vegas* (pp. 251-253).

Dodds, A. G., Howarth, C. I., & Carter, D. (1982). Mental maps of the blind: The role of previous visual experience. *Journal of Visual Impairment and Blindness, 76*(1), 5-12.

Dyck, I. (1989). Integrating home and wage workplace: Women's daily lives in a Canadian suburb. *Canadian Geographer, 33*, 329-341.

Easton, R. D., & Bentzen, B. L. (1999). The effect of extended acoustic training on spatial updating in adults who are congenitally blind. *Journal of Visual Impairment & Blindness, 93*(7), 407-415.

Fletcher, J. F. (1980). Spatial representations in blind children. 1. Development compared to sighted children. *Journal of Visual Impairment and Blindness, 74*, 381-385.

Foulke, E. (1982). Perception, cognition, and the mobility of blind pedestrians. In M. Potegal (Ed.), *Spatial Abilities: Development and Physiological Foundations* (pp. 55-76). New York: Academic Press.

Foulke, E. (1983). Spatial ability and limitations of perceptual systems. In H. L. Pick & L. P. Acredolo (Eds.), *Spatial Orientation: Theory, Research and Application* (pp. 125-141). New York: Plenum Press.

Golledge, R. G. (1993). Geography and the Disabled - a Survey With Special Reference to Vision Impaired and Blind Populations. *Transactions of the Institute of British Geographers, 18*(1), 63-85.

Golledge, R. G. (1994). *Disability, barriers and discrimination.* Paper presented at the International Conference on "The New Distributional Ethics: Differentiation and Discrimination", Gothenburg, Sweden.

Golledge, R. G. (2001). Cognitive maps. In R. F. Ballesteros (Ed.), *Encyclopedia of Psychological Assessment (In Press).* London: SAGE Publications.

Golldege, R. G. (2001). *Spatial cognition and congruent technologies*. Paper presented at the Convergent Technologies and Nano-Bio-Info-Ccogno-Systems conference, Washington, D. C.,Nov.

Golledge, R. G., Blades, M., Kitchin, R., & Jacobson, D. (1999). *Understanding geographic space without the use of vision* (NSF Final Report SBR95-14907). Santa Barbara, CA: Department of Geography, University of California Santa Barbara; Department of Psychology, University of Sheffield, UK; Department of Geography, National University of Ireland, Maynooth, Ireland; and Department of Geography, Queens University, Belfast, Ireland.

Golledge, R. G., Costanzo, C. M., & Marston, J. R. (1995). *The mass transit needs of a non-driving disabled population* (Final Report MOU167): University of California Richmond Field Station PATH Division.

Golledge, R. G., Costanzo, C. M., & Marston, J. R. (1996). *Public transit use by non-driving disabled persons: The case of the blind and vision impaired* (California PATH Working Paper UCB-ITS-PWP-96-1): Partners for Advanced Transit and Highways (PATH).

Golledge, R. G., Kitchin, R., Blades, M., & Jacobson, R. D. (2001). *Off-route strategies for non-visual navigation* (NSF Final Report BCS-9818545). Santa Barbara, CA: University of California Santa Barbara.

Golledge, R. G., Klatzky, R. L., & Loomis, J. M. (1996). Cognitive mapping and wayfinding by adults without vision. In J. Portugali (Ed.), *The Construction of Cognitive Maps* (pp. 215-246). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Golledge, R. G., Kwan, M., & Garling, T. (1994). Computational process modeling of household travel decisions using a geographic information system. *Papers in Regional Science, 73*(2), 99-117.

Golledge, R. G., Loomis, J., Klatzky, R., Pellegrino, J. W., Doherty, S., & Cicinelli, J. (1988). *Environmental cognition and assessment: Spatial cognition of the blind and visually impaired.* Paper presented at the Environmental Cognition and Assessment Conference, Umeå, Sweden.

Golledge, R. G., Loomis, J. M., & Klatzky, R. L. (1997). A New Direction for Applied Geography. *Applied Geography Studies, 1*(3), 151-168.

Golledge, R. G., Loomis, J. M., Klatzky, R. L., Flury, A., & Yang, X. L. (1991). Designing a personal guidance system to aid navigation without sight: Progress on the GIS component. *International Journal of Geographical Information Systems, 5*(4), 373-396.

Golledge, R. G., & Marston, J. R. (1999). Towards an accessible city: Removing functional barriers to independent travel for blind and vision impaired residents and visitors (California PATH Research Report UCB-ITS-PPR-99-33 for PATH project MOU 343): California PATH Program, Institute of Transportation Studies, University of California, Berkeley.

Golledge, R. G., Marston, J. R., & Costanzo, C. M. (1996). The impact of information access on transit behavior of blind or vision impaired people. Research Conference Proceedings: Spatial Technologies, Geographic Information and the City (Technical Report 96-10): National Center for Geographic Information and Analysis (NCGIA).

Golledge, R. G., Marston, J. R., & Costanzo, C. M. (1997). Attitudes of visually impaired persons toward the use of public transportation. *Journal of Visual Impairment & Blindness, 91*(5).

Golledge, R. G., Marston, J. R., & Costanzo, C. M. (1998a). *Assistive devices and services for the disabled* (Final Report MOU276): University of California Richmond Field Station PATH Division.

Golledge, R. G., Marston, J. R., & Costanzo, C. M. (1998b). Assistive devices and services for the disabled: Auditory signage and the accessible city for blind or vision impaired travelers (California PATH Working Paper UCB-ITS-PWP-98-18): University of California, Berkeley California PATH Program, Institute of Transportation Studies.

Golledge, R. G., & Stimson, R. J. (1997). *Spatial Behavior: A Geographic Perspective*. New York: Guilford Press.

Gould, P. (1969). *Spatial diffusion*. Paper presented at the Association of American Geographers, Washington, DC.

Green, C., & Tunstall, S. (1999). A Psychological Perspective. In I. J. Bateman & K. G. Willis (Eds.), *Valuing Environmental Preferences* (pp. 207-257). Oxford: Oxford University Press.

Hägerstrand, T. (1970). What about people in regional science? Papers and Proceedings, North American Regional Science Association, 24, 7-21.

Hägerstrand, T. (1975). Space, Time and Human Conditions. In A. Karlqvist & L. Lundqvist & F. Snickars (Eds.), *Dynamic Allocation of Urban Space* (pp. 3-14). Farnborough, England: Saxon House, Lexington, Massachusetts: Lexington Books.

Hanson, S. (1995). The Geography of Urban Transportation, 2nd Edition. New York: Guilford Press.

Hepworth, M., & Ducatel, K. (1992). *Transport in the Information Age: Wheels and Wires*. London: Bellhaven Press.

Hill, E. W., Rieser, J. J., Hill, M. M., Hill, M., Halpin, J., & Halpin, R. (1993). How persons with visual impairments explore novel spaces: Strategies of good and poor performers. *Journal of Visual Impairment and Blindness, October*, 295-301.

Hodge, D. C., & Morrill, R. L. (1996). Implications of intelligent transportation systems for metropolitan forms. *Urban Geography, 17*(8), 714-739.

Ingram, D. R. (1971). The concept of accessibility: A search for an operation form. *Regional Studies, 5*, 101-107.

Jacobson, R. D., Kitchin, R., M,, Garling, T., Golledge, R. G., & Blades, M. (1998). Learning a complex urban without sight: Comparing naturalistic versus laboratory measures. *Presentation made at Mind III: The Annual Conference of the Cognitive Science Society of Ireland*.

Jacobson, R. D., Kitchin, R., M,, Golledge, R. G., & Blades, M. (2002). Rethinking theories relating to the spatial abilities of vision impaired and blind people. *Journal of Visual Impairment and Blindness, (Submitted).*

Jacobson, W. H. (1993). The Art and Science of Teaching Orientation and Mobility to Persons with Visual Impairments. New York: AFB Press.

Kirchner, C., Schmeidler, E., & Todorov, A. (1999). Looking at Employment Through a Lifespan Telescope: Age, Health and Employment Status of People with Serious Visual Impairment: Mississippi State, MS.

Kitchin, R., M,, Blades, M., & Golledge, R. G. (1997). Understanding spatial concepts at the geographic scale without the use of vision. *Progress in Human Geography*, *21*(2), 225-242.

Kitchin, R. M. (1994). Cognitive maps: What are they and why study them? *Journal of Environmental Psychology, 14*(1), 1-19.

Kitchin, R. M. (2000). The researched opinions on research: Disabled people and disability research. *Disability and Society, 15*(1), 25-48.

Kitchin, R. M. (2001). Participatory Action Research Approaches in Geographical Studies of Disability: Some Reflections. *Disability Studies Quarterly, Fall, 21*(4, Symposium on Disability Geography: Commonalities in a World of Differences), 61-69.

Kitchin, R. M., & Jacobson, R. D. (1997). Techniques to collect and analyze the cognitive map knowledge of persons with visual impairment or blindness: Issues of validity. *Journal of Visual Impairment & Blindness, 91*(4), 360-376.

Kwan, M.-P. (1998a). Gender, the home-work link, and space-time patterns of non-employment activities. *Economic Geography, forthcoming*.

Kwan, M.-P. (1998b). Space-time and integral measures of individual accessibility: A comparative analysis using a point-based framework. *Geographical Analysis, 30*(3), 191-216.

Kwan, M.-P. (1999). Gender and individual access to urban opportunities: A study using space-time measures. *Professional Geographer, 51*(2), 210-227.

Lam, S.-P., & Cheng, S.-I. (2002). Cross-informant agreement in reports of environmental behavior and the effects of cross-questioning on report accuracy. *Environment and Behavior, 34*(4), 508-520.

Lenntorp, B. (1976). Paths in time-space environments: A time-geographic study of movement possibilities of individuals: University of Lund, Sweden.

Levy, W. H. (1872/1949). On the blind walking alone, and of guides. *Outlook for the Blind and the Teachers Forum*, *43*, 106-110.

Lockman, J. J., Rieser, J. J., & Pick, H. L. (1981). Assessing blind travelers' knowledge of spatial layout. *Journal of Visual Impairment and Blindness, 75*, 321-326.

Long, R. G., Rieser, J. J., & Hill, E. W. (1990). Mobility in individuals with moderate visual impairments. *Journal of Visual Impairment & Blindness, 84*, 111-118.

Loomis, J. M., Golledge, R. G., & Klatzky, R. L. (1998). Navigation system for the blind: Auditory display modes and guidance. *Presence: Teleoperators and Virtual Environments*, *7*(2), 193-203.

Loomis, J. M., Klatzky, R. L., Golledge, R. G., Cicinelli, J. G., Pellegrino, J. W., & Fry, P. A. (1993). Non-visual navigation by blind and sighted: Assessment of path integration ability. *Journal of Experimental Psychology, General, 122*(1), 73-91.

Loughborough, W. (1979). Talking lights. *Journal of Visual Impairment and Blindness*, *73*(June), 243.

Luminator. (2002). RE: Request for Information, email communication to J. Marston

Lynch, K. (1960). *The Image of the City*. Cambridge, MA: The MIT Press.

Marston, J. R., & Golledge, R. G. (1998a). Improving transit access for the blind and vision impaired. *Intellimotion*, *7*(2), 4,5,11.

Marston, J. R., & Golledge, R. G. (1998b). Removing functional barriers: Public transit and the blind and vision impaired, *Proceedings of the 1997 Society for Disability Studies, 10 Annual Meeting*, *Minneapolis, MN*.

Marston, J. R., & Golledge, R. G. (2000). *Towards an accessible city: Removing functional barriers for the blind and vision impaired: A case for auditory signs* (Final Report UCTC 65V430): University of California Berkeley: University of California Transportation Center.

Marston, J. R., Golledge, R. G., & Costanzo, C. M. (1997). Investigating travel behavior of nondriving blind and vision impaired people: The role of public transit. *The Professional Geographer*, *49*(2), 235-245.

McFadden, D. (1988). Measuring willingness-to-pay for transportation improvements. In T. Gärling & T. Laitila & K. Westin (Eds.), *Theoretical Foundations of Travel Choice Modeling* (pp. 339-364). Oxford: Pergamon.

Millar, S. (1981). Cross modal and intersensoray perception and the blind. In H. L. Pick & R. D. Walk (Eds.), *Intersensory perception and sensory integration*. New York: Plenum Press.

Miller, H. J. (1991). Modelling accessibility using space-time prism concepts within geographical information systems. *International Journal of Geographical Information Systems, 5*(3), 287-301.

Miller, H. J. (1999). *GIS software for measuring space-time accessibility in transportation planning and analysis.* Paper presented at the International Workshop on Geographic Information Systems for Transportation and Intelligent Transportation Systems, Hong Kong.

Montello, D. R. (1991). The measurement of cognitive distance: Methods and construct validity. *Journal of Environmental Psychology, 11*, 101-122.

NOAA, & Administration), N. O. a. A. (1993). Natural Resource Damage Assessments under the Oil Pollution Act of 1990 (58): Federal Register.

Okunuki, K., Church, R., & Marston, J. (1999). A study on a system for guiding of the optimal route with a hybrid network and grid data structure. *Papers and Proceedings of the Geographic Information Systems Association Japan, 8*, 135-138.

Okunuki, K., Church, R. L., & Marston, J. R. (1998). *Ellison Hall Guidance System*, Available: http://www.ncgia.ucsb.edu/~nuki/EllisonRep.html and http://www.ncgia.ucsb.edu/~nuki/EllisonMenu.html.

Passini, R. (1986). Visual impairment and mobility: Some research and design considerations, *EDRA 17*.

Passini, R., & Proulx, G. (1988). Wayfinding without vision: An experiment with congenitally blind people. *Environment and Behavior, 20*, 227-252.

Passini, R., Proulx, G., & Rainville, C. (1990). The spatio-cognitive abilities of the visually impaired population. *Environment and Behavior, 22*, 91-118.

Pirie, G. H. (1979). Measuring accessibility: A review and a proposal. *Environment and Planning A, 11*, 299-312.

Pred, A. (1977). The Choreography of Existence: Comments on Hägerstrand's Time-Geography and its Usefulness. *Economic Geography*, *53*, 207-221.

Recker, W. W., Chen, C., & McNally, M. G. (2001). Measuring the impact of efficient household travel decisions on potential travel time savings and accessibility gains. *Transportation Research Part A, 35*, 339-369.

Rieser, J. J., Guth, D., & Hill, E. W., (1986). Sensitivity to perceptive structure while walking without vision. *Perception*, *15*, 173-188.

Rieser, J. J., Lockman, J. J., & Pick, H. L. (1980). The role of visual experience in knowledge of spatial layout. *Perception & Psychophysics*, *28*(3), 185-190

San_Francisco_Municipal_Railway. (2002). *Muni San Francisco Municipal Railway* (9/9/2002), [web site]. Available: http://www.sfmuni.com/aboutmun/geninfo.htm.

Sholl, M. J. (1996). From visual information to cognitive maps. In J. Portugali (Ed.), *The Construction of Cognitive Maps*. Dordrecht: Kluwer Academic Publishers.

Strelow, E. R. (1985). What is needed for a theory of mobility: Direct perception and cognitive maps-lessons from the blind. *Psychological Review*, *92*(2), 226-248.

Sudman, S., & Bradbury, N. M. (1982). Asking Questions: A Practical Guide to Questionnaire Design. San Francisco.

Talen, E. (1995). The achievement of planning goals: A methodology for evaluating the success of plans. Unpublished Ph.D., University of California, Santa Barbara.

