14. M. E. More, *The Effect of Interpretation on Visitor Learning and Activity Choices in Natural Areas*, unpublished doctoral dissertation, University of Massachusetts, Department of Forestry, 1978.
15. J. Larkin, Interim Center Village Research Report, Old Sturbridge Village, (xerox), 1978.
16. D. G. Hayward and J. W. Larkin, Evaluating Visitor Experiences and Exhibit Effectiveness at Old Sturbridge Village, *Museum Studies Journal, 1*:2, pp. 42-51, 1983.
17. D. G. Hayward and A. D. Jensen, Enhancing a Sense of the Past: Perceptions of Visitors and Interpreters, *The Interpreter, 12*:2, pp. 4-12, 1981.
18. M. L. Brydon-Miller, An Evaluation of the Impact of Visitor Orientation Procedures at Old Sturbridge Village, Masters Thesis in Psychology, University of Massachusetts, 1980.
19. H. A. Parker, W. B. Gudykunst, W. I. Kantor, and J. A. Morra, Leisure Activities of Non-Visitors, Visitors and Friends of Old Sturbridge Village: A Preliminary Report, University of Hartford, Institute for Social Research, unpublished manuscript, 29 pp., 1978.
20. R. F. Washburne and J. A. Wagar, Evaluating Visitor Response to Exhibit Content, *Curator, 15*:3, pp. 248-254, 1972.

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WAYFINDING AND ORIENTATION BY THE VISUALLY IMPAIRED

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ABSTRACT

This paper addresses wayfinding and orientation by visually impaired people. First, the characteristics of visually impaired people and several common orientation and mobility strategies are reviewed. Then, two research studies are discussed: In Study I an indoor test track was developed to explore what qualities of paving materials make them detectable by long cane users. Twenty-four visually impaired people were tested. It was found that the noise the cane made when it struck the surface was the best predictor of detectability. Study II was a field study in which sixteen subjects traversed a one-half mile (800 m) test route both before and after various countermeasures were added. It was found that six countermeasures improved the subjects' performances: wooden shoreline, tweeter, metal plates, wooden plate, rubber mats and carpet mats. Several problems and solutions are proposed.

Getting lost can be very stressful. Not only does it entail "real world" consequences of being late for an appointment or missing an airplane flight, it may often cause feelings of panic and discomfort and create serious psychological stress (see Zimring [1] for a review), and in fact several studies suggest that spatial disorientation may be partly responsible for increased deaths by older people immediately after they have been relocated [2]. Whereas spatial disorientation is serious for able-bodied, sighted people, it is particuarly serious for the visually impaired. Sighted people rely on a host of visual landmarks and may often see their objective; visually impaired people are denied these cues and may wander into traffic or other dangers.

This paper focuses on wayfinding and orientation by the visually impaired both because the visually impaired represent a population of significant size and because much can be learned from them about the sighted population. We will briefly consider the wayfinding and orientation needs of visually impaired people and will describe two recent studies carried out at the Architectural Research Laboratory at the Georgia Institute of Technology. Finally, several implications of this and other related work will be discussed.

CHARACTERISTICS OF VISUALLY IMPAIRED PEOPLE

Often, when blindness is discussed, the image is created of someone totally blind from birth. In fact, such an individual is in the minority among visually impaired people. Most visually impaired people have some usable vision and have lost their vision during adulthood. Some 6.4 million people in the U.S. are termed visually impaired; that is, even with corrective lenses their visual disability causes them difficulty in everyday life [3]. About 1.7 million of these are legally blind–they have poorer than 20/200 vision in their best eye using corrective lenses or less than a 20° cone of vision. Of the severely visually impaired, about 76 percent have usable vision.

The principal causes of visual impairment in the developed world are: diabetic retinopathy, cataracts, glaucoma, retinitis pigmentosa and macular degeneration [3]. These syndromes produce a variety of visual problems, including loss of peripheral vision, loss of foveal vision, loss of acuity, susceptibility to glare, and decreased ability to accommodate to changes in light levels. These are also diseases of aging; some 65 percent of severely visually impaired people are over sixty-five years of age and over 96 percent lost their vision after age twenty-five [3]. As a result, visual impairment is often accompanied by other age-related problems such as balance problems or limited mobility.

ORIENTATION AND MOBILITY

Two sets of skills are needed if visually impaired people are to successfully negotiate the environment [4]. First, they must know where things are in their environment. They must comprehend their own relationship to furniture, streets, building entrances, and at a larger scale, the layout of buildings and towns. This set of skills has been labeled *orientation.* Second, visually impaired people must be able to travel safely from place to place, avoid hazards and stay on their path. This second set of skills, which has been labeled *mobility*, requires the minute-to-minute use of environmental information that a visually impaired person gets from a long cane, dog guide, or other mobility aid. Orientation and mobility skills are related but distinct. For example, travelers may be good at orientation but have poor mobility skills: They may know where they are but have difficulty walking a straight path. More commonly, they have good mobility skills but poor orientation abilities: They may be able to negotiate the immediate environment with relative ease but have little conception of their location in a building or city.

A well-designed environment should support effective orientation and mobility: It should be clearly organized, free of hazards and present adequate information about location and direction.

