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A PRELIMINARY EVALUATION OF THE BIONIC INSTRUMENTS - VETERANS ADMINISTRATION C-4 LASER CANE

A final report prepared by the Advisory Panel for the Evaluation of the Laser Cane, formed by the Subcommittee on Sensory Aids of the Committee on Prosthetics Research and Development, Division of Medical Sciences, National Research Council, National Academy of Sciences

September 1973

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PREFACE

This report describes a preliminary evaluation study performed on the C-4 laser typhlocane designed and manufactured by Bionics Instruments, Inc., with funds provided by the Veterans Administration (V.A.). The study project was planned and executed by a multidisciplinary panel formed under the auspices of the Subcommittee on Sensory Aids, Committee on Prosthetics Research and Development (CPRD), National Academy of Sciences-National Research Council (NAS-NRC). Of the panel's seven original members four were drawn from the Orientation and Mobility (O&M) research staffs of two Veterans Administration Hospitals and three were members of CPRD or its Subcommittee on Sensory Aids. Two additional consultants joined the panel about halfway through the study.

The C-4 laser cane utilizes three gallium arsenide pulsed lasers, associated photocells and electronic components which provide three optical triangulation-ranging systems. One ranging system is responsible for detecting obstacles ahead of the man and is intended to permit relaxed walking without fear of collision. This sensor, referred to as the "forward channel," has a switch enabling the user to select a detection range of about either four feet or 12 to 14 feet. Any obstacle detected within the selected range will actuate a vibrating stimulator that contacts the index finger when the cane is carried in the usual "long cane" manner. A second system, the upper channel, points upward to detect overhanging branches, signs, casement windows and other above-the-waist hazards which appear from 18 to 24 inches in front of the cane tip. The third system projects downward, ahead of the cane tip to provide assurance of an extended level walking surface.

All three receivers (upper, forward and lower) operate a sound-emitting warning device which generates tones of different frequency; a low tone for the lower channel and a high tone for the upper channel. The audible warning for the forward channel may be switched off if so desired leaving only the tactile warning.

Mechanically, the laser cane is very similar to the conventional long cane, being as long although a little heavier. The laser cane is intended to perform all the functions of the long cane and, in addition, provide early warnings of obstacles through the agency of its added electronic components.

In an effort to avoid any misunderstanding about the objectives of this evaluation it should be made clear at the outset that the study makes no claim to comprehensiveness. It was not the intent of the project to determine the utility of the laser cane to the blind veteran population at large. The extremely small scale of the evaluation should clearly indicate that any inferences from our data relating to a general population may be invalid.

When the project began, there were only ten models of the C-4 laser cane available. The panel was therefore constrained to focus its investigation on only the most important questions which had emerged during the laser cane's development. These questions, posed by the staff of the Veterans Administration and the developer, sought information about the value of the device to people who were equipped to take full advantage of its features, and other similar facts which might materially affect the direction that the development contract could take in the immediate future. Hence, in its scope, the study was concerned primarily with the technical performance of the laser cane as a device, the effect it had on the mobility of selected blind travelers, and their opinions as to the usefulness of the instrument.

The active phase of the evaluation plan took place during the 16 months from August 1971 to November 1972. The project used eight blind veterans who volunteered for a five-week course of training at a Veteran Administration Hospital. Following the training period, each volunteer returned to his own home with a laser cane and was subjected to a schedule of periodic questioning on the extent of his use of the laser cane and on his impressions of its performance and utility. In addition, after each man had acquired many months of experience with the device, he was observed as he negotiated a familiar and an unfamiliar route using the laser cane and the conventional long cane. The performance achieved with the long cane was taken as each man's norm against which his corresponding performance with the laser cane could be compared.

Two basic sources of data were utilized: objective behavioral measurements and subjective assessments. The latter were offered by the eight veterans, by the O&M researchers who assessed the volunteers' travel skills, and by independent groups of O&M specialists who, upon examining videotape recordings of the volunteers negotiating the familiar and unfamiliar routes, rated each of the performances.

There is a well-known maxim concerning evaluation technique which stresses the importance of gathering data in such a way that the measurements can be compared with data obtained under control conditions. Moreover, the maxim dictates that measurement procedures should be sufficiently well specified to allow their reproduction at a later date when a new or possibly improved device becomes available. In the preliminary evaluation of the C-4 laser cane special efforts were made to follow these principles. The control data were obtained from parallel observations of ordinary long-cane travel undertaken by the same eight subjects who used the laser cane. Also a considerable time was spent in documenting the measurement procedures to be used. Furthermore, with a view to the future, several technical improvements were noted at the end of the project for implementation if the procedures are used in a subsequent study. The sheer bulk of the descriptive material so collected has made necessary its separation from the main body of the report and its organization as a series of appendixes. Thus, those readers who need a ready access to the principal facts and findings will find such information in the main text. Those who may wish to learn more about the procedural details will find these data in the appropriate appendixes.