Talen, E. (1996). The social equity of urban service distribution: An exploration of park access in Pueblo, CO and Macon, GA. *Urban Geography*, *18*(6), 521-541.

Talking_Signs_Inc. (2000). Presentation at Universal Traffic Management Internationl Seminar, September, 2000.

Talking_Signs_Inc. (2002). *Talking Signs*. Talking Signs, Inc. Available: http://www.talkingsigns.com/.

Thapar, N. (1999). *Changing activity spaces of persons with Multiple Sclerosis.* Unpublished Ph.D. dissertation, Kent State University, Kent, Ohio.

Thapar, N., Bhardwaj, S. M., & Bhardwaj, C. A. (2001). Multiple Sclerosis in its Context: Individual Narratives. *Disability Studies Quarterly, Fall, 21*(4, Symposium on Disability Geography: Commonalities in a World of Differences), 29-41.

Thinus-Blanc, C., & Gaunet, F. (1997). Representation of space in blind persons: Vision as a spatial sense? *Psychological Bulletin, 121*(1), 20-42.

von Senden, M. (1960). Space and sight. The perception of space and shape in the congenitally blind before and after operations. Glencoe, IL.: Free Press.

Wachs, M., & Kumagai, J. (1973). Physical accessibility as a social indicator. *Socio-Economic Planning Studies, 7*, 437-456.

Weibull, J. W. (1980). On the numerical measurement of accessibility. *Environment and Planning A, 12*, 53-67.

Wolpert, J. (1965). Behavioral aspects of the decision to migrate. *Papers and Proceedings in the Regional Science Association*, 15, 159-169.

Appendices

APPENDIX 1: Sighted Subjects for Baseline

Task #	First Time Sighted User	Familiar Sighted User	Comment On FTSU
1-A	108	21	Lost, asked for help
1-B	25	31	
1-C	62	54	
1-D	8	10	
1-E	7	11	
2-A	7	12	
2-B	56	57	
2-C	8	8	
2-D	38	28	Walk and search
2-E	25	31	
3-A	56	61	
3-B	22	20	
3-C	31	41	
4-A	29	30	
4-B	13	15	
4-C	26	28	
4-D	0	0	
5-A	13	14	
5-B	14	13	
5-C	20	21	
TOTAL	568	506	

APPENDIX 2: User Comments about Finding a Bus Stop

Question: "What was the difference using Talking Signs (at the bus stop) than not using it?

Ss #	**Response**
1	regular method is difficult, have to ask
2	wish we had them, takes a person to it
3	home in on signal, gives better direction
4	lost without it, points like an arrow, gives direction, simple
5	leads to precise point, no guess work
6	info available, definite direction, knew it could be found, more sure of where you are, comfortable and reassuring, know where I am, like a person saying "Here is the stop"
7	find it without asking
8	could have missed the bus stop w/o TS, no doubt, gives confidence
9	more direct, knew she was going in right direction, TS increases confidence
10	familiar with area if not it would be helpful
11	tells you when at bus stop, don't have to ask, feel better
12	helped more by giving guidance to find a place
13	can go directly to it, likes it
14	gives direction, indication, easier
15	just follow beam, no worry about drift, confident of direction, so you only think about safety, confident
16	walked further without
17	knew what I was looking for
18	knew exactly where it was
19	w/TS know it's a bus stop, gives positive ID, usually have to ask
20	confirmed direction, comfort because you know it is in reach, more simple, helps to push ahead, aware of surroundings
21	direct to pole, didn't miss it
22	know it's there, didn't have to ask or look all over, gives assurance
23	I don't always know where sign is so must search for it, TS would find exact location
24	guides me right to it
25	didn't have to guess, TS told me where it is
26	sure of where you are, positive ID

APPENDIX 3: User Comments about Finding the Proper Bus

Question: “What was the difference using Talking Signs (at the bus stop) than not using it?

Ss #	**Response**
1	regular method is difficult, have to ask
2	wish we had them, takes a person to it
3	home in on signal, gives better direction
4	lost without it, points like an arrow, gives direction, simple
5	leads to precise point, no guess work
6	info available, definite direction, knew it could be found, more sure of where you are, comfortable and reassuring, know where I am, like a person saying "Here is the stop"
7	find it without asking
8	could have missed the bus stop w/o TS, no doubt, gives confidence
9	more direct, knew she was going in right direction, TS increases confidence
10	familiar with area if not it would be helpful
11	tells you when at bus stop, don't have to ask, feel better
12	helped more by giving guidance to find a place
13	can go directly to it, likes it
14	gives direction, indication, easier
15	just follow beam, no worry about drift, confident of direction, so you only think about safety, confident
16	walked further without
17	knew what I was looking for
18	knew exactly where it was
19	w/TS know it's a bus stop, gives positive ID, usually have to ask
20	confirmed direction, comfort because you know it is in reach, more simple, helps to push ahead, aware of surroundings
21	direct to pole, didn't miss it
22	know it's there, didn't have to ask or look all over, gives assurance
23	I don't always know where sign is so must search for it, TS would find exact location
24	guides me right to it
25	didn't have to guess, TS told me where it is
26	sure of where you are, positive ID

APPENDIX 4: Subject Questionnaire for San Francisco RIAS Experiment

Part I: Pre-test questions Circle or write answer

Date………..   Time----------   Source_________________

Personal Details

Name:... Subject #:………..

Address:………………………………………………..

Phone:………………………………………………..

Are you?   Male ☐   Female ☐

Age:...........

Highest Grade Level of Education Finished

No HS   Some HS   HS grad   Some college   college grad   Advanced degree

NATURE OF VISUAL IMPAIRMENT OR BLINDNESS

Age of onset of blindness:...

How long blind?…………………………………………………………..

Cause of blindness:...

Describe blindness including any light or shape perception:

What is your visual acuity after correction, e.g., (20/200) or field of vision?…………………..

Are you legally blind? Yes: ☐   No: ☐

(2) Which of the following best describes your ability to read:

Can read large print	
Can read large print with aid i.e. magnifier	
Cannot read large print at all	
Can read Braille	

Do you use any adaptive technology to aid reading? Yes: ☐   No: ☐

Name and describe it:..

Do you have a hearing loss? Yes: ☐   No: ☐

MOBILITY INFORMATION AND EXPERIENCE

Do you use mobility aids CANE TALKING SIGNS DOG ECHO OTHER

How long have you had O&M training on using transit? ---------------

How long have you had O&M training on other independent travel skills? ---------

How helpful was your O&M training? On a scale of 1-5 (5=Very helpful) _____

Please rate yourself in terms of your mobility and travel in the following areas:

	Very Confident	Confident	"Average"	Unsure	Very unsure
Independent travel					
General Sense of Direction					
New environments					

TRAVEL AND TRANSPORTATION:

How often do you learn a new route or navigate around a new place?

daily several times a week weekly several times a month once a month

less than once a month

Had you heard of Talking Signs before being contacted about this experiment? YES NO

How often have you used the auditory signage system "Talking Signs"?

NEVER FEW TIMES REGULAR USER

How often have you been to the downtown SF Caltrains stations at 4th and King?

NEVER BEEN THERE FEW TIMES QUITE OFTEN

How many trips or outings do you make in an average week? ____________

Is this less than before you lost your sight CIRCLE YES NO SAME N/A

If you make fewer trips what is the major reason for your reduced travel?_____________

In an average week:

1. How often do you use bus transit? ______
2. How often do you use the BART system? _______
3. How often do you use the Light Rail system? _______
4. How often do you use door to door van services? ______
5. How often do you use family or friends private car? ______
6. How often do you use a taxi or other paid service (not van) ______
7. How often do you walk to your activities? ______

EMPLOYMENT

Employment Status: Are you?

Employed Full time Part time Self Employed Student Volunteer Not employed

Is this current employment status what you desire? Yes No

What employment status would you prefer?

Full time Part time Self Employed Student Volunteer Not employed

Are you able to work flexible hours? Yes No

What type of job skill certification, training or degree do you have? ___________________

If Employed:

What is your occupation? ______________________

How long have you been employed? _________

If you were already working when you became visually impaired, have you become underemployed because of your impairment? YES NO

If underemployed, how much less do you make? ___________

Do you feel that you are underemployed (skills not utilized)? Yes No

Do you feel that you are underemployed because of transit or other access problems?

Yes No

If Unemployed:

What was your occupation? ________________

How long have you been unemployed? _________

If you were already working when you became visually impaired, have you become unemployed because of your impairment? YES NO

If unemployed, how much less do you make? ___________

Do you feel that you are unemployed because of transit and other access problems?

Yes No

Transportation and employment:

List any transportation problems that restrict your choices for employment or job search.

Are there any specific problems with transferring between different transit modes which restrict your choice of employment locations or job search?

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
My vision impairment has caused problems in transit use, which restrict my range of locations for jobs.					
My vision impairment has caused problems in transit use which restrict my range of non-job related activities.					
If transit and mode transfers were made less difficult I could find a better job.					

Housing

How long have you lived at your present location?__________

How do you conduct a search for a new place to live?

What problems do you face as a visually impaired person when searching for a good location in which to live.

Travel Information

What is your regular method to get and recall information when you have to learn about a new route or how to get to a new location.

If a special concert or movie I was looking forward to attending was being held 10 miles away in an unfamiliar location that was served by an unfamiliar transit route and also required a transfer to another mode, I would probably:

1 Forego the event

2 Ask a friend for a ride

3 Ask a family member for a ride

4 Ask someone to teach me the transit route

5 Pay for a cab

6 Call dial-a-ride

7 Get information and then rely on my travel skills and by asking for help on the way

8 Other ----------------

How much would you be willing to pay for a sighted guide to get you to and from the event?

$ Per Day?

How much money would you be willing to pay if you were able to independently travel the new route and make the transfer yourself?

$ Per Day?

How much extra money would you be willing to pay for this event if you were able to have the same access to the information on signs, at streets intersections, on transit and in buildings that the sighed public enjoys?

$ Per Day?

If a job that you wanted was located 10 miles away in an unfamiliar location that was served by an unfamiliar transit route and also required a transfer to another mode, I would probably:

1 Forego the job

2 Ask a friend for a ride

3 Ask a family member for a ride

4 Ask someone to teach me the transit route

5 Pay for a cab

6 Call dial-a-ride

7 get information and then rely on my travel skills and by asking for help on the way

8 Other ------------------------------

How much would you be willing to pay a sighted guide to get you to and from the job?

$Per Day?

How much money would you be willing to pay if you were able to independently travel the new route and make the transfer?

$Per Day?

How much money would you be willing to pay if you were able to have the same access to the information on signs, at street intersections, on transit and in buildings that the sighted public enjoys?

$ Per Day?

Monetary gains from independent travel

If I was able to use unfamiliar transit and make transfers independently and with less difficulty, I could probably make $------------------ more per year.

If I was able to use unfamiliar transit and make transfers independently and with less difficulty I could reduce my spending for assistance by $----------- per year.

Travel

How often during an average week do you make these types of trips or activities? How long is your total round trip transit travel and/or walk time?

Trips	Total transit time	Walk time
Work	---------- ------------	--------------
Shopping	---------- ------------	--------------
Social events	---------- ------------	--------------
Recreation	---------- ------------	--------------
Entertainment	---------- ------------	--------------
Educational	---------- ------------	--------------
Religious	---------- ------------	--------------
Medical	---------- ------------	--------------
Banking / Financial	---------- ------------	--------------
Other	---------- ------------	--------------

Do you sometimes avoid trips or activities because of your visual impairment and the difficulties of independent travel YES NO

If YES, How often during a week do you avoid these types of trips or activities because of you visual impairment and difficulties of independent travel?

Work	----------
Shopping	----------
Social events	----------
Recreation	----------
Entertainment	----------
Educational	----------
Religious	----------
Medical	----------
Banking / Financial	----------
Other	----------

How difficult are the following transit and modal transfer tasks? (5 pt. scale)

Extremely difficult, Very difficult, Difficult, Somewhat difficult, Not at all difficult

TRANSIT INFORMATION	Extm	Very	Diff	Some	Not
Getting enough suitable information about an unfamiliar transit terminal or building so that you could make an unaided trip.					
Getting enough suitable information about an unfamiliar transit route so that you could make an unaided trip					
Getting enough suitable information about transit boarding locations on an unfamiliar transit route so that you could make an unaided trip					
Preplanning and remembering instructions, directions and routes for an unfamiliar area so that you can make an unaided transit trip					
Having the same access and ease of use of transit and public buildings as enjoyed by the general public is?					

BUSES	Extm	Very	Diff	Some	Not
Finding a bus stop					
Knowing which buses stop at a bus stop					
Finding the proper bus					
Finding a bus door safely and quickly for easy boarding					
Transferring to another bus on the line					
Transferring buses at a busy terminal					

TRAIN STATION	Extm	Very	Diff	Some	Not
Finding my way around an unfamiliar train or bus terminal					
Finding information or ticket windows, services and amenities such as phones and bathrooms in a new building or terminal.					
Finding the proper boarding gate at a train station when there are many doors or gates to various platforms					
Finding the door to a train at an unfamiliar platform					

Muni (Light Rail)	Extm	Very	Diff	Some	Not
Finding the entrance and the platform for a street level Muni platform					
Finding out which Muni routes are served by a platform					
Finding which side of the platform to wait at for the proper train					
Finding the door to a Muni train					

TRANSFERING MODES	Extm	Very	Diff	Some	Not
Transferring from a train or bus terminal to another mode of transit (light rail or bus) one block away.					
Leaving a station and finding a taxi stand on the street.					

STREET INTERSECTIONS	Extm	Very	Diff	Some	Not
Crossing a busy street in an unfamiliar area.					
Realizing I am lost while travelling and don't know which street corner I am at.					
Determining the traffic flow and intersection type in order to safely cross at an unfamiliar street intersection					
Knowing what street corner I am at when in an unfamiliar area.					
Keeping my mental map continually updated so that I know which block or crossing I am at while traveling					

These questions attempt to determine how much a person views transit transfers as a barrier to travel

For each situation, assume that you are a regular rider of a transit line and your trip home takes you one hour. You find out that a new route such as an express bus or rail service has opened up. You can save some time on your one hour trip but will have to make a transfer from your regular route to the new route or system. For these situations, assume that there is no waiting time at the transfer site, only the walking and search time and effort. The questions ask about making this new modal transfer in both familiar and unfamiliar areas.

How much time would you have to save before you would make a transfer to another mode located in the same block as your stop:

In a familiar area --------

In an unfamiliar area -------

How much time would you have to save before you would make a transfer to another mode located across the street from your stop:

In a familiar area --------

In an unfamiliar area -------

How much time would you have to save before you would make a transfer to another mode located three blocks from your stop:

In a familiar area --------

In an unfamiliar area -------

Part II TS Field Test Circle one TS 1st TS 2nd

Name:.. Subject #:………..

Train TS using sign for future fare machine. Explain the cone of light, have them check top, bottom, right and left sides. Walk to it 3 times. Go to plaza door and practice toward door 3 times. Put portable unit on pole near door and walk to it twice. Explain how to know when you walk past. Put them in middle and let them experience 180, <180 and >180 angles. Walk them until disorientated and then take to nearby street corner info sign so they understand how the information is given.