ORIENTATION AND COGNITIVE MAPPING

Orientation is an important and sometimes difficult task for independent visually impaired travelers. Whereas sighted travelers in a building or a city have a surfeit of directional aids available such as tall landmarks, signs, and maps, visually impaired people often lack such visual clues. As a result they depend heavily on their mental image of the environment, their *cognitive map*, and whatever landmarks and cues are useful to them [1]. (A cognitive map is a mental representation of the environment. It is often idiosyncratic and may be distorted and personalized). Visually impaired people who are just getting to know a setting typically use a sequential strategy for finding their way [5]. For example, to get from an office to a restroom, a visually impaired person may not know the overall spatial relationship of the rooms, but may be able to find the way by following a memorized route from corridor to corridor. This strategy is similar to the type of instructions one gets when driving in an unfamiliar area– "go straight passing two traffic lights then turn left, turn right. . . ." This sort of sequential strategy emphasizes a string of landmarks, without providing the relationship between them.

Alternatively, a traveler may use a cognitive map that incorporates an understanding of the interrelationships between points in the environment [6]. For example, a visually impaired person walking to the restroom may understand that the building is H-shaped and may know where to go in the overall circulation plan of the building. Similarly, on the urban scale the traveler may simply follow a bus route from home to work, or may understand something about the organization of the city. In general, this interrelated strategy is built up over time. Many travelers begin by learning paths and landmarks, then build them into an integrated whole.

Mobility specialists teach an integrated strategy by encouraging visually impaired travelers to learn overall building forms, and to keep track of cardinal points–North, South, East and West [7]. In cities, travelers are encouraged to understand the city's street pattern, and to learn street names and spatial relationships. The cardinal points are used in cities as well, although in some cities with irregular streets this may be less useful.

The difference between using a sequential and a more integrated cognitive mapping strategy is in the flexibility the two strategies permit. Consider the problem with following sequential directions of the "go-ahead-two-stop-light" variety. When the instruction-giver has forgotten a turn, or when there is a detour, it is very easy to get lost. If the traveler knows a city well and understands the relationship between areas, it is easier to change the route when necessary.

MOBILITY AIDS AND STRATEGIES

Mobility Aids

The information a visually impaired person requires for safe mobility may come from a wide range of mobility aids. Most travelers classified as visually impaired use no aid at all. Although their visual acuity is limited, these travelers depend on what they can see and what they can detect through their feet or with their other senses. Some visually impaired travelers occasionally use a sighted guide, and will walk through a crowded restaurant or theater by lightly holding onto the elbow of the sighted individual. Others never travel independently at all and are guided everywhere by a sighted person.

A large group of visually impaired people use a long cane (also known as the Typho or Hoover cane). This cane, which is usually made of thin aluminum tubing, is used to sweep the area in front of the traveler. A systematic method is used: When the left foot is back, the cane touches in front of the left foot; then the right foot, and so on. Travelers are trained to sweep an area just as wide as their shoulders (24 inches or so), although most actually sweep an area of 42 inches or more [8]. A competent traveler can easily detect solid objects, such as stairs, curbs, walls, and trees. However, because the cane is held at waist level and is angled toward the ground, it cannot detect overhanging objects such as tree limbs. Indoors, the same techniques are generally used. But some people may use a diagonal cane technique where the cane is angled and held motionless in front of the body to prevent collisions.

A much smaller group of visually impaired people use dog guides. The potential group of dog guide users is limited for several reasons: Travelers using dogs need to be able to care for a dog, and temperamentally suited to the relationship; dogs walk quickly and travelers using them need to be in good condition and able to walk rapidly; travelers using dogs are usually expected to be totally blind, so that they don't react to something they see and pull one way while the dog is leading in another direction. Dog users are not as susceptible to problems caused by overhanging branches or guy wires as are cane travelers. However, because they do not touch the pavement with the sensitive cane, the information they receive about the paving surface is much less precise than that received by a cane traveler.

Some partially sighted people also use travel aids specifically aimed at helping their disability. For example, an individual with poor distance vision may use a compact telescope to read street signs; a person with poor night vision may use an infrared spotting scope similar to rifle scopes developed for night warfare. As attention of mobility trainers and eye care specialists moves from the totally blind to those with some functional vision, low-vision aids are becoming increasingly common.

Also, a few visually impaired people use electronic travel aids. Developed in the late 1960s and 1970s, these aids, such as the Laser Cane, Mowat Sensor and sonic guide, use lasers or sonic signals to detect obstacles in the environment. The devices produce an audible tone or vibration when an obstacle is detected. Although initially hailed as major breakthroughs, the devices have not been generally accepted by visually impaired clients. Many of the devices have a somewhat odd appearance and are quite expensive costing from $500 to $2,500 or more. Even travelers who can afford the devices do not seem to find this supplemental information to be better for independent travel than a cane or a dog guide. In addition, some users have found it difficult to become accustomed to and interpret the information relayed by the equipment.

Mobility Strategies

The overall mobility strategy a visually impaired person uses is quite simple: Gather as much specific, significant, or critical information as possible to allow safe, purposeful travel. The best method of acquiring information depends on the individual and setting. For example, an office worker may familiarize himself/herself with an office by starting at a doorway and trailing around the walls with his hand or cane, then learn the relationship between the doorway and significant objects, then relationships between the significant objects. Someone walking down a hallway may learn that he or she has entered a lobby because of a sudden change in acoustics, or use information from a cane by sensing changes in the paving surface such as from carpet to terrazzo, or from dirt to brick.

A particular mobility problem occurs at street crossings. This is a life-threatening situation: How can travelers learn that a traffic light has changed? For some, the answer is traffic sound. By paying attention to traffic sound, visually impaired travelers can usually hear when traffic starts and stops, when it is safe to cross, and what is the direction of traffic flow. However, visually impaired people still face the problem of successfully crossing from curb to curb without veering into traffic, which is a particular problem when, for example, the streets do not intersect at right angles.