It should be noted that this study was not the first to have been carried out on the laser cane, although it was probably the largest. Prior studies have been made by the Cincinnati Association for the Blind, teams at the Veterans Administration Hospitals at Hines and at Palo Alto, The Missouri School for the Blind, The Seeing Eye Inc., and Western Michigan University. Each institution based its conclusions on one cane. In cases where the procedures used have been similar, the results of these studies are generally in good agreement with the data reported here. In a number of other areas, however, where new methods or resources have been used which were unavailable to other workers, additional important data have been collected which will serve to give the most comprehensive account of the status of the laser cane available at the present time.

Patrick W. Nye
Panel Chairman
September 1973

ACKNOWLEDGMENTS

As with many projects of its kind, the evaluation program did not always proceed smoothly according to plan. However, it is a pleasure to note that when the panel members planned their occasional meetings at V.A. facilities events proceeded smoothly largely because the members could always rely on the availability of excellent facilities. For the hospitality, helpful consideration and full cooperation extended to us by Mr. Eugene Apple, Chief of the Western Blind Rehabilitation Center at Palo Alto, and Mr. John Malamazian, Chief of Central Rehabilitation Section for Visually Impaired and Blinded Veterans at Hines, the panel members wish to express their warm appreciation. Additional thanks are due to Mr. Howard Freiberger of the V.A. Prosthetic and Sensory Aids Service and to Mr. Malvern Benjamin of Bionic Instruments, both of whom provided valuable advice and information at various times throughout the program.

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CONTENTS

		Pages
Chapter 1.	PROJECT DESCRIPTION Introduction Objectives Design Philosophy Subject Selection	1
Chapter 2.	PROJECT PLAN & TIMETABLE Introduction Training Program Follow-up Timetable	13
Chapter 3.	GENERAL DESCRIPTION OF METHODS Introduction The Subtask Checklist The Task Rating Form The Questionnaire	23
Chapter 4.	ANALYSIS OF SUBTASK CHECKLIST DATA Introduction Problems of Analysis Analysis Conclusions	34
Chapter 5.	ANALYSIS OF TASK RATING DATA Introduction The Model Data Adjustments Results	41
Chapter 6.	SUMMARY OF REPLIES TO QUESTIONNAIRE Introduction The Replies Summary of Suggested Modifications	54
Chapter 7.	CONCLUSIONS Introduction Utility of the Laser Cane Structure of the Laser Cane Recommendations for the Future	68
	APPENDIXES I Preliminary Data Collection II Lessons Used in Training III Subtask Checklist IV Task Rating Form V Rater Questionnaire VI Subject Questionnaire	71
	SUPPLEMENT	197

Chapter 1.

PROJECT DESCRIPTION

INTRODUCTION

Although the adoption of basic principles of evaluation procedure should provide a common bond among all evaluation studies, in practice, each individual study conducted on the same device often emerges with its own special character and identity. This situation arises largely from the fact that the questions which are posed are seldom exactly the same and the study reported here is unlikely to be an exception. It is therefore appropriate to begin with an explicit statement, not only of the objectives of our study but also of the underlying philosophy.

OBJECTIVES

The broad objective of the study was to provide data concerning the technical performance of the laser cane, the extent to which the device enhanced the travel skills of good long-cane travelers and the value judgments that blind travelers made about the laser cane. It was also the intention that these data might assist in arriving at a decision as to whether the laser cane should be manufactured (to the design existing in 1971) in sufficient quantity to permit a full field evaluation, whether the design should be researched and refined still further, or whether the laser cane in anything like its 1971 design should be abandoned as inadequate. In formulating its evaluation plan the panel concluded that the issue could be resolved if as complete a set of answers as possible could be obtained to the following questions:

a) Relative to the conventional long cane, does the laser cane enable a subject to travel more effectively and/or more safely?

b) What kinds of information about the environment do the laser components of the cane provide?

c) Does the traveler value this information and, if so, how highly?

d) Should the information obtained by the laser-system be displayed in a different manner to increase user efficiency?

e) How should the training program be improved?

f) Does the availability of the laser cane increase the travel frequency of the user?

g) Is the laser cane technically reliable?

DESIGN PHILOSOPHY

Characteristically, in the evolution of the plan, consideration had to be given to such matters as cost and the availability of time and manpower. These problems, essentially imposed by practical constraints, sometimes forced the panel to decisions which led to perplexing difficulties. Most prominent among these was the decision to divide the work between the Palo Alto and Hines Hospitals. Also, in several other cases, owing to the absence of any pressing arguments favoring one side or the other, arbitrary decisions were made, not all of which were without unforeseen repercussions. The details of these problems as well as the project's accomplishments are fully discussed in this report. At this point, however, we propose to discuss four of the more important decisions that exemplify the underlying philosophy of our approach.