Start at the outside train platform if possible. Go to inside door and have them stand with back to door. Draw upside down "T" on their hand and explain tracks behind them and the hallway and amenities are in front and to left. "The many railroad tracks all come in behind us. There is a central hallway leading to the main exit and the street in front. Different customer amenities and counters are located along hallway and opposite wall.

TASK I &2 TERMINAL TO RAIL TO TERMINAL

In this experiment we will be simulating making transfer between various transit modes. We will be making 4 street crossings altogether. I need you to stop at the crossing ramp before crossing the street. We will wait through one cycle of the "WAIT" signal. When you think it is clear to go please tell me before crossings. I will stop you if it is too early to cross safely. Please stop at the opposite side crossing ramp each time you cross. Let me know when you know you are at the proper crossing ramp.

Start at terminal door 7. "For this task, we will transfer from the train station to the Muni light rail area. You are at the back of the train station facing the front. There is a hallway leading to the street in front. At the street turn right and go to the corner. After crossing the street, find the Muni light rail station area which is on your right in the median strip. Find where to pay the fare.

"Before leaving the Caltrain station and going to Muni rail, we will first stop at the (proper) bathroom which is located somewhere on the opposite wall. Then find where to buy a candy bar. After that, find the main exit and turn right to go to the corner toward the Muni platform"

Any questions? Please repeat the instructions"

"Please say "here" or otherwise let me know when you arrive at each of the selected locations. You will have a maximum of 4 minutes for each leg of the trip. You can ask other people for information or directions but do not let them guide you. If you want to give up, you will be given the maximum time of 4 minutes and I will walk you to the next location. If at any time you are uncomfortable with a task, please let me know. Your comfort and safety are the central concern in this experiment"

TASK !

FROM	TO	RT	ERROR	COMMENTS
TRACK7 --	BATHROOM	________	________	________________
BATHROOM--	CANDY	________	________	________________
CANDY--	CORNER	________	________	________________
CORNER--	CORNER	________	________	________________
CORNER--	FARE BOX	________	________	________________

In TS condition, take them up the platform to hear the installed transmitters.

"From here we will walk back the way we came, when you get to the entrance to the train terminal find the ticket and information window, then find where to buy flowers, find the inside pay phone and then go to the door for Track 2. Any Questions? Please repeat instructions."

TASK 2

FROM TO	RT	ERROR	COMMENTS
CORNER--CORNER	________	________	_______________
CORNER--TICKET WIN	________	________	_______________
TICKET --FLOWERS	________	__________	______________
FLOWERS --PHONE	________	____________	_______________
PHONE--TRACK 2	________	________	_______________

TASK 3 TERMINAL TO TAXI TO TERMINAL

"This test takes us from the train station to a taxi cab stand. In this task I will guide with you from this door to the main exit, turn left and go to the corner. At the corner we turn left again and walk to the taxi stand pole. It is located where the curb is indented for cabs to park. As we travel listen or scan for cues."

AT TAXI STAND: "In this task you will go to the drinking fountain (use any path you want), then to the ticket window and then to Track 11

FROM TO	RT	ERROR	COMMENTS
TAXI POLE--WATER	________	________	_______________
WATER- TICKET WIN	________	________	_______________
TICKET WIN-TRACK 1 1	________	________	_______________

TASK 4& 5 TERMINAL TO BUS STAND TO TERMINAL

"In this task you will walk from this door to the street in front (use any path or door you want) and find the first corner we visited, the one leading to the Muni platform.. This time instead of going straight across to Muni, we will cross the street on your left, remember to stop at the crosswalk. After crossing the street, turn left and find a pay phone and then find the bus stop for bus #15. There will be someone there that you can ask."

TASK 4

FROM	TO	RT	ERROR	COMMENTS
TRACK 11--CORNER		________	________	________________
CORNER--CORNER		________	________	________________
CORNER--PAY PHONE		________	________	________________
PAY PHONE-BUS SH #15		________	________	________________

"For the return trip to the train terminal I will guide you back the way we came, stopping at the corners before and after you cross. I will then guide you back to the main entrance and to the ticket window. Then walk to find a hot dog and then to Track 3.

TASK 5

FROM	TO	RT	ERROR	COMMENTS
BUS SH #13 - CORNER		Guided walk		
CORNER - CORNER		________	________	________________
CORNER – TICKET WIN		Guided walk		
TICKET WIN – HOT DOG		________	________	________________
HOT DOG - TRACK 3		________	________	________________

Spatial Knowledge

Circle answer or fill in

Which concession counter is closest to the front street?

Hot Dog Don't know ________________

What concession counter is closest to the train area?

Flowers Don't know ________________

Which concession counter is closest to or across from the ticket window?

Candy Don't know ________________

What concession counter is closest tot he Candy counter?

Flowers Don't know ________________

Which amenity is closest tot he water fountain?

Men's bathroom Don't know ________________

What amenity is closest to the phone?

Women's bathroom Don't know ________________

What amenity is furthest from the phone

Water fountain Don't know ________________

What street is in front of the train station

4^{th} Don't know ________________

How many lanes and what direction (one way / two way) is this street?

4 lanes, two way Don't know ________________

What street did you cross to get to the Muni rail platform?

King Don't know ________________

How many lanes and what direction (one way / two way) is this street?

2 lanes, one way Don't know ________________

What street is the taxi stand on?

Townsend Don't know ________________

How many train tracks serve the Caltrain station?

12 Don't know ________________

The highest track # is closest to which of the other transit modes we visited

Muni Don't know ________________

Which track door # is closest to track door 6?

5 Don't know ________________

Which track door # is closest to track door7?

8 Don't know ________________

Which tracks are closest to the main entrance?

3/4 Don't know ________________

Which tracks are closest to the waiting room?

5/6 Don't know ________________

Which track # did we first start at?

7/8 Don't know ________________

Where do the doors across from tracks 9-12 lead

King Plaza Don't know ________________

Think about the street crossings we just made. What was different from your regular method when using TS?

Think about finding various features in the terminal. What was different from your regular method when using TS?

Think about the transfers we made between different modes of transit. What was different from your regular method when using TS?

Part III: Post-test questions

Date………..

Time----------

Name:... Subject #:………..

"Our experiment today has taken place in an area which is fairly rich with Talking Signs transmitters. There were about 30 transmitters at the Caltrain station, there were signs at the Muni rail platform, the taxi stand, the bus stop and outdoor phone and at street intersections for the 4 crossings we made. For all the questions in this post-test interview, please imagine that your entire travel area and neighborhood was equipped with this concentrated type of Talking Signs installation."

If Talking Signs were installed on transit, intersections, signs and buildings how would you rate yourself in terms of your mobility and travel in the following areas:

	Very Confident	confident	"average"	unsure	very unsure
Independent travel					
General Sense of Direction					
New environments					

TRAVEL AND TRANSPORTATION:

How often would you learn a new route or navigate around a new place?

Daily	Several times a week	Weekly	Several times a month	Once a month	Less frequently than monthly
_______	_________	________	__________	___________	____________

If a special concert or movie I was looking forward to attending was being held 10 miles away in an unfamiliar location that was served by an unfamiliar transit route and also required a transfer to another mode, I would probably:

1 Forego the event

2 Ask a friend for a ride

3 Ask a family member for a ride

4 Ask someone to teach me the transit route

5 Pay for a cab

6 Call dial-a-ride

7 Get information and then rely on my travel skills and by asking for help on the way

8 Other ------------------------

How much money would you be willing to pay to be able to use Talking Signs for this trip if they were installed on transit, intersections, signs and buildings

$ Per Day?

If a job that you wanted was located 10 miles away in an unfamiliar location that was served by an unfamiliar transit route and also required a transfer to another mode, I would probably:

1 Forego the job

2 Ask a friend for a ride

3 Ask a family member for a ride

4 Ask someone to teach me the transit route

5 Pay for a cab

6 Call dial-a-ride

7 Get information and then rely on my travel skills and by asking for help on the way

8 Other ------------------------

How much money would you be willing to pay to be able to use Talking Signs for this trip if they were installed on transit, intersections, signs and buildings

$ Per Day?

Monetary gains from independent travel

If Talking Signs were installed citywide on all transit, intersections, signs and buildings I could probably make

$---------------- more per year.

If Talking Signs were installed citywide on all transit, intersections and buildings I could reduce my spending for assistance by $------------------ per year.

Travel

How many more trips a week would you make if Talking Signs were installed citywide in all transit, intersections, signs and buildings?

Work	----------
Shopping	----------
Social events	----------
Recreation	----------
Entertainment	----------
Educational	----------
Religious	----------
Medical	----------
Banking / Financial	----------
Other	----------

I would be willing to pay $------------ per day to be able to use Talking Signs if they were installed citywide and gave me the same access to signs as the sighted public.

If Talking Signs were installed on all transit, intersections and buildings

How difficult would the following transit and modal transfer tasks be (5 pt. scale)

Extremely difficult, Very difficult, Difficult, Somewhat difficult, Not at all difficult

TRANSIT INFORMATION	Extm	Very	Diff	Some	Not
Getting enough suitable information about an unfamiliar transit terminal or building so that you could make an unaided trip.					
Getting enough suitable information about an unfamiliar transit route so that you could make an unaided trip					
Getting enough suitable information about transit boarding locations on an unfamiliar transit route so that you could make an unaided trip					
Preplanning and remembering instructions, directions and routes for an unfamiliar area so that you can make an unaided transit trip					
Having the same access and ease of use of transit and public buildings as enjoyed by the general public is?					

BUSES	Extm	Very	Diff	Some	Not
Finding a bus stop					
Knowing which buses stop at a bus stop					
Finding the proper bus					
Finding a bus door safely and quickly for easy boarding					
Transferring to another bus on the line					
Transferring buses at a busy terminal					

TRAIN STATION	Extm	Very	Diff	Some	Not
Finding my way around an unfamiliar train or bus terminal					
Finding information or ticket windows, services and amenities such as phones and bathrooms in a new building or terminal.					
Finding the proper boarding gate at a train station when there are many doors or gates to various platforms					
Finding the door to a train at an unfamiliar platform					

Muni (Light Rail)	Extm	Very	Diff	Some	Not
Finding the entrance and the platform for a street level Muni platform					
Finding out which Muni routes are served by a platform					
Finding which side of the platform to wait at for the proper train					
Finding the door to a Muni train					

TRANSFERING MODES	Extm	Very	Diff	Some	Not
Transferring from a train or bus terminal to another mode of transit (light rail or bus) one block away.					
Leaving a station and finding a taxi stand on the street.					

STREET INTERSECTIONS	Extm	Very	Diff	Some	Not
Crossing a busy street in an unfamiliar area.					
Realizing I am lost while travelling and don't know which street corner I am at.					
Determining the traffic flow and intersection type in order to safely cross at an unfamiliar street intersection					
Knowing what street corner I am at when in an unfamiliar area.					
Keeping my mental map continually updated so that I know which block or crossing I am at while traveling					

If Talking Signs were installed on all transit, intersections, signs and buildings

For each situation, assume that you are a regular rider of a transit line and your trip home takes you one hour. You find out that a new route such as an express bus or rail service has opened up. You can save some time on your one hour trip but will have to make a transfer from your regular route to the new route or system. For these situations, assume that there is no waiting time at the transfer site, only the walking and search time and effort. The questions ask about making this new modal transfer in both familiar and unfamiliar areas.

How much time would you have to save before you would make a transfer to another mode located in the same block as your stop:

In a familiar area --------

In an unfamiliar area -------

How much time would you have to save before you would make a transfer to another mode located across the street from your stop:

In a familiar area --------

In an unfamiliar area -------

How much time would you have to save before you would make a transfer to another mode located three blocks from your stop:

In a familiar area --------

In an unfamiliar area -------

Please rate if you agree or disagree with the following statements (5 point scale)

Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree

TALKING SIGNS INSTALLATIONS	S Ag	Ag	Neut	Disa	S Di
TS are helpful and should be installed at terminals					
TS are helpful and should be installed at bus stops					
TS are helpful and should be installed at transit platforms					
TS are helpful and should be installed at street intersections					
TS are helpful and should be installed in buildings					
TS are helpful and should be installed where printed signs are located					
TS are helpful and should be installed at transit vehicle boarding doors					
TS give vital spatial information at intersections and should be installed					
TS at intersection crosswalks make crossings safer					
TS makes transit transfers easier and safer					
A city-wide TS system would help me financially					
A city-wide TS system would allow me to travel to more places					
From what I experienced in this test, I feel that the TS system helped me use unfamiliar transit and make transfers					

If TS were installed citywide on transit, intersections, signs and buildings, how would they affect your travel?

What is your overall opinion of Talking Signs?

APPENDIX 5: Times (in seconds) for Task 1

Subject Data for Transfer task 1. Maximum time allowed was 240 seconds.											TOT.	TOT.
Subject & condition	NTS	TS	NTS	TS	NTS	TS	NTS	TS	NTS	TS	NTS	TS
N= NTS 1st	1-A	1-A	1-B	1-B	1-C	1-C	1-D	1-D	1-E	1-E	Task 1	Task 1
T= TS 1st												
N 1	240	40	240	53	186	115	21	24	240	24	927	256
N 2	240	80	240	160	240	125	105	11	157	19	982	395
N 3	86	31	31	40	69	67	11	10	21	9	218	157
N 4	28	26	41	31	58	57	11	9	14	7	152	130
N 5	166	85	99	101	80	83	16	14	240	20	601	303
N 6	58	66	51	60	240	169	21	13	232	12	602	320
N 7	123	95	197	135	137	115	31	15	146	15	634	375
N 8	26	30	184	80	81	61	109	11	240	25	640	207
N 9	92	46	105	51	67	82	22	11	22	13	308	203
N 10	152	113	158	131	213	105	99	15	240	11	862	375
N 11	51	50	72	35	84	62	19	10	240	11	466	168
N 12	240	43	240	50	116	80	160	9	31	11	787	193
N 13	143	43	56	53	123	101	30	10	46	15	398	222
N 14	240	103	218	240	240	240	29	16	122	22	849	621
N 15	240	54	75	72	70	75	32	9	102	18	519	228
T 1		150		240		153		13		63		619
T 2		68		121		88		24		15		316
T 3		55		64		130		13		14		276
T 4	38	95	44	121	61	73	13	8	15	15	171	312
T 5		145		178		126		12		21		482
T 6	73	76	112	75	240	105	13	16	33	14	471	286
T 7	54	50	28	69	95	75	143	9	23	15	343	218
T 8		81		120		92		17		13		323
T 9	54	67	80	66	107	122	92	12	17	14	350	281
T 10	240	101	169	91	240	148	71	13	104	27	824	380
T 11	91	141	59	162	92	131	19	15	26	22	287	471
T 12	26	44	35	82	83	74	12	12	12	13	168	225
T 13	74	37	64	116	89	98	17	8	17	23	261	282
T 14	26	44	35	36	59	74	17	9	15	15	152	178
T 15	240	119	179	142	240	222	24	15	33	24	716	522
AVG NTS FIRST	142	60	134	86	134	102	48	12	140	15	596	277
AVG TS FIRST	92	85	81	112	131	114	42	13	30	21	374	345
AVG ALL	122	73	112	99	132	108	45	13	96	18	508	311
T-TEST NTS 1st		0.00054		0.008		0.006		0.006		0.00006		0.00001
T-TEST TS 1st		0.4		0.08		0.24		0.010		0.14		0.34
T-TEST ALL		0.003		0.23		0.066		0.0001		0.00001		0.0004
T-TEST TS2-TS1		0.04		0.14		0.27		0.35		0.058		0.11