There are several sorts of environmental information that can be transmitted to the visually impaired:

- *Shorelines*–Similar to a boat navigating by following a shoreline, these cues are the edges of a path that a cane traveler may follow. The grass at the edge of a sidewalk, the edge of a carpet strip, or a wall may all serve as shorelines—or a textured strip may be incorporated into the paving surface itself.

- *Landmarks*—Somewhat self-explanatory, landmarks are objects or places that are memorable because of their distinctive qualities of sound, temperature, reverberation, smell, or texture; or, for the partially sighted, color, light, or visual contrast.
- *Area Information*—The nondirectional sound from a crowd may tell a traveler that he or she is in the general area of a building lobby. An audible signal could be located over an elevator or over an important location (such as the restroom) that indicates to the traveler: "Your destination is in this direction."
- *Tactual Maps or Audio Messages*—On entering a space, a visually impaired traveler may be oriented through the use of a map of the space that can be felt, or by an auditory message tape that describes the setting.

RESEARCH STUDIES AT GEORGIA TECH

Although the general outlines of mobility, orientation, and wayfinding by the visually impaired are understood, a number of key questions remain unanswered.

The present research focused on several issues: What are the key qualities of paving surfaces that serve to make them detectable to the visually impaired? Although some paving material cues are in fairly common use (such as using white marble borders along subway platforms to contrast with tile flooring elsewhere in the station), it is unclear which, if any, of these cues are actually detectable by the visually impaired. Second, how do the cues identified as detectable in laboratory testing function in field application?

Study I: Laboratory Testing of Surface Treatments

The purpose of this study was to determine what paving surfaces are detectable to visually impaired long cane users. Whereas previous work had suggested that some materials such as textured rubber mats may be reliably detected (see, for example, [8]), it was unclear what *qualities* of materials best predicted detectability. For example, is texture important? If so, what aspects of texture? Is the resilience of the surface significant? Is the noise made when the cane strikes the material important?

In an attempt to explore these questions, a 120 panel concrete test track was developed, which included thirty-two test panels. These test panels represented a systematic varying of five qualities: rebound, impact sound, groove width, groove spacing, and groove depth. The panels represent a crossing of high and low qualities of each of the factors [25].

Methods and Procedures—Visually impaired people traversed the test track in a random sequence and were asked to stop when they detected a panel. Each subject traversed the course at least four times. The detection rate and stopping distance was recorded for each panel.

The test track—The test track was constructed of broom-finish concrete and was located in an environmentally-controlled test chamber. Each 42" by 42" (107 cm by 107 cm) test panel had a three-layer construction and the surface finish of the test panels was flush with that of the blank panels on the rest of the track. The under-base was an air cavity that ranged in depth from ¼" to 1-¾" (6.4 mm to 45 mm) or was solid concrete. The base was concrete, wood, steel or thermoplastic. The surface finish was constructed of one of a range of materials and textures such as smooth concrete, grooves cut into concrete, smooth neoprene, neoprene strips, steel checker plate, steel washers, sandpaper squares, textured Pirelli-pattern rubber, or grooves cut into plywood. The panels were designed so that high and low qualities of each quality (rebound, impact noise, etc.) were represented. Equipment was designed to test each of the qualities in a controlled manner. For example, a rebound tester was developed based on a videotape analysis of the way actual long cane users employed their cane. (In the rebound tester a pivoted cane was released by electromagnet and the rebound of the cane was recorded on videotape.)

Subjects—Two sets of experiments were run. In the first, twenty-four visually impaired people without usable vision were tested. The subjects were paid for their time and were solicited through the local Radio Reading Service, and a number of local clinics and service agencies. These tended to be moderately young (median age-category, 31-40) and lost their vision early in life (median age-category 1-10); 58.3 percent were male, and 50 percent have received eight months training or less. In the second experiment, partially-sighted people were tested. This group was similar in demographic profile to the totally blind group.

Results and Discussion

In general, the results indicated a great range in the detectability of the various test panels—from 9 percent of the trials (smooth concrete) to 100 percent (steel washers on steel). Overall, the multiple regression of the physical variables regressed against the panel detection rate yielded an $R^2 = .85457$.

Further analysis suggested that the presence of concrete was significantly related to the *sound* produced when struck by a cane. When concrete was suppressed in this equation, and all sound-related factors entered, the multiple R remained high. (This relationship is confirmed by the self-report of the participants, who 42.7 percent of the time reported that they had detected the panel using noise, versus 31.9 percent by texture, 15.8 percent by sound and texture, 4,6 percent by sound and rebound, 2.5 percent by rebound and texture and 2.4 percent by rebound.) Most of the highly-detected panels were constructed of wood or steel plate. A list of recommended materials is presented in Table 1. Highly recommended materials were detected 95 percent of the time