APPENDIX 6: Times (in seconds) for Task 2

Subject Data for Transfer Task 2. Maximum time allowed was 240 seconds.											TOTAL	TOTAL
Subject & condition	NTS	TS	NTS	TS	NTS	TS	NTS	TS	NTS	TS	NTS	TS
N= NTS 1st	2-A	2-A	2-B	2-B	2-C	2-C	2-D	2-D	2-E	2-E	TASK 2	TASK 2
T= TS 1st												
N 1	26	13	240	153	151	28	220	240	187	207	824	641
N 2	240	9	240	143	193	16	226	240	202	151	1101	559
N 3	11	8	59	59	12	9	119	40	106	95	307	211
N 4	11	8	58	58	20	14	50	32	82	46	221	158
N 5	15	12	96	77	60	15	53	62	240	53	464	219
N 6	240	24	100	122	36	27	100	84	119	87	595	344
N 7	124	13	170	103	145	12	97	174	240	43	776	345
N 8	113	9	240	101	27	18	93	56	240	70	713	254
N 9	14	11	72	69	16	9	42	33	72	63	216	185
N 10	116	16	119	116	240	16	240	106	101	77	816	331
N 11	14	8	125	81	126	8	41	53	184	47	490	197
N 12	18	12	108	95	137	16	89	61	124	44	476	228
N 13	106	15	94	94	47	7	84	45	240	72	571	233
N 14	29	21	137	124	170	21	136	240	240	172	712	578
N 15	10	11	69	98	15	15	44	52	197	63	335	239
T 1		22		40		21		121		79		283
T 2		14		83		89		181		123		490
T 3		14		118		21		39		75		267
T 4	15	12	62	95	11	7	37	63	63	106	188	283
T 5		13		128		15		130		109		395
T 6	113	17	93	100	100	32	123	132	193	100	622	381
T 7	240	8	134	68	20	11	80	48	138	33	612	168
T 8		18		136		28		228		90		500
T 9	98	13	84	153	24	11	39	140	111	114	356	431
T 10	110	24	240	99	57	13	240	105	80	66	727	307
T 11	34	15	100	149	16	10	62	223	79	90	291	487
T 12	81	12	48	66	8	5	29	30	40	46	206	159
T 13	17	13	82	108	12	18	37	45	67	51	215	235
T 14	16	9	64	60	20	7	32	35	56	53	188	164
T 15	19	16	240	207	180	26	125	119	240	147	804	515
AVG NTS FIRST	72	13	128	100	93	15	109	101	172	86	574	315
AVG TS FIRST	74	15	115	107	45	21	80	109	107	85	421	338
AVG ALL	73	14	123	103	74	18	98	105	146	86	513	326
T-TEST TS 1st		0.006		0.017		0.0006		0.30		0.0002		0.00001
T-TEST TS1st		0.002		0.4		0.069		0.15		0.14		0.14
AVG ALL		0.00004		0.085		0.00006		0.34		0.0001		0.0006
T-TEST TS2-TS1		0.12		0.32		0.16		0.39		0.5		0.35

APPENDIX 7: Times (in seconds) for Task 3

Subject Data for Transfer task 3. Maximum time allowed was 240 seconds.							TOTAL	TOTAL
Subject & condition	NTS	TS	NTS	TS	NTS	TS	NTS	TS
N= NTS 1st	3-A	3-A	3-B	3-B	3-C	3-C	TASK 3	TASK 3
N= NTS 1st								
T= TS 1st	240	240	240	98	240	177	720	515
N 2	240	240	47	59	240	109	527	408
N 3	103	64	30	25	58	39	191	128
N 4	60	62	24	27	45	54	129	143
N 5	239	112	34	35	240	61	513	208
N 6	182	131	128	52	240	83	550	266
N 7	240	240	137	39	240	86	617	365
N 8	185	106	48	31	138	51	371	188
N 9	107	90	27	30	114	52	248	172
N 10	240	209	221	95	232	89	693	393
N 11	165	89	44	36	197	69	406	194
N 12	146	51	29	27	149	51	324	129
N 13	178	147	29	28	208	59	415	234
N 14	178	240	156	148	240	143	574	531
N 15	101	98	26	39	87	63	214	200
T 1		54		50		120		224
T 2		240		131		183		554
T 3		98		39		109		246
T 4		107		51		72		230
T 5		138		38		117		293
T 6		122		148		137		407
T 7		97		24		32		153
T 8		168		63		172		403
T 9		183		44		82		309
T 10		128		67		81		276
T 11		202		77		84		363
T 12		86		26		54		166
T 13		153		55		65		273
T 14		71		23		54		148
T 15		223		142		119		484
AVG NTS FIRST	174	141	81	51	178	79	433	272
AVG TS FIRST		138		65		99		302
AVG ALL	174	140	81	58	178	89	433	287
T-TEST TS 1st		0.010		0.02		0.00001		0.00002
T-TEST ALL		0.045		0.09		0.000002		0.002
T-TEST TS2-TS1		0.45		0.18		0.10		0.3

APPENDIX 8: Times (in seconds) for Task 4

Subject Data for Transfer task 4. Maximum time allowed was 240 seconds.									TOTAL	TOTAL
Subject & condition	NTS	TS	NTS	TS	NTS	TS	NTS	TS	NTS	TS
N= NTS 1st	4-A	4-A	4-B	4-B	4-C	4-C	4-D	4-D	TASK 4	TASK 4
T= TS 1st										
N 1	240	63	25	20	82	54	50	0	397	137
N 2	240	193	24	21	240	81	15	0	519	295
N 3	182	34	17	16	34	21	44	0	277	71
N 4	31	32	13	16	31	25	3	0	78	73
N 5	68	59	19	13	240	49	240	0	567	121
N 6	130	119	29	14	240	42	145	0	544	175
N 7	193	181	27	16	66	54	34	0	320	251
N 8	134	47	18	13	77	53	5	0	234	113
N 9	178	53	15	14	32	32	0	0	225	99
N 10	240	111	32	19	240	47	58	0	570	177
N 11	76	43	20	12	71	46	92	0	259	101
N 12	109	59	24	14	91	44	22	0	246	117
N 13	200	49	45	15	70	43	10	0	325	107
N 14	240	240	31	29	95	240	240	0	606	509
N 15	119	15	17	12	40	35	113	0	289	62
T 1		90		16		62		0		168
T 2		144		20		45		0		209
T 3		46		15		45		0		106
T 4		60		12		38		0		110
T 5		95		12		78		0		185
T 6		107		18		84		0		209
T 7		33		8		35		0		76
T 8		119		15		81		0		215
T 9		201		13		117		0		331
T 10		100		22		53		0		175
T 11		78		17		57		0		152
T 12		42		12		36		0		90
T 13		92		13		84		0		189
T 14		30		10		38		0		78
T 15		86		23		119		0		228
AVG NTS FIRST	159	87	24	16	110	58	71	0	364	161
AVG TS FIRST		88		15		65		0		168
AVG ALL	159	87	24	16	110	61	71	0	364	164
T-TEST TS 1st		0.0003		0.001		0.025		0.002		0.00001
T-TEST ALL		0.0003		0.00005		0.006		0.00001		0.000002
T-TEST TS2-TS1		0.5		0.25		0.34				0.43

APPENDIX 9: Times (in seconds) for Task 5

Subject Data for Transfer task 5 Maximum time allowed was 240 seconds							TOTAL	TOTAL
Subject & condition	NTS	TS	NTS	TS	NTS	TS	NTS	TS
N= NTS 1st	5-A	5-A	5-B	5-B	5-C	5-C	TASK 5	TASK 5
T= TS 1st								
N 1	38	21	158	41	240	58	436	120
N 2	39	21	63	33	240	83	342	137
N 3	16	12	13	9	53	20	82	41
N 4	16	13	18	18	29	25	63	56
N 5	14	16	36	37	78	52	128	105
N 6	42	18	51	23	70	35	163	76
N 7	20	15	54	37	240	73	314	125
N 8	25	17	144	21	127	60	296	98
N 9	16	16	31	17	42	53	89	86
N 10	19	18	40	36	75	131	134	185
N 11	21	13	90	22	93	58	204	93
N 12	14	14	69	23	80	33	163	70
N 13	23	13	49	17	240	64	312	94
N 14	33	22	240	35	136	166	409	223
N 15	15	12	39	22	141	39	195	73
T 1		15		24		28		67
T 2		15		32		56		103
T 3		11		16		28		55
T 4		14		35		83		132
T 5		15		30		68		113
T 6		16		35		101		152
T 7		8		39		24		71
T 8		16		24		115		155
T 9		14		36		42		92
T 10		19		60		63		142
T 11		19		44		92		155
T 12		19		13		31		63
T 13		11		21		42		74
T 14		11		19		19		49
T 15		20		79		108		207
AVG NTS FIRST	23	16	73	26	126	63	222	105
AVG TS FIRST		15		34		60		109
AVG ALL	23	15	73	30	126	62	222	107
T-TEST TS 1st		0.001		0.004		0.004		0.0003
T-TEST ALL		0.0001		0.0004		0.0002		0.00002
T-TEST TS2-TS1		0.19		0.067		0.4		0.43

APPENDIX 10: Transit Problems That Restrict Employment

Question: "List any transportation problems which restrict your choices for employment or job search"

Ss #	Comment
1	Don't announce stops
2	Having to transfer buses, expensive cab rides, unsure when transferring
3	
4	Bus is too slow, long transit wait times
5	Takes too long
6	Lack of service, info is hard to get, not easy to make connections
7	
8	Problems with transfers, limited service area
9	Limited service area
10	Transit is a disadvantage, limited area, slow service, unsafe street crossings
11	Infrequent service, don't announce stops, not reliable, don't announce which train, poor driver attitude
12	Can't go long distances, huge time expense, limited service area
13	Service area limited
14	No weekend service, limited hours in PM & weekends, limited service area, slow times, paratransit is limited
15	Limited service hours & weekends, limited service areas, expensive cabs, transit not close, too much time, long walks
16	Limited area
17	Limited service area
18	
19	Frequency of transportation
20	Lack of continuity of transit service, length of time for travel
21	Limited service area. Limited hours
22	Limited service, too much time
23	Can't take dog in cab, limited service area, had accidents
24	
25	
26	Limited service area
27	Finding proper bus, finding where the bus stop is, knowing where you are
28	Can only work close to transit, time constraints
29	Takes too long on bus, finding locations using transit
30	Schedules, location of stations, limited service area, not much connecting service

APPENDIX 11: Categorization of Transportation Problems

Question: "List any transportation problems which restrict your choices for employment or job search"

Category	59 Responses
Excess time	Bus is too slow
Excess time	Huge time expense
Excess time	Length of time for travel
Excess time	Long transit wait times
Excess time	Slow service
Excess time	Slow times
Excess time	Takes too long
Excess time	Takes too long on bus
Excess time	Time constraints
Excess time	Too much time
Excess time	Too much time
Lack of information	Don't announce stops
Lack of information	Don't announce stops
Lack of information	Don't announce which train
Lack of information	Finding locations using transit
Lack of information	Finding proper bus
Lack of information	Finding where the bus stop is
Lack of information	Info is hard to get
Lack of information	Knowing where you are
Limited service	Can only work close to transit
Limited service	Can't go long distances
Limited service	Frequency of transportation
Limited service	Infrequent service
Limited service	Lack of continuity of transit service
Limited service	Lack of service
Limited service	Limited area
Limited service	Limited area

Category	59 Responses
Limited service	Limited hours
Limited service	Limited hours in PM & weekends
Limited service	Limited service
Limited service	Limited service area
Limited service	Limited service area
Limited service	Limited service area
Limited service	Limited service area
Limited service	Limited service area
Limited service	Limited service area
Limited service	Limited service area
Limited service	Limited service area
Limited service	Limited service area
Limited service	Limited service areas
Limited service	Limited service hours & weekends
Limited service	Location of stations
Limited service	Long walks
Limited service	No weekend service
Limited service	Paratransit is limited
Limited service	Schedules
Limited service	Service area limited
Limited service	Transit not close
Misc.	Expensive cab rides
Misc.	Expensive cab rides
Misc.	Poor driver attitude
Misc.	Not reliable
Misc.	Transit is a disadvantage
Safety	Had accidents
Safety	Unsafe street crossings
Transfer problems	Having to transfer buses
Transfer problems	Not easy to make connections
Transfer problems	Not much connecting service
Transfer problems	Problems with transfers
Transfer problems	Unsure when transferring

APPENDIX 12: Transfer Problems That Restrict Employment

Question: "Are there any specific problems with transferring between different transit modes which restrict your choice of employment or job search?"

Ss #	Response
1	Don't know where stops or stations are
2	Transfers to buses and BART
3	
4	Hard to find bus stop, hard to read BART signs
5	
6	
7	
8	Miss vehicles at transfers, have to pay for paratransit, weather problems
9	Poor signage, can't find buses in terminal, limited service
10	Bad connection times, long wait, hard to make transfers, dangerous street crossings
11	Limited service, need taxis or long walks, finding a bus stop
12	Time constraints, have to learn many systems, Don't know where stops and transfer points are, stations not built alike, can make mistakes, time problems, requites research and preplanning
13	Locating where to go, need training for new places
14	Fear of learning new routes, infrequent bus routes, no one to learn from, don't know where to find transit points, tough to cross new streets, don't know ID of bus or BART
15	Use 3 modes for work, no unified pass, don't know where stops or modes are, have to know many time schedules, no unified transit information, many calls needed, hard to get info on stops, street #, crossing, buildings
16	
17	
18	
19	Finding transportation points, conflicting information, absence of landmarks
20	Not always clear how to transfer unassisted, hard to transfer, too many modes, terminals are a nightmare, bus transfer points not safe
21	Stations not standardized
22	Hard to find transfer points
23	Hard to learn in a new city, some towns don't have transit
24	Hard to find traffic signals, doors

Ss #	Response
25	Transfer points are hard to find
26	Being able to determine bus stops and buses, finding stations
27	Finding transfer points, where to get off & on, finding entrance gate, have to make advance trips, lack of info
28	Connection time problems, long waits, knowing which bus to take, stations not accessible, can't read signs and directions
29	Finding bus stops and bus #'s, drivers don't call stops, finding ticker machine, find fare gate
30	Hard to navigate in terminal, lack of info and signs, hard to get help, finding bus stop, no human assistance

APPENDIX 13: Categorization of Transfer Problems

Question: "Are there any specific problems with transferring between different transit modes which restrict your choice of employment or job search?"