Table 1. Recommended Materials Study I

Panel #	Recommendation	Detection method	Material
1	0	T	Concrete
2	1	S/T	1/16″ Neoprene on wood on concrete
3	1	S	Steel on concrete
4	0	T	1/16″ Neoprene on concrete
5	1	T	1/8″ Corrugated Rubber on concrete
6	0	T	Concrete
7	0	T	1/4″ Thermoplastic on concrete
8	1	T	Steel on thermoplastic on concrete
9	1	T	1/8″ Neoprene on concrete over cavity
10	1	S	Plywood over cavity
11	1	S	Plywood over cavity
12	1	S/T	Concrete over cavity
13	1	S/T	Wood over cavity
14	2	T	1/16″ Thermoplastic on concrete over cavity
15	0	T	Concrete over cavity
16	1	S/T	1/16″ Neoprene on plywood over cavity
17	0	T	Sandpaper squares on concrete
18	1	S/T	Pirelli pattern on steel on concrete
19	1	S	Steel on concrete
20	2	T	Pirelli pattern on concrete
21	1	S/T	Neoprene squares on steel plate
22	0	T	Concrete
23	0	T	1/8″ Neoprene on concrete
24	1	S/T	Steel washers on steel on concrete
25	1	S	1/2″ Sandpaper on wood on cavity
26	1	S/T	Steel on cavity
27	1	S/T	1/16″ Thermoplastic on wood on cavity
28	0	S/T	Concrete on cavity
29	1	S/T	Steel on cavity (with sandpaper squares)
30	0	T	1/8″ Neoprene on concrete over cavity
31	0	S	Concrete over cavity (with sandpaper squares)
32	1	S/T	Pirelli pattern on steel plate

T = Texture
S = Sound
S/T = Sound and Texture

0 – Not Recommended
1 – Highly Recommended
2 – Recommended

or more; the remaining materials were detected 90 percent of the time or more; the remaining eleven were not recommended. It should be remembered however, that these tests were conducted in a quiet indoor laboratory. If the intended application is in a noisy location, such as by a busy road, materials should be chosen that were detected primarily by texture rather than sound, or by a combination of both ("T" rather than "S").

Study II: Field Testing of Orientation and Mobility Cues

The purpose of this study was to test some of the cues ("countermeasures") identified in Study I in an actual field experiment. (See Figure 1, pp. 342 and 343).

Methods and Procedures

Test route–A ½ mile (800 m) outdoor test route was established on the Georgia Tech campus. The route was divided into eight segments, each of which represented common mobility and orientation problems encountered by the visually impaired: crossing undifferentiated open space, crossing a street, crossing a parking lot, traversing dirt paths or broken pavement, and so on.

Procedure–Subjects were asked to traverse the course one segment at a time and were given tape-recorded instructions describing the path. Each recording was played twice and then the subject attempted to negotiate the path. Each subject was accompanied by an experimenter who recorded the subject's travel errors such as reversing direction or veering off the path, the subject's time, and their self report of the difficulty of the route. (A number of other measures were recorded as well but will not be reported in the present article.)

All observational measures were tested for reliability and achieved an inter-rater concordance of at least .9 prior to data-gathering. All subjects were familiarized with the procedures using a shorter practice route prior to actually traversing the test route. Direction of testing was counterbalanced to control for exposure effects of countermeasures.

Research design–The research design was a simple before-after design with an additional control group added to help understand the impact of familiarity with the route. Subjects were randomly assigned to groups. Group 1 (six subjects) traversed the test route twice without countermeasures in place, then returned about two weeks later with the countermeasures set up on the course, at which time they again twice traversed the course. Group 2 (five subjects), the control group, also traveled the course on two days about two weeks apart. However, the control group traversed the course without countermeasures on the second day as well.

The use of the control group allowed the effects of familiarity with the route to be assessed. In the present test Group 1 had shown improvement from Day 1 to Day 2, but without a control group it would have been difficult to discern whether the countermeasures were effecting this change, or whether it was

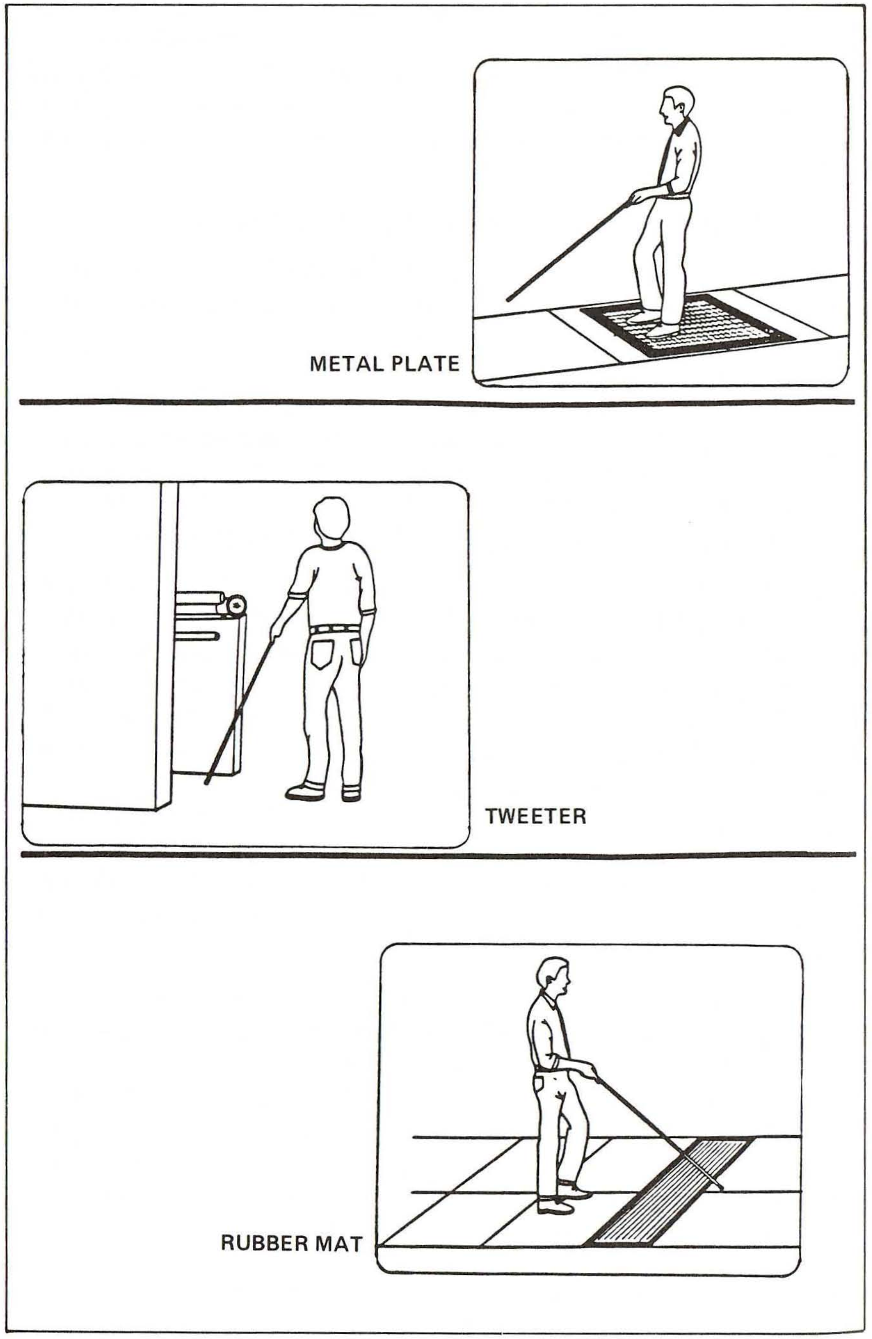

Figure 1. Countermeasures used in Study 1.