Category	90 Responses
Misc.	Have to make advance trips
Misc.	Can make mistakes
Poor signage	Can't read directions
Poor signage	Can't read signs
Poor signage	Conflicting information
Poor signage	Hard to read BART signs
Poor signage	Lack of signs
Poor signage	Poor signage
Problems with identity or spatial information	Absence of landmarks
Problems with identity or spatial information	Being able to determine bus stops
Problems with identity or spatial information	Being able to determine buses
Problems with identity or spatial information	Can't find buses in terminal
Problems with identity or spatial information	Don't know ID of bus or BART
Problems with identity or spatial information	Don't know where modes are
Problems with identity or spatial information	Don't know where stations are
Problems with identity or spatial information	Don't know where stops are
Problems with identity or spatial information	Don't know where stops are
Problems with identity or spatial information	Don't know where stops are
Problems with identity or spatial information	Don't know where to find transit points
Problems with identity or spatial information	Don't know where transfer points are
Problems with identity or spatial information	Drivers don't call stops
Problems with identity or spatial information	Fear of learning new routes
Problems with identity or spatial information	Finding a bus stop
Problems with identity or spatial information	Finding bus #'s
Problems with identity or spatial information	Finding bus stop
Problems with identity or spatial information	Finding bus stops
Problems with identity or spatial information	Finding entrance gate

Category	90 Responses
Problems with identity or spatial information	Finding fare gate
Problems with identity or spatial information	Finding stations
Problems with identity or spatial information	Finding ticker machine
Problems with identity or spatial information	Finding transfer points
Problems with identity or spatial information	Finding transportation points
Problems with identity or spatial information	Finding where to get off & on
Problems with identity or spatial information	Hard to find bus stop
Problems with identity or spatial information	Hard to find doors
Problems with identity or spatial information	Hard to find traffic signals
Problems with identity or spatial information	Hard to find transfer points
Problems with identity or spatial information	Hard to get help
Problems with identity or spatial information	Hard to get info on street block #
Problems with identity or spatial information	Hard to get info on buildings
Problems with identity or spatial information	Hard to get info on stops
Problems with identity or spatial information	Hard to get info on crossing
Problems with identity or spatial information	Hard to learn in a new city
Problems with identity or spatial information	Hard to make connections
Problems with identity or spatial information	Hard to make transfers
Problems with identity or spatial information	Hard to transfer
Problems with identity or spatial information	Have to know many time schedules
Problems with identity or spatial information	Have to learn many systems
Problems with identity or spatial information	Knowing which bus to take
Problems with identity or spatial information	Lack of info
Problems with identity or spatial information	Lack of info
Problems with identity or spatial information	Lack of info
Problems with identity or spatial information	Locating where to go
Problems with identity or spatial information	Many calls needed
Problems with identity or spatial information	Need training for new places
Problems with identity or spatial information	No human assistance
Problems with identity or spatial information	No one to learn from
Problems with identity or spatial information	Not always clear how to transfer unassisted
Problems with identity or spatial information	Requires research and preplanning
Problems with identity or spatial information	Tough to cross new streets
Problems with identity or spatial information	Transfer points are hard to find

Category	90 Responses
Problems with identity or spatial information	Transfers to buses and BART
Problems with identity or spatial information	Use 3 modes for work
Safety problems	Bus transfer points not safe
Safety problems	Dangerous street crossings
System problems	Bad connection times
System problems	Connection time problems
System problems	Have to pay for paratransit
System problems	Infrequent bus routes
System problems	Limited service
System problems	Limited service
System problems	Long wait
System problems	Long waits
System problems	Long walks
System problems	Many calls needed
System problems	Miss vehicles at transfers
System problems	Need taxis
System problems	No unified transit information
System problems	No unified, pass
System problems	Not efficient
System problems	Some towns don't have transit
System problems	Stations not accessible
System problems	Stations not built alike
System problems	Stations not standardized
System problems	Terminals are a nightmare
System problems	Time constraints
System problems	Time problems
System problems	Too many modes
System problems	Weather problems

APPENDIX 14: Comments about Street Crossing Differences

Question: "Think about the street crossings we just made.

What was different from your regular method when using TS?"

Ss #	Response
1	Knew which direction to cross, didn't veer
2	Don't have to ask, tells when to go or wait, tells street info, know direction
3	Don't have to listen to traffic, faster to cross
4	Was able to know street names, knew when to walk, knew when to stop and go
5	Tells you when to walk safely, gives direction, learned details, gave direction I was walking
6	Gives a positive walk sign, gives direction across street, tells me where I am
7	Know when to walk, keep aligned for crossing, knew which direction, knew block #, knew # of lanes
8	Gives direction, # of lanes, walk signal, what's across street, don't have to ask, more independent
9	Knew when to walk, duration of walk signal, block #, crosswalk button, name of street
10	Knew initial start time, center & align crosswalk, more confident, gave orientation & cardinal direction, knew points of interest and destination
11	Knew 100% I was crossing safe, didn't have to ask, knew direction I'm walking, knew block #
12	Knew names of streets, TS helped me understand traffic flow & change, great for weird intersections, knew there was a button, gives info I didn't have
13	Got info on walk signs, don't have to listen & wait for cycle, much faster, know block #, direction I'm facing, street names, knew when not to go, more secure, gives additional info
14	Know when to walk, gives guide beam across crosswalk, gives info on direction, what's around, ID push button, street names
15	Told me when safe to go, could locate center of crosswalk, gives me street name, cardinal direction
16	Know walk signal immediately, likes beam for path to cross, mow which block #, street I am at
17	More information, easier to cross, safer to cross
18	Tells where to go, know what street you're crossing

Ss #	Response
19	More assurance, know when to walk, signs gave info on intersection type, info on signal, faster to find corner
20	Extra tool for alignment, know when to start, don't have to pause, know there is a push button, saves search time for button, gives directional info, gives cardinal direction, can fill in visual map in my mind
21	Can listen to message & learn spatial information
22	Knowing when to go is great help, can align self across street, more safe to cross, gives direction, 100's #, location of places you wouldn't visually know
23	Gives direction, block #, name of street, know when to walk
24	Helps orient faster, orient easier, helped me know where to go, would not have known the block #, direction, street names
25	Follow beam when walk sign comes on, with regular method couldn't hear traffic, safer, knew direction, block #, didn't have to search, no ask, knew to only cross 2 lanes for muni, gave me info without learning
26	Told me when walk signal is lit, more safe, gave me block #, knew street names, what was across street, knew if push button
27	Wait signal was good validation of regular technique, knew exactly where I was, didn't have to deduce, count, remember
28	Incredible difference, wouldn't have to wait for passers-by to ask, didn't have to assume they spoke English, got positive ID, timely info, able to align myself, not distracted crossing street, easy to find push button, knew when to safely walk
29	Know what is around you, gives location info, confirms where you are, know when light says to go
30	Can concentrate on message instead of traffic noise, could find location of crosswalk, walk direct, know which direction, street names, block #, much safer, know when walk signal is on

APPENDIX 15: Categorization of Street Crossing Differences

Question: "Think about the street crossings we just made. What was different from your regular method when using TS?"

Category	146 responses
Confirms walk signal	Don't have to listen & wait for cycle
Confirms walk signal	Don't have to listen to traffic
Confirms walk signal	Don't have to pause
Confirms walk signal	Easier to cross
Confirms walk signal	Faster to cross
Confirms walk signal	Gives a positive walk sign
Confirms walk signal	Got info on walk signs
Confirms walk signal	Great for weird intersections
Confirms walk signal	Helped me know where to go
Confirms walk signal	Info on signal
Confirms walk signal	Knew 100% I was crossing safe
Confirms walk signal	Knew initial start time
Confirms walk signal	Knew when not to go
Confirms walk signal	Knew when to safely walk
Confirms walk signal	Knew when to stop and go
Confirms walk signal	Knew when to walk
Confirms walk signal	Knew when to walk
Confirms walk signal	Know walk signal immediately
Confirms walk signal	Know when light says to go
Confirms walk signal	Know when to start
Confirms walk signal	Know when to walk
Confirms walk signal	Know when to walk
Confirms walk signal	Know when to walk
Confirms walk signal	Know when walk signal is on
Confirms walk signal	Knowing when to go is great help

Category	146 responses
Confirms walk signal	More safe to cross
Confirms walk signal	Not distracted crossing street
Confirms walk signal	Safer to cross
Confirms walk signal	Tells when to go or wait
Confirms walk signal	Tells you when to walk safely
Confirms walk signal	Told me when safe to go
Confirms walk signal	Told me when walk signal is lit
Confirms walk signal	Wait signal was good validation of regular technique
Confirms walk signal	Walk signal
Confirms walk signal	With regular method couldn't hear traffic
Confirms crosswalk alignment	Able to align myself
Confirms crosswalk alignment	Can align self across street
Confirms crosswalk alignment	Center & align crosswalk
Confirms crosswalk alignment	Could find location of crosswalk
Confirms crosswalk alignment	Could locate center of crosswalk
Confirms crosswalk alignment	Didn't veer
Confirms crosswalk alignment	Duration of walk signal
Confirms crosswalk alignment	Extra tool for alignment
Confirms crosswalk alignment	Follow beam when walk sign comes on
Confirms crosswalk alignment	Gives direction across street
Confirms crosswalk alignment	Gives guide beam across crosswalk
Confirms crosswalk alignment	Keep aligned for crossing
Confirms crosswalk alignment	Knew which direction to cross
Confirms crosswalk alignment	Likes beam for path to cross
Confirms crosswalk alignment	Tells where to go
Confirms crosswalk alignment	Walk direct
Confirms direction	Cardinal direction
Confirms direction	Direction
Confirms direction	Direction I'm facing
Confirms direction	Gave direction I was walking
Confirms direction	Gave orientation & cardinal direction
Confirms direction	Gives cardinal direction
Confirms direction	Gives direction
Confirms direction	Gives direction
Confirms direction	Gives direction

Category	146 responses
Confirms direction	Gives direction
Confirms direction	Gives directional info
Confirms direction	Gives info on direction
Confirms direction	Knew direction
Confirms direction	Knew direction I'm walking
Confirms direction	Knew which direction
Confirms direction	Know direction
Confirms direction	Know which direction
Confirms presence of push buttons	Crosswalk button
Confirms presence of push buttons	Easy to find push button
Confirms presence of push buttons	ID push button
Confirms presence of push buttons	Knew if push button
Confirms presence of push buttons	Knew there was a button
Confirms presence of push buttons	Know there is a push button
Confirms presence of push buttons	Saves search time for button
Confirms presence of push buttons	Didn't have to search
Gives more independence	Didn't have to ask
Gives more independence	Don't have to ask
Gives more independence	Don't have to ask
Gives more independence	No ask
Gives more independence	Didn't have to assume they spoke English
Gives more independence	More assurance
Gives more independence	More confident
Gives more independence	More independent
Gives more independence	Wouldn't have to wait for passers-by to ask
Identifies Block Number	100's #
Identifies Block Number	Block #
Identifies Block Number	Block #
Identifies Block Number	Block #
Identifies Block Number	Block #
Identifies Block Number	Gave me block #
Identifies Block Number	Knew block #
Identifies Block Number	Knew block #
Identifies Block Number	Know block #
Identifies Block Number	Mow which block #
Identifies Block Number	Would not have known the block #

Category	146 responses
Identifies intersection & lanes	TS helped me understand traffic flow & change
Identifies intersection & lanes	# of lanes
Identifies intersection & lanes	Knew # of lanes
Identifies intersection & lanes	Knew to only cross 2 lanes for muni
Identifies intersection & lanes	Signs gave info on intersection type
Identifies street names	Knew names of streets
Identifies street names	Knew street names
Identifies street names	Gives me street name
Identifies street names	Know what street you're crossing
Identifies street names	Name of street
Identifies street names	Name of street
Identifies street names	Street I am at
Identifies street names	Street names
Identifies street names	Street names
Identifies street names	Street names
Identifies street names	Street names
Identifies street names	Tells street info
Identifies street names	Was able to know street names
Increased spatial orientation	Faster to find corner
Increased spatial orientation	Gave me info without learning
Increased spatial orientation	Gives additional info
Increased spatial orientation	Gives info I didn't have
Increased spatial orientation	Got positive ID
Increased spatial orientation	Knew points of interest and destination
Increased spatial orientation	Learned details
Increased spatial orientation	Location of places you wouldn't visually know
Increased spatial orientation	What was across street
Increased spatial orientation	What's across street
Increased spatial orientation	What's around
Increased spatial orientation	Can fill in visual map in my mind
Increased spatial orientation	Can listen to message & learn spatial information
Increased spatial orientation	Confirms where you are
Increased spatial orientation	Gives location info
Increased spatial orientation	Helps orient faster
Increased spatial orientation	Knew exactly where I was

Category	146 responses
Increased spatial orientation	Know what is around you
Increased spatial orientation	Orient easier
Increased spatial orientation	Tells me where I am
Increased spatial orientation	More information
Increased spatial orientation	Timely info
General efficiency	Can concentrate on message instead of traffic noise
General efficiency	(Don't have to) count
General efficiency	Didn't have to deduce
General efficiency	More safe
General efficiency	More secure
General efficiency	Much faster
General efficiency	Much safer
General efficiency	(Don't have to) remember
General efficiency	Safer
General efficiency	Incredible difference

APPENDIX 16: Comments about Terminal Differences

Question: "Think about finding various features in the terminal.

What was different from your regular method when using TS?"

Ss #	Response
1	Knew where things were, they tell where it is, didn't have to ask, people don't give clear directions
2	Don't have to ask, avoid bad directions (by others), could know which door, (know) place I was at
3	Don't have to find and ask people, more independent, more comfortable
4	Didn't have to get up close trying to read signs, was able to find exit easier
5	Easier to find locations, didn't have to ask
6	Gave positive ID, got orientation, label, greater confidence, didn't have to ask
7	Easier, tells where it's at
8	No asking, quicker, able to use reference points, scan and orient, like "looking around", found locations I didn't know were there
9	Travel more unencumbered, direction cues for orientation, label cues for orientation, didn't have to ask, more independent, more finite spatial orientation, very high traveling confidence
10	Able to use other points to find & locate amenities, gave spatial orientation, very helpful to find doors, didn't have to ask, able to pinpoint locations without moving, helps construct mental maps, I can point & get info instead of someone else moving my hand with no logical sequence, understand relationships, help get precise line of travel
11	Was able to have more options, found stuff I wasn't looking for, didn't have to count doors, knew where exits lead to
12	Knew amenities were in same room, didn't have to count to find doors, didn't know they (doors) were in pairs, could align to what's across from doors, able to find direct path to vendors
13	Didn't have to ask, independent, didn't have to feel dirty walls & counters, knew where I was & where I was going, able to find platform, locations, spatial relationships, can make shortcuts, can find landmarks without going there, learned what was sold even though not looking for it, able to quickly locate & use amenities
14	Didn't have to ask, knew what was flowers, new locations, found stuff I wouldn't have asked for, didn't have to count, didn't have to feel, I look more normal & confident, easy to find right bathroom, easy to find right track door

Ss #	Response
15	Very specific info on where I was, didn't have to worry about using my limited vision, took me exactly to locations, didn't have to guess, felt safer, instant feedback, don't have to find people, ask for help, secure, had positive ID, more confident, could learn spatial layout & orientation
16	Don't have to ask, immediate access to info, didn't have to accumulate knowledge, know which street I exit to, easy to know track #
17	Didn't have to ask, faster, more confident
18	Know where to go, made it easier
19	Didn't have to ask, able to associate features with others
20	Didn't have to ask, better sense of spatial relationships, gives clearer mental map, don't have to stay close to walls, can use interior space
21	ID's the doors, ID's the counters, didn't have to ask, more helpful for orientation to streets & tracks
22	Know quickly when you're close, less worry, can concentrate on safety, faster, just knowing they exist helps travel, didn't have to ask, more independent, increased spatial orientation
23	Would have had to ask, went direct to what I wanted, knew which side of building I was in, knew where facing
24	Helped to learn spatial relationships, didn't have to ask, didn't have to memorize, helps me learn more spatial knowledge, great help in finding gate #'s
25	Didn't have to ask, would have wanted a sighted guide, more independent, self esteem, knew what was around by scanning, could explore better, could learn better
26	Much info about building, wouldn't have to ask, or use trail & error, didn't have to count doors, knew what was nearby without walking
27	Didn't have to ask, or have sighted guide, didn't have to shoreline, or count doors, didn't have to stand in line to get assistance, didn't have to ask, saves time, nice to know what is around me
28	Easy, not frustrating, makes things do-able, had a clear spatial orientation, learn more than from O & M training, more detailed spatial orientation, got specific info, didn't have to grope, could tell things from a distance, easy to line up and go to it, veering was easy to fix, didn't have to re-orient, didn't have to ask, knew I could do it with ease
29	Much quicker to get idea where things are, much quicker to find out what is around you, gives spatial info, helps emotionally when I can know what's around, makes it fun to go out & explore, "it's the difference between a walk in the park & a walk on a treadmill facing a wall", can go right to track or location rather than counting, don't have to search for landmarks, don't have to ask, independent
30	Concentrate on hazard & safety instead of spatial configuration & orientation, shorter distance, quicker travel, would have had to ask for help, was not distracted by noise & movement, more focus, knew which direction I was to go, learn more detail, found things I didn't know, explains layout

APPENDIX 17: Categorization of Terminal Differences

Question: "Think about finding various features in the terminal.