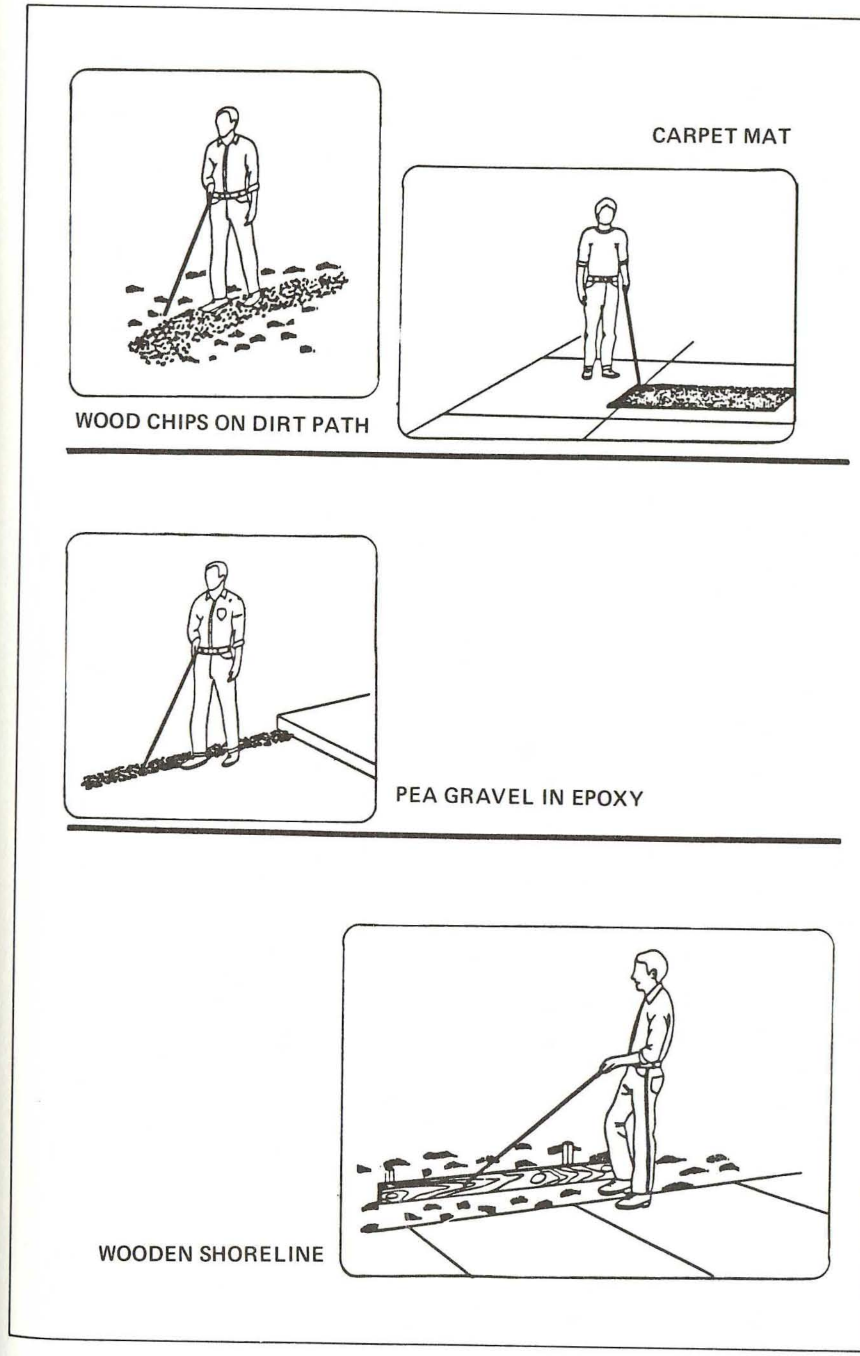

Figure 1. Continued

Table 1. Improvements in Time on Day 2 with and without Countermeasures

Subsegment	*Environmental Situation*	*Countermeasure(s)*	*Mean Diff. No CM Group*	*Significant Level*	*Mean Diff. CM Group*	*Significant Level*
1A	Crossing Open Space	Wooden Shoreline	− .03	NS	+2.12	.01
1B	Crossing Open Space	Tweeter	− .13	NS	+1.83	.05
2A	Non-Perpendicular Path Intersection	Carpet Mats	+1.0	.1	− .03	NS
3A	Finding Appropriate Street Crossing	Metal Plate Traffic Button	0.0	NS	+3.3	.01
3B	Crossing Street	Pea Gravel set in Epoxy	.80	NS	− .17	NS
4A	Crossing Street	None[c]				
4B	Confusing Path Intersection	Carpet Mats	− .55	NS	+2.3	.01
4C	Crossing Open Space	Rubber Mat	1.15	.1	1.63	.05
5A	Traversing Stairs	None[c]	+ .17	NS	− .16	NS
6A	Finding Stairs From Broken Path	Wooden Plate Wooden Shoreline	− .7	NS	+ .3	NS
6B	Crossing Parking Lot	None[c]	−1.2	NS	− .5	NS
7A	Finding Dirt Path	Wooden Shoreline	+1.15	.1	+2.81	.01
8A	Finding Destination in Open Area	Rubber Mat	+ .55	NS	1.61	.05

[a] Day 2 minus Day 1 (Trial 1 and Trial 2 averaged) computed as within subject factor
[b] One tailed *t*-tests
[c] No countermeasures were used in situations not found difficult on first day of testing

Table 2. Improvements in Time on Day 2 with and without Countermeasures

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1B	Crossing Open Space	Tweeter	− .13	NS	+1.83	.05
2A	Non-Perpendicular Path Intersection	Carpet Mats	+1.0	.1	− .03	NS
3A	Finding Appropriate Street Crossing	Metal Plate Traffic Button	0.0	NS	+3.3	.01
3B	Crossing Street	Pea Gravel set in Epoxy	.80	NS	− .17	NS
4A	Crossing Street	None[c]				
4B	Confusing Path Intersection	Carpet Mats	− .55	NS	+2.3	.01
4C	Crossing Open Space	Rubber Mat	1.15	.1	1.63	.05
5A	Traversing Stairs	None[c]	+ .17	NS	− .16	NS
6A	Finding Stairs From Broken Path	Wooden Plate Wooden Shoreline	− .7	NS	+ .3	NS
6B	Crossing Parking Lot	None[c]	−1.2	NS	− .5	NS
7A	Finding Dirt Path	Wooden Shoreline	+1.15	.1	+2.81	.01
8A	Finding Destination in Open Area	Rubber Mat	+ .55	NS	1.61	.05

[a] Day 2 minus Day 1 (Trial 1 and Trial 2 averaged) computed as within subject factor
[b] One tailed *t*-tests
[c] No countermeasures were used in situations not found difficult on first day of testing

Observer rating by subsegment–Table 2 illustrates the observer rating by subsegment. Of the five data sets, this set shows the clearest results. The first column shows the subsegment; this division allows individual environmental situations to be analyzed. Column Two is the environmental situation as described above. Column Three is the countermeasure. Columns Four through Eight are, respectively, the mean differences between the first day and second day for the countermeasure group (i.e., the ratings for the trials with countermeasures less ratings for the trials without countermeasures), significance levels for a one-tailed within-subject t-test (5 degrees of freedom), the comparable difference and significance levels (4 degrees of freedom) for the group who did not experience countermeasures.

Overall, the differences were quite striking. The countermeasure group improved significantly ($\alpha \leqslant .05$) in seven of twelve situations; the control group improved marginally in three of twelve. In addition, several countermeasures were effective in contributing to improved ratings in the countermeasure group:

1. wooden shoreline
2. tweeter
3. metal plate
4. carpet mat (one situation only)
5. rubber mat

Discussion

Although this experiment needs to be approached with appropriate caution–sample sizes were small–a number of relatively clear conclusions emerged. First, several of the problems initially identified as important did indeed provide difficulty for the subjects. These include:

1. crossing open space;
2. non-perpendicular path intersections;
3. finding the appropriate place to cross a street (especially at a rounded corner);
4. finding an end condition from a broken or uneven path;
5. finding a dirt or gravel path end condition from a paved path.

Several situations that some pretest informants had suggested would be problematic were not difficult for the present subjects. For example, finding and traversing stairs was sometimes mentioned as difficult, but was not for subjects in this experiment, perhaps because the stairs used in the testing were well-formed and regular. Also, crossing a parking lot was mentioned as being difficult in the earlier interviews but was also fairly easy here, although the reason is unclear.

A number of countermeasures were found to be effective. They are listed in Table 3. In general, six types of countermeasures improved performance of the subjects (in approximate decreasing order of effectiveness): 1) wooden shoreline; 2) tweeter; 3) metal plate; 4) wooden plate; 5) rubber mat; and 6) carpet mat.

Table 3. Summary of Countermeasure Effectiveness as Indicated by the Various Data Sets

	Data Set		
Countermeasure	*Observer Ratings*	*Subjects' Self-Ratings*	*Mean Errors*
Wooden Shoreline	+	+	+
Rubber Mat	+	0	0
Carpet Mat	+,0	0	0
Wooden Plate	0	+	0
Metal Plate	+	0	+
Tweeter	+	+	+
Pea Gravel/Epoxy	0	0	0
Traffic Button	0	0	0

0 = Inconclusive
+ = Significantly Effective
Multiple marks indicate countermeasure produced different results on different subsegments.