What was different from your regular method when using TS?"

Category	177 responses
Better mental state	Can concentrate on safety
Better mental state	Easier
Better mental state	Easy
Better mental state	Faster
Better mental state	Faster
Better mental state	Felt safer
Better mental state	Greater confidence
Better mental state	Helps emotionally when I can know what's around
Better mental state	I look more normal & confident
Better mental state	Knew I could do it with ease
Better mental state	Less worry
Better mental state	Made it easier
Better mental state	Makes it fun to go out & explore
Better mental state	Makes things do-able
Better mental state	More comfortable
Better mental state	More confident
Better mental state	More confident
Better mental state	More focus
Better mental state	Much quicker to find out what is around you
Better mental state	Not frustrating
Better mental state	Or use trail & error
Better mental state	Quicker
Better mental state	Quicker travel
Better mental state	Saves time
Better mental state	Secure
Better mental state	Travel more unencumbered

Category	177 responses
Better mental state	Very high traveling confidence
Better mental state	"It's the difference between a walk in the park & a walk on a treadmill facing a wall"
Better mental state	Was not distracted by noise & movement
Better mental state	Just knowing they exist helps travel
Don't have to count or feel	Didn't have to count
Don't have to count or feel	Didn't have to count doors
Don't have to count or feel	Didn't have to count doors
Don't have to count or feel	Didn't have to count to find doors
Don't have to count or feel	Didn't have to feel
Don't have to count or feel	Didn't have to feel dirty walls & counters
Don't have to count or feel	Didn't have to grope
Don't have to count or feel	Or count doors
Discovery of new locations	Found locations I didn't know were there
Discovery of new locations	Found stuff I wasn't looking for
Discovery of new locations	Found stuff I wouldn't have asked for
Discovery of new locations	Found things i didn't know
Discovery of new locations	Learned what was sold even though not looking for it
Gave direct path to locations	Able to find direct path to vendors
Gave direct path to locations	Could align to what's across from doors
Gave direct path to locations	Easy to line up and go to it
Gave direct path to locations	Help get precise line of travel
Gave direct path to locations	Knew which direction I was to go
Gave direct path to locations	Took me exactly to locations
Gave direct path to locations	Veering was easy to fix
Gave direct path to locations	Went direct to what I wanted
Gave direct path to locations	Shorter distance
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask

Category	**177 responses**
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Didn't have to ask
increased independence, no asking	Don't have to ask
increased independence, no asking	Don't have to ask
increased independence, no asking	Don't have to ask
increased independence, no asking	Don't have to find and ask people
increased independence, no asking	Don't have to find people
increased independence, no asking	Independent
increased independence, no asking	Independent
increased independence, no asking	More independent
increased independence, no asking	More independent
increased independence, no asking	More independent
increased independence, no asking	More independent
increased independence, no asking	No asking
increased independence, no asking	Or have sighted guide
increased independence, no asking	Self esteem
increased independence, no asking	Would have had to ask
increased independence, no asking	Would have had to ask for help
increased independence, no asking	Would have wanted a sighted guide
increased independence, no asking	Wouldn't have to ask
increased independence, no asking	Didn’t have to ask
increased independence, no asking	Ask for help
increased independence, no asking	Avoid bad directions (by others)
increased independence, no asking	Didn't have to stand in line to get assistance
increased independence, no asking	People don't give clear directions
Increased knowledge of spatial relationships	Much quicker to get idea where things are
Increased knowledge of spatial relationships	Able to associate features with others
Increased knowledge of spatial relationships	Able to use other points to find & locate amenities
Increased knowledge of spatial	Able to use reference points

Category	177 responses
relationships	
Increased knowledge of spatial relationships	Better sense of spatial relationships
Increased knowledge of spatial relationships	Can use interior space
Increased knowledge of spatial relationships	Could learn better
Increased knowledge of spatial relationships	Could learn spatial layout & orientation
Increased knowledge of spatial relationships	Didn't have to accumulate knowledge
Increased knowledge of spatial relationships	Didn't have to memorize
Increased knowledge of spatial relationships	Didn't have to re-orient
Increased knowledge of spatial relationships	Didn't have to shoreline
Increased knowledge of spatial relationships	Direction cues for orientation
Increased knowledge of spatial relationships	Don't have to stay close to walls
Increased knowledge of spatial relationships	Explains layout
Increased knowledge of spatial relationships	Gave spatial orientation
Increased knowledge of spatial relationships	Gives clearer mental map
Increased knowledge of spatial relationships	Gives spatial info
Increased knowledge of spatial relationships	Got orientation
Increased knowledge of spatial relationships	Had a clear spatial orientation
Increased knowledge of spatial relationships	Helped to learn spatial relationships
Increased knowledge of spatial relationships	Helps construct mental maps
Increased knowledge of spatial relationships	Helps me learn more spatial knowledge
Increased knowledge of spatial relationships	Increased spatial orientation
Increased knowledge of spatial relationships	Knew what was nearby without walking
Increased knowledge of spatial relationships	Knew where I was & where I was going

Category	177 responses
Increased knowledge of spatial relationships	Label cues for orientation
Increased knowledge of spatial relationships	More detailed spatial orientation
Increased knowledge of spatial relationships	More finite spatial orientation
Increased knowledge of spatial relationships	More helpful for orientation to streets & tracks
Increased knowledge of spatial relationships	Spatial relationships
Increased knowledge of spatial relationships	Understand relationships
Increased knowledge of spatial relationships	Can make shortcuts
Increased knowledge of spatial relationships	Concentrate on hazard & safety instead of spatial configuration & orientation
Increased knowledge of spatial relationships	Could explore better
Increased knowledge of spatial relationships	Knew which side of building I was in
Increased knowledge of spatial relationships	Learn more than from O & M training
Increased knowledge of spatial relationships	Nice to know what is around me
Increased knowledge of spatial relationships	Scan and orient
Increased knowledge of spatial relationships	Was able to have more options
Positive identification of locations	(know) place I was at
Positive identification of locations	Able to find platform
Positive identification of locations	Able to pinpoint locations without moving
Positive identification of locations	Able to quickly locate & use amenities
Positive identification of locations	Can find landmarks without going there
Positive identification of locations	Can go right to track or location rather than counting
Positive identification of locations	Could tell things from a distance
Positive identification of locations	Didn't have to get up close trying to read signs
Positive identification of locations	Didn't have to guess
Positive identification of locations	Didn't know they (doors) were in pairs
Positive identification of locations	Don't have to search for landmarks
Positive identification of locations	Easier to find locations
Positive identification of locations	Easy to find right bathroom

Category	177 responses
Positive identification of locations	Easy to find right track door
Positive identification of locations	Easy to know track #
Positive identification of locations	Gave positive ID
Positive identification of locations	Great help in finding gate #'s
Positive identification of locations	Had positive ID
Positive identification of locations	ID's the counters
Positive identification of locations	ID's the doors
Positive identification of locations	Knew amenities were in same room
Positive identification of locations	Knew what was around by scanning
Positive identification of locations	Knew what was flowers
Positive identification of locations	Knew where exits lead to
Positive identification of locations	Knew where facing
Positive identification of locations	Knew where things were
Positive identification of locations	Know quickly when you're close
Positive identification of locations	Know where to go
Positive identification of locations	Know which street I exit to
Positive identification of locations	Label
Positive identification of locations	Locations
Positive identification of locations	Much info about building
Positive identification of locations	New locations
Positive identification of locations	Tells where it's at
Positive identification of locations	They tell where it is
Positive identification of locations	Very helpful to find doors
Positive identification of locations	Was able to find exit easier
Positive identification of locations	Could know which door
Positive identification of locations	Got specific info
Positive identification of locations	I can point & get info instead of someone else moving my hand with no logical sequence
Positive identification of locations	Immediate access to info
Positive identification of locations	Instant feedback
Positive identification of locations	Like "looking around"
Positive identification of locations	Very specific info on where I was
Positive identification of locations	Didn't have to worry about using my limited vision
Positive identification of locations	Learn more detail

APPENDIX 18: Comments about Transfer Differences

Question: "Think about the transfers we made between different modes of transit. What was different from your regular method when using TS?"

Ss #	Response
1	Knew which bus stop you were at, knew which platform you were at, you're not sure when people tell you
2	Tells you where you are, easy to find places, don't have to ask, don't have to wait for people, gives instructions
3	More comfortable, didn't have to ask people, more independent, a lot faster
4	Could find bus stop easier, didn't have to get up close, would have missed Muni, knew how & where to find fare machine,
5	Tells where I am at, more easy, gives orientation
6	Helped to identify entrance, helped to identify fare box, easier to cross street, easy to find bus stop, didn't have to ask
7	Takes you to right locations, easy to find right doors
8	Able to do it independent, quicker, positive ID, confident I will find locations, self-assured
9	Knew which bus was there, easy to find transfers, no guess, defines areas, gives boarding direction, could find fare machine, knew which train to catch
10	Alleviates stress of finding someone to answer questions accurately, found bus stop quicker & easier, found phone quicker & easier, clarified correct locations, ID correct vehicle or mode, takes away anxiety of rushing to bus or pole, without TS wasn't sure, had to ask & got wrong info
11	Usually waste SO much time, TS helped me navigate quicker, can go to unfamiliar areas & navigate efficiently, TS helps make travel & transfers quickly & safely, don't have to ask, or deal with strangers, feel more independent, self-sufficient
12	Knew which way to go for Muni train, no 50/50 guess, told me where bus stops was, cardinal direction, TS located taxi stand, easy to find track doors, led me right there, ID right track, ID bus routes, knew where to get Muni ticket, right platform
13	Know where you are, confirms direction, know where bus stop is, know what bus stops there, confirms all spatial info, hell of a lot easier, confirms which direction transit runs
14	Knew where things were, where to turn for entrance, which buses stop at stop, don't miss locations and have to retrace, easier, more fluid, more confident, less stress, get good spatial layout, helps mental state

Ss #	Response
15	Told me where fare machine was, bus was, knew which way to go, help find taxi, knew which direction to leave station, knew exactly where bus stop is, which bus stops there, saves time, don't wander around, feel at ease, secure, had fun, makes travel simpler
16	Much easier, less hit & miss, better mental map, likes not having to ask for help
17	Easier, quicker, more confident
18	Faster, tells where it is
19	Instant access to locations, instant access to information
20	Was able to visit a variety of locations instead of only necessary ones, know when I've passed the bus stop or entrance, not just relying on physical landmarks, able to find new locations like ticket machine
21	Didn't have to ask, felt safer
22	Know where transfer points are, TS gives advance knowledge, pinpoints locations, less frustrating, positive ID, confirmation, able to find fare box & change machine to make transfers easier, gives specificity
23	Didn't' have to ask questions, more efficient, didn't need guidance, felt independent, more confidence, felt worthwhile, felt equal to sighted people
24	Didn't have to ask, TS gives relationships
25	Didn't have to ask, could do it on my own, saved time, could travel easier, gave me bus # of shelter so I could find it easy, cuts out the middleman
26	Would not have known Muni was there without TS, knew where ticket machine was, knew where bus stop was, knew info from a distance
27	Could not have found cab stand without TS, more sure of my choices, didn't have to always remember, gives me info I would not have had, ID's bus stop and other transit
28	I could easily find modes on my own, didn't have to ask & hope it's right, felt secure to do it, able to find various locations in a timely manner, wouldn't miss connections, didn't have to ask, felt independent, would not have done it on my own, assured of correct info, wouldn't have known where cab stand was, didn't have to get escort, knew where bus was located would not have known, learned that phones were in bus shelters
29	When you ask people for directions you can get close enough to use TS, didn't have to ask many people, opens up the world to independent travel, can find exact locations, don't have to guess, ID's bus stop. ID's where you are, know exact pole or gate to wait at, no missed connections, ID's bus #'s that stop
30	Can expand your usage of different modes, knew direction, street names, what was on other side (of street), more beneficial, told me what bus stops at platform, saves much time, saves agony & frustration

APPENDIX 19: Categorization of Transfer Differences

Question: "Think about the transfers we made between different modes of transit. What was different from your regular method when using TS?"