ORIENTATION AND WAYFINDING PROBLEMS AND SOLUTIONS

The two studies reported, above and others performed at Georgia Tech (see, for example, Templer et al.) suggest a range of orientation and wayfinding problems and solutions [9].

ORIENTATION PROBLEMS

Some settings cause visually impaired people serious orientation problems. Because visually impaired travelers depend on well-defined paths and memorable landmarks to find their way, ambiguous and poorly defined settings may be difficult to orient in. For example, many visually impaired people complain about the difficulty in crossing large open spaces, such as building lobbies or paved plazas. After a limited distance, it becomes easy to lose one's bearings and particularly so if there are no auditory or other cues. Similarly, because visually impaired people depend on their cognitive maps, environments that are hard to represent mentally are also hard to orient in. A building with a simple geometric circulation plan, such as a square or cross, is likely to be easy to understand and is generally simple to map cognitively. A complex building, with many turns and oblique angles or curves, may be very difficult to orient in (even for people with perfect vision).

Because many travelers are taught to pay attention to the cardinal points and simple rectangular shapes, oblique angles and curves present special orientation problems. Whereas it is relatively easy to maintain cardinal directions with a

90-degree turn, it is difficult with a 45-degree turn. It may be very difficult with an odd turn, such as 35-degrees or 65-degrees, and almost impossible when following a curvilinear path.

Design Solutions to Orientation Problems

How may the designer aid orientation by the visually impaired? During building planning, circulation should be made clear and straight forward and should use right-angle turns wherever possible. It is important to remember that the path visually impaired people remember is the one they experience, not the one experienced by the sighted designer. A square room with much equipment against the walls may be experienced as hopelessly complex by a visually impaired person who is trailing along a wall. Conversely, if a visually impaired person traveling through a complicated lobby can follow a clear path constructed of patterned floor or wall materials (carpet, fieldstone, battens, etc.) detectable by people who use a long cane, the route may be experienced as simple. Similar concerns apply to site planning. If the route to the building entry is complex and circuitous, orientation may be difficult. If the route is simple and direct, orientation may be easy.

Finally, at the urban scale, the Pedestrian Research Laboratory at the Georgia Institute of Technology has developed the concept of the "pedestrian accessible network." In urban design, it is insufficient to simply design an isolated transit stop or street crossing for visually impaired people. Rather, all of the urban elements that are to be used by the visually impaired person must be linked to form a continuous accessible network: A building that is easy to orient in may not be used if visually impaired travelers cannot find the way to the building from the bus stop; a route from the bus stop may not be used if the bus system is not usable, and so on.

SOME TYPICAL MOBILITY PROBLEMS AND SOLUTIONS

Problem 1. According to Provisions for Elderly and Handicapped Pedestrians, Volume 2, (9), 44 percent of all accidents experienced by severely visually handicapped pedestrians occur at level changes. Of these, 31 percent occur at stairs, and 19 percent at curbs and ramps. The greatest danger occurs when there are unexpected level changes, such as stairs with a walkway.

Solutions:

1. Vertical level changes such as stairs should be located out of the direct walkway or corridor route.
2. Detectable warning materials should be put at the top of stairs. Station platform edges should be treated similarly. For those with limited vision, the warning strips should be made to contrast visually with the walkway.

Problem 2. Stairs are potentially dangerous, and many serious accidents occur on stairs when people do not clearly see the nosing edge because of confusing carpet or tile patterns, or because treads are not visually distinct from each other.

Solution:
Providing materials with patterns and colors that emphasize nosings and edges. Yellowing or opacity of the eye lens (a common manifestation of the aging process) causes a loss of ability to discriminate between colors, especially of the blue-green end of the color spectrum. Therefore colors at the red-yellow end of the spectrum should predominate where accents are required. Preliminary research at Georgia Tech indicates that contrast in color intensity may be more important than the actual hue chosen.

Problem 3. Many outdoor and indoor places have meandering, nonparallel pedestrian circulation systems that are difficult for visually impaired people to understand and remember.

Solutions:

1. In new layouts, simple routes should be designed. These would also help people with poor cognitive abilities to understand the environment.
2. Existing places may be fitted with recorded route guides, tactile map guides, tactile floor texture strips, etc. (These are discussed in problems 5, 9, 10, and 12).

Problem 4. Visually impaired people may bump into street and advertising signs, tree branches, guy wires, drinking fountains, and other things that project into walkways and passages.

Solutions:

1. A protected zone that is at least 80 inches high and the full width of the walkway should be kept clear of branches, bushes, signs, and other overhanging objects.
2. According to the American National Standards Institute (ANSI A.117. 1-1980), if a sign or other object projects into or overhangs a walkway (or crosses a walkway, like a chain), but is no higher than 27 inches from the ground, then it may overhang or project by any amount because it can be detected by long cane techniques. If it is

higher than 27 inches, it should not project into the protected zone more than 4 inches. However, for people who do not use canes and have low vision, the object may still be a hazard and should not be permitted, or, at least, should be brightly painted with high contrasts to draw attention to it.

Problem 5. When streets do not intersect at a right angle, visually people attempting to cross the road may inadvertently veer out of the crosswalk and into the path of traffic.