Category	176 Responses
Identifies locations, bus stop	Knew where bus was
Identifies locations, bus stop	Could find bus stop easier
Identifies locations, bus stop	Easy to find bus stop
Identifies locations, bus stop	Found bus stop quicker & easier
Identifies locations, bus stop	Gave me bus # of shelter so I could find it easy
Identifies locations, bus stop	ID bus routes
Identifies locations, bus stop	ID's bus #'s that stop
Identifies locations, bus stop	ID's bus stop and other transit
Identifies locations, bus stop	ID's bus stop
Identifies locations, bus stop	Knew exactly where bus stop is
Identifies locations, bus stop	Knew where bus stop was
Identifies locations, bus stop	Knew where bus was located would not have known
Identifies locations, bus stop	Knew which bus stop you were at
Identifies locations, bus stop	Knew which bus was there
Identifies locations, bus stop	Know what bus stops there
Identifies locations, bus stop	Know where bus stop is
Identifies locations, bus stop	Takes away anxiety of rushing to bus or pole
Identifies locations, bus stop	Told me what bus stops at platform
Identifies locations, bus stop	Told me where bus stops was
Identifies locations, bus stop	Which bus stops there
Identifies locations, bus stop	Which buses stop at stop
Identifies locations, bus stop	Know when i've passed the bus stop
Identifies locations, doors and platforms	Easy to find right doors
Identifies locations, doors and platforms	Easy to find track doors
Identifies locations, doors and platforms	Helped to identify entrance

Category	176 Responses
Identifies locations, doors and platforms	ID right track
Identifies locations, doors and platforms	Know exact pole or gate to wait at
Identifies locations, doors and platforms	Would have missed Muni
Identifies locations, doors and platforms	Would not have known Muni was there without TS
Identifies locations, doors and platforms	Knew which platform you were at
Identifies locations, doors and platforms	Knew which train to catch
Identifies locations, doors and platforms	Right platform
Identifies locations, doors and platforms	Where to turn for entrance
Identifies locations, doors and platforms	Know when i've passed the entrance
Identifies locations, fare machine	Able to find fare box & change machine to make transfers easier
Identifies locations, fare machine	Could find fare machine
Identifies locations, fare machine	Helped to identify fare box
Identifies locations, fare machine	Knew how & where to find fare machine
Identifies locations, fare machine	Knew where ticket machine was
Identifies locations, fare machine	Knew where to get Muni ticket
Identifies locations, fare machine	Told me where fare machine was
Identifies locations, fare machine	Able to find new locations like ticket machine
Identifies locations, general information	Gives instructions
Identifies locations, general information	Gives me info I would not have had
Identifies locations, general information	Gives specificity
Identifies locations, general information	Instant access to information
Identifies locations, general information	Knew info from a distance
Identifies locations, general information	TS gives advance knowledge
Identifies locations, general information	Can find exact locations

Category	176 Responses
Identifies locations, general information	Clarified correct locations
Identifies locations, general information	Confident I will find locations
Identifies locations, general information	Confirmation
Identifies locations, general information	Confirms all spatial info
Identifies locations, general information	Easy to find places
Identifies locations, general information	ID's where you are
Identifies locations, general information	Instant access to locations
Identifies locations, general information	Knew where things were
Identifies locations, general information	Know where you are
Identifies locations, general information	Pinpoints locations
Identifies locations, general information	Positive ID
Identifies locations, general information	Positive ID
Identifies locations, general information	Takes you to right locations
Identifies locations, general information	Tells where I am at
Identifies locations, general information	Tells where it is
Identifies locations, general information	Tells you where you are
Identifies locations, general information	ID correct vehicle or mode
Identifies locations, general information	What was on other side (of street)
Identifies locations, phone	Found phone quicker & easier
Identifies locations, phone	Learned that phones were in bus shelters
Identifies locations, street names	Street names
Identifies locations, street names	Street names
Identifies locations, taxi stand	Could not have found cab stand without TS
Identifies locations, taxi stand	Help find taxi

Category	176 Responses
Identifies locations, taxi stand	TS located taxi stand
Identifies locations, taxi stand	Wouldn't have known where cab stand was
Increases independence	Able to do it independent
Increases independence	Could do it on my own
Increases independence	Cuts out the middleman
Increases independence	Didn't have to ask
Increases independence	Didn't have to ask
Increases independence	Didn't have to ask
Increases independence	Didn't have to ask
Increases independence	Didn't have to ask
Increases independence	Didn't have to ask & hope it's right
Increases independence	Didn't have to ask many people
Increases independence	Didn't have to ask people
Increases independence	Didn't't' have to ask questions
Increases independence	Didn't need guidance
Increases independence	Don't have to ask
Increases independence	Don't have to ask
Increases independence	Don't have to wait for people
Increases independence	Feel more independent
Increases independence	Felt independent
Increases independence	Felt independent
Increases independence	Had to ask & got wrong info
Increases independence	I could easily find modes on my own
Increases independence	Likes not having to ask for help
Increases independence	More independent
Increases independence	Opens up the world to independent travel
Increases independence	Or deal with strangers
Increases independence	Self-sufficient
Increases independence	Would not have done it on my own
Increases spatial orientation	Better mental map
Increases spatial orientation	Get good spatial layout
Increases spatial orientation	Gives orientation
Increases spatial orientation	TS gives relationships
Increases spatial orientation	Defines areas
Improves mental state	Easier to cross street
Improves mental state	Assured of correct info

Category	176 Responses
Improves mental state	Felt safer
Improves mental state	No 50/50 guess
Improves mental state	No guess
Improves mental state	Feel at ease
Improves mental state	Felt equal to sighted people
Improves mental state	Felt secure to do it
Improves mental state	Felt worthwhile
Improves mental state	Hell of a lot easier
Improves mental state	Helps mental state
Improves mental state	Less frustrating
Improves mental state	Less stress
Improves mental state	More comfortable
Improves mental state	More confidence
Improves mental state	More confident
Improves mental state	More confident
Improves mental state	More easy
Improves mental state	More efficient
Improves mental state	More sure of my choices
Improves mental state	Much easier
Improves mental state	Saves agony & frustration
Improves mental state	Secure
Improves mental state	Self-assured
more efficient travel	A lot faster
more efficient travel	Able to find various locations in a timely manner
more efficient travel	Alleviates stress of finding someone to answer questions accurately
more efficient travel	Can go to unfamiliar areas & navigate efficiently
more efficient travel	Could travel easier
more efficient travel	Didn't have to always remember
more efficient travel	Didn't have to get up close
more efficient travel	Don't have to guess
more efficient travel	Don't miss locations and have to retrace
more efficient travel	Don't wander around
more efficient travel	Easier
more efficient travel	Easier
more efficient travel	Easy to find transfers

Category	176 Responses
more efficient travel	Faster
more efficient travel	Had fun
more efficient travel	Less hit & miss
more efficient travel	More beneficial
more efficient travel	More fluid
more efficient travel	Quicker
more efficient travel	Quicker
more efficient travel	Saved time
more efficient travel	Saves much time
more efficient travel	Saves time
more efficient travel	TS helped me navigate quicker
more efficient travel	TS helps make travel & transfers quickly & safely
more efficient travel	Usually waste SO much time
more efficient travel	Without TS wasn't sure
more efficient travel	Know where transfer points are
more efficient travel	No missed connections
more efficient travel	Wouldn't miss connections
more efficient travel	Can expand your usage of different modes
more efficient travel	Not just relying on physical landmarks
more efficient travel	Can expand your usage of different modes
more efficient travel	Was able to visit a variety of locations instead of only necessary ones
more efficient travel	You're not sure when people tell you
spatial information, directions	Cardinal direction
spatial information, directions	Confirms direction
spatial information, directions	Confirms which direction transit runs
spatial information, directions	Gives boarding direction
spatial information, directions	Knew direction
spatial information, directions	Knew which direction to leave station
spatial information, directions	Knew which way to go
spatial information, directions	Knew which way to go for MOON train
spatial information, directions	Led me right there
spatial information, directions	When you ask people for directions you can get close enough to use TS

APPENDIX 20: Comments about RIAS Affect on Travel Behavior

Question: "If TS were installed citywide on transit, intersections, signs and buildings, how would they affect your travel?"

Ss #	Response
1	More independent, don't have to ask, better understand new environments, if lost can better figure out where you are
2	Travel more, more confident, easier, faster
3	Travel more places, more independent, wouldn't get lost as much, feels safer
4	Easier to find location, don't have to ask, quicker, more confident
5	More independent, travel more often, saves time
6	More confident, reduces uncertainty, get info in timely fashion, would go to new destinations
7	Easier to travel, find things quicker, more at ease, more confident
8	Makes transfer easier, more places, more confident, felt safer, quicker, wouldn't be late so often
9	Travel more, more spontaneous, adds certainty to spatial orientation, more ease of mind
10	Alleviate anxiety of unfamiliar places, more confidence, more self-esteem, independence, enhance my ability to function at maximum, safer travel, reduce my family's fear & anxiety
11	Increased safety, independence, knowledge of the environment, don't have to remember all details, more enjoyable travel, wouldn't hesitate to travel, go more places
12	Make better choices, make unfamiliar places easier to find, would travel more, I could be an example for my students to travel more, more confident, more independent
13	Wouldn't have to preplan as much, more spontaneous, gave me freedom, would know what was around, travel whenever I wanted, travel without assistance, more independently, more confidence, less stress, would be great, independent
14	Travel more, less fear, less confusion, know where you are, more relaxed, less inhibition for travel
15	More confident, more safe & secure, would know spatial layout better, would travel more, would have more fun, instant feedback, more quickly

Ss #	Response
16	Travel more, go to new places, less anxiety, learn city faster, more options for jobs and housing, more enjoyment to travel
17	Easier, faster, more independent
18	Would know where things are, wouldn't have to ask
19	Could make informed decisions, would travel more, independent
20	More frequent trips, go to unfamiliar places, larger range of activities, larger space & further, could comparison shop, rely less on others, could get jobs in wider area, willing to use multiple modes of transit
21	Easier to orient myself, would know what street I'm on
22	Could go to 20-30 more places per year, more independent, travel time cut in half, more confidence, less frustration
23	Saves time, more convenient, would be free to travel more, more confidence
24	More effective travel, great for new places
25	Much easier, safer, more willing to travel, don't need sighted guide, wouldn't have to practice before going, increases self-esteem, travel more often
26	Increase my travel, ease my anxiety about travel, more simple, greatly improve my state of mind
27	Much less stressful, don't have to ask for assistance, more independent travel, saves time, could make more complicated trips, more trips to new locations
28	Travel more, more spontaneous, more relaxed, significantly higher level of confidence, less fearful, less vulnerable
29	Greatly increase my travel, more & different places, not boring, would make travel much more interesting, makes me want to go out much more, broaden my horizons
30	Decrease travel time, decrease travel cost, less time spent, increase desire to travel, more confident, safer, would explore new environments

APPENDIX 21: Categorization of RIAS Affect on Travel Behavior

Question: "If TS were installed citywide on transit, intersections, signs and buildings, how would they affect your travel?"

Category	152 responses
Improves mental state	Alleviate anxiety of unfamiliar places
Improves mental state	Ease my anxiety about travel
Improves mental state	Feels safer
Improves mental state	Felt safer
Improves mental state	Greatly improve my state of mind
Improves mental state	Increased safety
Improves mental state	Increases self-esteem
Improves mental state	Less anxiety
Improves mental state	Less confusion
Improves mental state	Less fear
Improves mental state	Less fearful
Improves mental state	Less frustration
Improves mental state	Less inhibition for travel
Improves mental state	Less stress
Improves mental state	Less vulnerable
Improves mental state	More at ease
Improves mental state	More confidence
Improves mental state	More confidence
Improves mental state	More confidence
Improves mental state	More confidence
Improves mental state	More confident
Improves mental state	More confident
Improves mental state	More confident
Improves mental state	More confident
Improves mental state	More confident
Improves mental state	More confident
Improves mental state	More confident

Category	152 responses
Improves mental state	More confident
Improves mental state	More convenient
Improves mental state	More ease of mind
Improves mental state	More enjoyable travel
Improves mental state	More enjoyment to travel
Improves mental state	More relaxed
Improves mental state	More relaxed
Improves mental state	More safe & secure
Improves mental state	More self-esteem
Improves mental state	Much less stressful
Improves mental state	Not boring
Improves mental state	Reduce my family's fear & anxiety
Improves mental state	Reduces uncertainty
Improves mental state	Safer
Improves mental state	Safer
Improves mental state	Safer travel
Improves mental state	Significantly higher level of confidence
Improves mental state	Would have more fun
Improves mental state	Would make travel much more interesting
Increased independence	Don't have to ask
Increased independence	Don't have to ask
Increased independence	Don't have to ask for assistance
Increased independence	Don't need sighted guide
Increased independence	Gave me freedom
Increased independence	Independence
Increased independence	Independence
Increased independence	Independent
Increased independence	Independent
Increased independence	More independent
Increased independence	More independent
Increased independence	More independent
Increased independence	More independent
Increased independence	More independent
Increased independence	More independent
Increased independence	More independent travel
Increased independence	More independently

Category	152 responses
Increased independence	Rely less on others
Increased independence	Travel without assistance
Increased independence	Wouldn't have to ask
Increases spatial orientation	Adds certainty to spatial orientation
Increases spatial orientation	Better understand new environments
Increases spatial orientation	Easier to find location
Increases spatial orientation	Easier to orient myself
Increases spatial orientation	If lost can better figure out where you are
Increases spatial orientation	Know where you are
Increases spatial orientation	Knowledge of the environment
Increases spatial orientation	Would know spatial layout better
Increases spatial orientation	Would know what street I'm on
Increases spatial orientation	Would know what was around
Increases spatial orientation	Would know where things are
Increases spatial orientation	Wouldn't get lost as much
More efficient travel	Could make informed decisions
More efficient travel	Decrease travel cost
More efficient travel	Decrease travel time
More efficient travel	Don’t have to remember all details
More efficient travel	Easier
More efficient travel	Easier
More efficient travel	Easier to travel
More efficient travel	Enhance my ability to function at maximum
More efficient travel	Faster
More efficient travel	Faster
More efficient travel	Find things quicker
More efficient travel	Get info in timely fashion
More efficient travel	Instant feedback
More efficient travel	Learn city faster
More efficient travel	Less time spent
More efficient travel	Make better choices
More efficient travel	Makes transfer easier
More efficient travel	More effective travel
More efficient travel	More quickly
More efficient travel	More simple
More efficient travel	Much easier

Category	152 responses
More efficient travel	Quicker
More efficient travel	Quicker
More efficient travel	Saves time
More efficient travel	Saves time
More efficient travel	Saves time
More efficient travel	Travel time cut in half
More efficient travel	Would be great
More efficient travel	Wouldn't be late so often
More efficient travel	Wouldn't have to practice before going
More efficient travel	Wouldn't have to preplan as much
More efficient travel	Wouldn't hesitate to travel
Travel more often	Greatly increase my travel
Travel more often	I could be an example for my students to travel more
Travel more often	Increase desire to travel
Travel more often	Increase my travel
Travel more often	Makes me want to go out much more
Travel more often	More frequent trips
Travel more often	More spontaneous
Travel more often	More spontaneous
Travel more often	More spontaneous
Travel more often	More willing to travel
Travel more often	Travel more
Travel more often	Travel more
Travel more often	Travel more
Travel more often	Travel more
Travel more often	Travel more
Travel more often	Travel more often
Travel more often	Travel more often
Travel more often	Travel whenever I wanted
Travel more often	Would be free to travel more
Travel more often	Would travel more
Travel more often	Would travel more
Travel more often	Would travel more
Travel to more places	Broaden my horizons
Travel to more places	Could comparison shop

Category	152 responses
Travel to more places	Could get jobs in wider area
Travel to more places	Could go to 20-30 more places per year
Travel to more places	Could make more complicated trips
Travel to more places	Go more places
Travel to more places	Go to new places
Travel to more places	Go to unfamiliar places
Travel to more places	Great for new places
Travel to more places	Larger range of activities
Travel to more places	Larger space & further
Travel to more places	Make unfamiliar places easier to find
Travel to more places	More & different places
Travel to more places	More options for jobs and housing
Travel to more places	More places
Travel to more places	More trips to new locations
Travel to more places	Travel more places
Travel to more places	Willing to use multiple modes of transit
Travel to more places	Would explore new environments
Travel to more places	Would go to new destinations

APPENDIX 22: Comments about Opinion of RIAS

Question: "What is your overall opinion of Talking Signs?"