Solutions:

1. The painted markings delineating the edges of the crosswalk can be made detectable to people who use long canes by the use of carefully selected materials, such as pea gravel or glass beads set into thermoplastic strips glued to the paving.

   Although 12 inch-wide strips were found effective in some Georgia Tech tests [8], other designers have used strips as narrow as 2 inches with apparent success. One method of installation uses an aluminum template to lay a strip of epoxy cement (the type normally used for highway work). Clean pea gravel is then poured on wet epoxy and is brushed when dry to remove the loose material.
2. When laying out buildings, urban areas, paths, etc., special care should be exercised to provide gridiron layouts, or to provide directional guidance for the blind.

Problem 6. Even at signalized intersections which have traffic signals, crossing the street is particularly hazardous for people with poor vision.

Solution:

Audible traffic signals are used extensively in Japan and parts of Europe, in conjunction with scramble system pedestrian crossings where traffic is stopped in all directions to allow pedestrians to cross. Audible signals are useful to indicate to severely visually impaired people when they may cross. Of course, the users must still exercise care to ensure that there is no traffic in the road that is moving or turning. The audible traffic signals must respond to ambient noise levels to be useful, and to avoid causing unnecessary additional noise pollution. The effectiveness of these devices in this country is still to be established.

Problem 7. Urban sidewalks often contain many types of street furniture (mailboxes, trash containers, signs, parking meters, lamp poles, trees, planters, etc.), and these are useful to severely handicapped people as landmarks. However, these objects often make the sidewalk into a complicated obstacle course.

Solution:

Locate street furniture in a strip along the outer edge of sidewalks, leaving a clear path free from obstructions. If the furniture strip is finished with a material that is detectably different from the sidewalk itself, this division can act as a useful artificial "shoreline."

Problem 8. Large open spaces such as parking lots, public parks, etc., are difficult for many visually impaired people to navigate through, because they have no pathways or shorelines that can be followed.

Solution:

Whenever practical, provide paths to be followed by visually impaired people. These paths can be formed by the use of a detectable paving material and color contrasts. Where large open spaces about a walkway, there is the possibility that a blind person may veer into the open area by mistake. This can be avoided by providing a detectable strip or separation between the two. Commonly, this problem also occurs at gas stations where the concrete of the sidewalk extends up into the pump and service areas.

CONCLUSIONS

Because of their disabilities, visually impaired people often face difficult problems in wayfinding and orientation. The research at Georgia Tech suggests that relatively modest improvements in the physical setting, such as adding paving textures or landmarks, may have a significant impact on performance. However, the research remains incomplete. Studies are needed with larger numbers of subjects with varying ages and abilities in a wider range of environmental situations.

REFERENCES

1. C. M. Zimring, Stress and the Designed Environment, *Journal of Environmental Systems*, *37*, pp. 145-171, 1981.
2. T. Heller, The Effects of Involuntary Residential Relocations: A Review, *American Journal of Community Psychology*, *10*, pp. 471-492, 1982.
3. J. Templer, and C. M. Zimring, *Access Information Bulletin: Accessibility for Persons with Visual Impairments*, National Center for a Barrier-Free Environment, Washington, D.C., 1981.
4. B. Blasch, Environmental Orientation and Human Mobility, in *Foundations of Orientation and Mobility*, R. L. Welsh and B. B. Blasch (eds.), American Foundation for the Blind, New York, 1980.
5. C. M. Zimring, Cognitive Mapping and the Blind, paper presented at the Annual Meeting of the Environmental Design Research Association, Buffalo, New York, May, 1979.
6. G. W. Evans, Environmental Cognition, *Psychological Bulletin*, *88*, pp. 259-287, 1980.
7. R. L. Welsh and B. B. Blasch (eds.), *Foundations of Orientation and Mobility*, American Foundation for the Blind, New York, 1980.
8. J. Aiello and E. Steinfeld, *Access and Use of Buildings by People with Severe Impairments of Vision*, Syracuse University School of Architecture Research Office, Syracuse, New York, 1979.
9. J. Templer, J. Wineman, and C. M. Zimring, *Provisions for Making Pedestrian Highway Crossing Structures Accessible to the Physically Handicapped*, final project report submitted to the U.S. Department of Transportation, March 25, 1982.

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WAYFINDING IN THE HOSPITAL ENVIRONMENT: THE IMPACT OF VARIOUS FLOOR NUMBERING ALTERNATIVES*

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ABSTRACT

Finding one's way around a large, complex building like a hospital is a difficult task at best. Add in the stress that most hospital patients and visitors experience and the task becomes even more arduous. A decision as basic as how floors are numbered can have important ramifications on orientation and wayfinding. A study was designed to discover which of several feasible floor numbering schemes would be most comprehensible to hospital patients (both inpatients and outpatients), visitors (inpatient visitors and outpatient companions), and staff. Patients and visitors were asked to complete a simple wayfinding task as well as to rate each of the floor numbering alternatives for preference; staff rated the alteratives in terms of their overall desirability. The results showed that one option (Sub 1, Sub 2) was interpreted correctly most often and was highly preferred by the patients and visitors interviewed. Conversely, staff members preferred numbering the floors 1, 2. The divergence in preferences and its relationship to wayfinding is discussed.

Finding one's way in an unfamiliar environment can be a trying experience. The importance of being able to orient oneself, locate oneself in space, and know where to go next is fundamental [1, 2]. There is also considerable evidence to support the notion that spatial disorientation can be disruptive to the individual [3]; evidence has been presented by Best to suggest that an unsuccessful

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