Ss #	Response
1	Helpful, know where you are
2	Don't have to ask others, pretty good, needed for blind travelers
3	Great, wonderful, helpful
4	Should be installed all over, really needed, would make travel easier, make travel safer, never would get lost
5	Great help for blind, able to find more information, know where you're at, helps find transit, I'm impressed
6	Very useful but don't ignore normal cues; it's unobtrusive so public should like
7	Pretty good device, helpful, makes life a lot easier
8	Great invention for blind travel
9	Very good for blind, vision-impaired, dyslexic, learning differences & developmentally disabled
10	Very helpful for independent travel, non-intrusive device to provide visual info for blind & vision-impaired, safer, confident, independent, financial benefits, less accidents & fatalities
11	They're great, (I am) very supportive, want them installed all over
12	Represents a major breakthrough, independent travel for blind & vision-impaired
13	Should be installed where there are signs, I love them, want them, very helpful, needed wayfinding tool
14	Good, make travel easy, gives good info, hope they are installed universally
15	Love them, very useful, great tool for vision-impaired, should be involved per ADA
16	Very good, needs lots of user input, likes getting angle of intersection, wants more
17	Should be installed everywhere, they are cool, they make travel easier, more independent, don't have to rely on others, don't get lost
18	Good, better for those with no vision, likes them at bathrooms, street crossings, bus stop
19	Excellent system, needs fine tuning

Ss #	Response
20	Simple & eloquent solution to the problems of blind, independence, important to have more TS installed, should be in malls
21	Pretty good, needs input from users
22	Increases independence dramatically, provides new info about unfamiliar locations, can find out about things you wouldn't normally find, saves time locating hard to find places, not asking for help
23	It's great for blind travelers, make you socially able to live like a sighted person
24	Really like it, love the street sign information, helps make for more effective travel
25	They are absolutely great, endorse city-wide installation
26	Very positive, was apprehensive at first, very helpful, would use it many times a day, love the block # info
27	Extremely important tool for access to the environment
28	Awesome, provides equality, provides safety, confidence, hell of a lot less stress
29	Great if installed all over, greatly enhances vision-impaired to become productive
30	Great, the public needs it, could benefit everyone sighted also

APPENDIX 23: Categorization of Opinion of RIAS

Question: "What is your overall opinion of Talking Signs?"

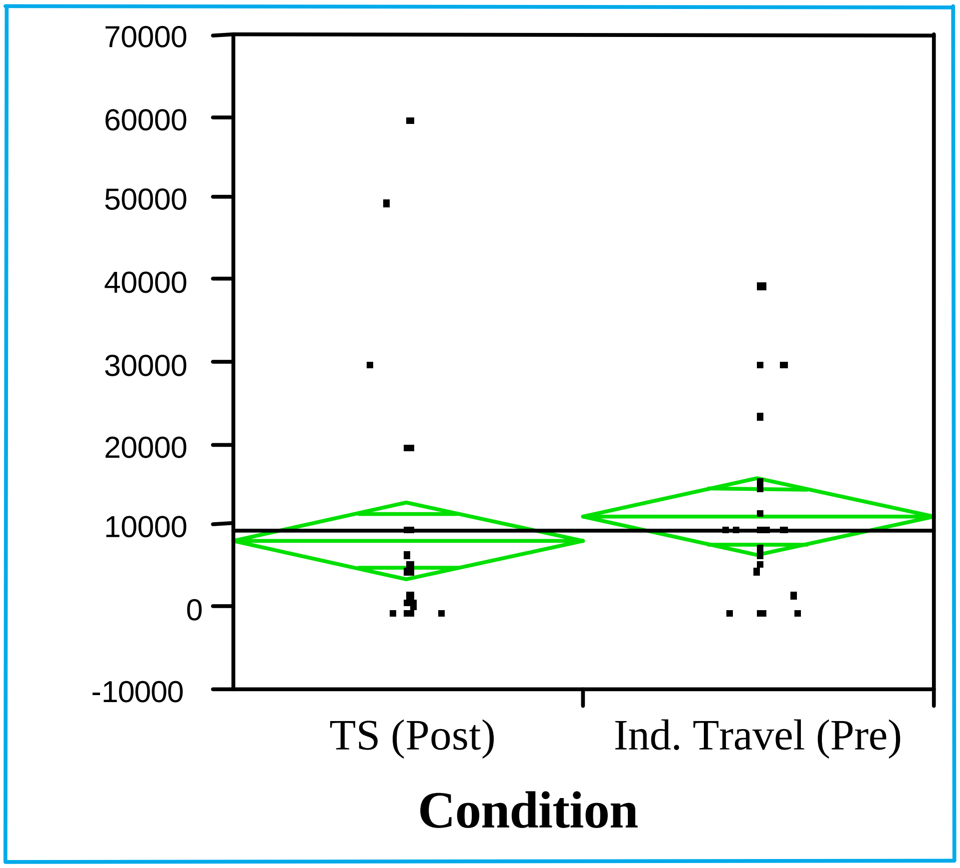
Category	104 responses
General Superlatives	(I am) very supportive
General Superlatives	Awesome
General Superlatives	Better for those with no vision
General Superlatives	Could benefit everyone sighted also
General Superlatives	(Good for) dyslexic
General Superlatives	Excellent system
General Superlatives	Extremely important tool for access to the environment
General Superlatives	Financial benefits
General Superlatives	Good
General Superlatives	Good
General Superlatives	Great
General Superlatives	Great
General Superlatives	Great help for blind
General Superlatives	Great invention for blind travel
General Superlatives	Great tool for vision-impaired
General Superlatives	Greatly enhances vision-impaired to become productive
General Superlatives	Helpful
General Superlatives	Helpful
General Superlatives	Helpful
General Superlatives	I love them
General Superlatives	I'm impressed
General Superlatives	It's great for blind travelers
General Superlatives	It's unobtrusive so public should like
General Superlatives	Love them
General Superlatives	Pretty good
General Superlatives	Pretty good
General Superlatives	Pretty good device
General Superlatives	Really like it
General Superlatives	Represents a major breakthrough

Category	104 responses
General Superlatives	Simple & eloquent solution to the problems of blind
General Superlatives	They are absolutely great
General Superlatives	They are cool
General Superlatives	They're great
General Superlatives	Very good
General Superlatives	Very good for blind
General Superlatives	Very helpful
General Superlatives	Very helpful
General Superlatives	Very positive
General Superlatives	Very useful
General Superlatives	Very useful but don't ignore normal cues
General Superlatives	(Good for) vision-impaired
General Superlatives	Was apprehensive at first
General Superlatives	Wonderful
General Superlatives	Would use it many times a day
General Superlatives	(Good for) learning differences & developmentally disabled
Improved mental state	Confidence
Improved mental state	Confident
Improved mental state	Hell of a lot less stress
Improved mental state	Helps make for more effective travel
Improved mental state	Less accidents & fatalities
Improved mental state	Make travel easy
Improved mental state	Make travel safer
Improved mental state	Make you socially able to live like a sighted person
Improved mental state	Makes life a lot easier
Improved mental state	Provides equality
Improved mental state	Provides safety
Improved mental state	Safer
Improved mental state	They make travel easier
Improved mental state	Would make travel easier
Increases independence	Don't have to ask others
Increases independence	Don't have to rely on others
Increases independence	Increases independence dramatically
Increases independence	Independence
Increases independence	Independent
Increases independence	Independent travel for blind & vision-impaired

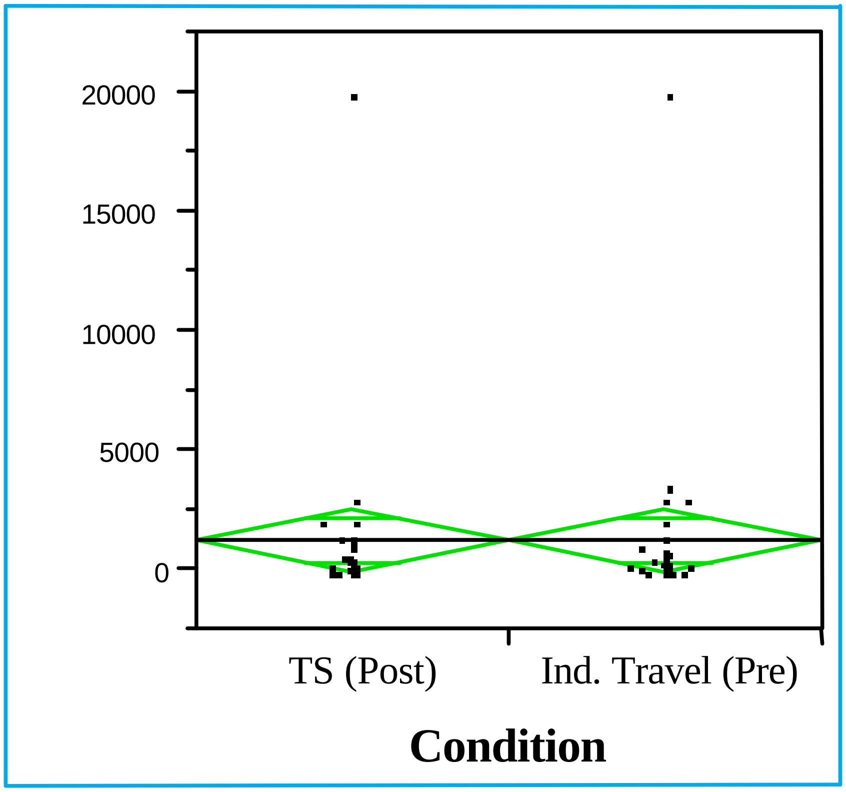
Category	104 responses
Increases independence	More independent
Increases independence	(Like) not asking for help
Increases independence	Very helpful for independent travel
Should be installed	Endorse city-wide installation
Should be installed	Great if installed all over
Should be installed	Hope they are installed universally
Should be installed	Important to have more TS installed
Should be installed	Needed for blind travelers
Should be installed	Really needed
Should be installed	Should be in malls
Should be installed	Should be installed everywhere
Should be installed	Should be installed where there are signs
Should be installed	Should be installed all over
Should be installed	Should be involved per ADA
Should be installed	The public needs it
Should be installed	Want them
Should be installed	Want them installed all over
Should be installed	Wants more
Spatial orientation aid	Able to find more information
Spatial orientation aid	Can find out about things you wouldn't normally find
Spatial orientation aid	Don't get lost
Spatial orientation aid	Gives good info
Spatial orientation aid	Helps find transit
Spatial orientation aid	Know where you are
Spatial orientation aid	Know where you're at
Spatial orientation aid	Needed wayfinding tool
Spatial orientation aid	Never would get lost
Spatial orientation aid	Non-intrusive device to provide visual info for blind & vision-impaired
Spatial orientation aid	Provides new info about unfamiliar locations
Spatial orientation aid	Saves time locating hard to find places
Specific places	Bus stop
Specific places	Likes getting angle of intersection
Specific places	Likes them at bathrooms
Specific places	Love the block # info
Specific places	Love the street sign information

Category	104 responses
Specific places	Street crossings
Suggestions	Needs fine tuning
Suggestions	Needs input from users
Suggestions	Needs lots of user input

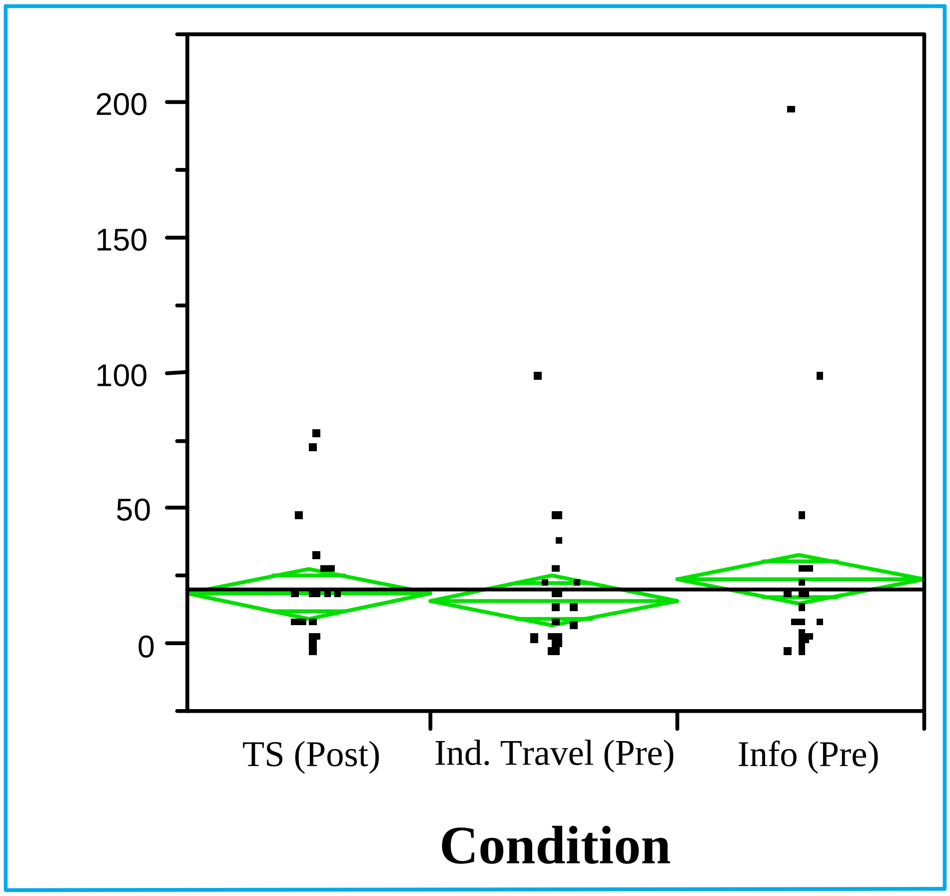
APPENDIX 24: Data Plot of Estimated Additional Earnings



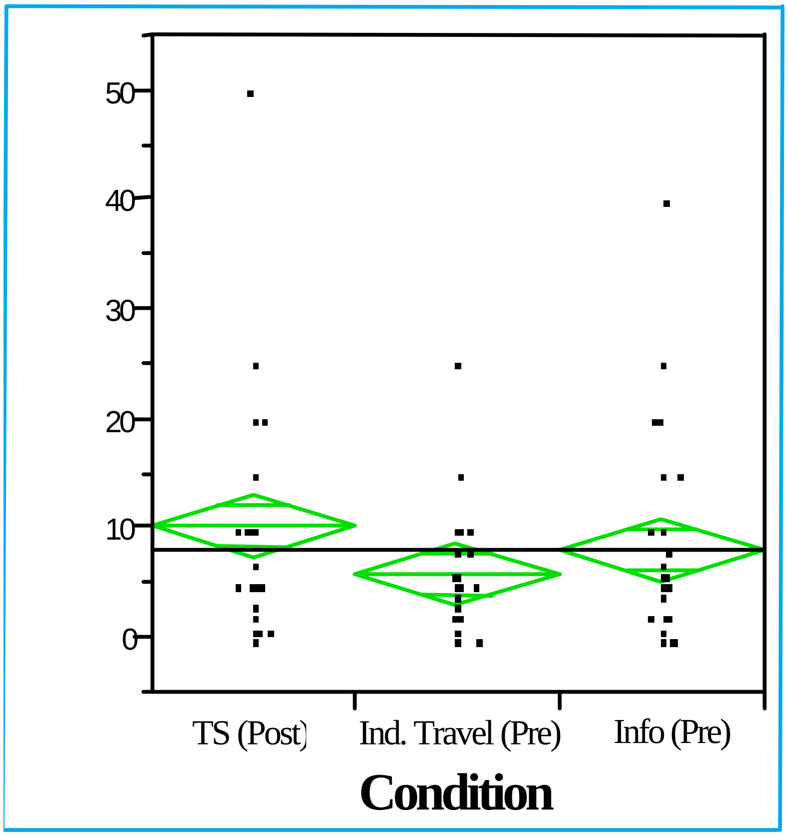
APPENDIX 25: Data Plot of Estimated Savings for Travel Assistance



APPENDIX 26: Data Plot of Offer to Pay, Independent Travel To a One-Time Event.



APPENDIX 27: Data Plot of Offer to Pay, Independent Travel To a Daily Job.



APPENDIX 28: Data Plot of Offer to Pay, Daily Use of RIAS