One of these decisions was to rely more on the informed opinion and judgment of trained mobility instructors than on objective physical measurement. To reduce the influence of observer bias, however, it was especially important to gather data from a large number of experts. The use of video-recording techniques as an aid in the analysis of different mobility performances by trained mobility instructors thus became an important part of our research plan.* Actually, at the outset it was not known whether recordings of sufficient quality could be obtained. In preliminary experimentation a substantial amount of time had to be spent in assembling suitable equipment and in developing methods of mobile recording which were adapted to a downtown urban environment.

Another decision revolved on the relationship of the laser mechanism to the long cane and the possible need to modify the so-called "long cane technique" to take advantage of the lasers. The question was, therefore, should the laser cane be regarded as being a long cane to which the laser system is attached or should it be treated as an entirely new composite instrument which might require an entirely new set of rules for its use? The panel decided that it should take what appeared to be the developer's view--that the device is primarily a long cane. Given this position an important immediate conclusion became apparent, namely, that in order to observe the full benefit provided by the laser system each of the experimental trainees must already possess good long-cane skills. This prerequisite was necessary as evidence

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*The analysis of a blind traveler's performance in terms of his ability to perform a number of discrete "critical tasks" was pioneered by J. A. Leonard[1] who, before his death, had also employed videotape recording to increase the number and reliability of sampled judgments. In the laser cane study these procedures, which are still in the developmental stage, saw more extensive and systematic usage than had been previously undertaken in this field. A detailed account of the methods used is given in Appendix 3.

that the trainees could absorb nonvisual (i.e., auditory and tactile) information and use it to control motor performance, and equally important that, having previously demonstrated mastery of the long cane, each man was more likely than a novice to be in a position to devote his attention to new sources of information.

A third decision concerned the personality and motivation of the subjects who were to be selected. To ensure that the scant amount of training time available would be used to maximum efficiency, it was decided that only highly motivated people would be invited to volunteer. Such men were easy to find because the V.A. hospitals maintain files on all blinded veterans with their training histories on record. However, any serious attempt to investigate the important relationship between psychological measures and mobility performance could not be made because of the small number of trainees and their greater-than-average mobility.

SUBJECT SELECTION

With the intent of stimulating motivation, a fourth decision made by the panel was to guarantee that each trainee could retain a laser cane for as long as he felt that it was of use to him. Morale, in fact, was high throughout the entire program, and at the time that this report was prepared (September 1973) only one trainee* had surrendered his laser cane. He did this several months after completion of the evaluation program on the grounds that he felt that he was not making sufficient use of it.

From the foregoing discussion it may be apparent that underlying many of the decisions was a deliberate effort to avoid introducing any conditions which might be construed as representing a bias against the laser cane. Thus, on the basis of these decisions, a set of trainee qualifications was drawn up as follows:

1. A male veteran who has received his O&M training at a V. A. Center and graduated in an above average category.

2. No useful form vision.

3. Good health and good hearing.

4. Right handedness.

5. Good motivation and the need and desire to travel frequently.

6. Willingness to spend an entire month at a V. A. Center while receiving training and to cooperate in the follow-up program.

7. Residence in the vicinity of one or the other of the two participating V. A. Centers.

* Subject P3 returned his cane in the Spring of 1973.

The selection of the eight volunteers (subjects P1, P2, P3 and P4 at Palo Alto and Subjects H1, H2, H3 and H4 at Hines) proved to be difficult, primarily because most of the veterans having the high qualifications demanded from potential trainees were already employed or fully occupied and unable to devote an entire month to the training program. To meet the required quota, the area of search was increased and eight men were eventually found who either fully met or very closely approached the initial criteria. During the course of the program, however, subject H2 recovered some useful form vision and the health of subject P3 deteriorated and may have interfered with his video-recorded trials over familiar and unfamiliar routes. Table 1 provides background information on the eight subjects extracted from V. A. records. The names and addresses have been withheld.

TABLE 1

BACKGROUND INFORMATION ON C-4 LASER CANE SUBJECTS

Subject H1

BIRTH DATE:	March 11, 1950
HEIGHT & WEIGHT:	5' 11", 170 lbs
DATE ADMITTED TO BRS FOR O/M REHAB TRNG.	September 26, 1970
DATE DISCHARGED:	March 4, 1971
DIAGNOSIS:	Multiple lacerations and injuries of face, eyes, shoulder and hands, sustained in combat in South Viet Nam. Both eyes enucleated. Subject has two plastic eyes.
ONSET OF BLINDNESS:	Subject injured April 20, 1970, by booby trap hanging from a tree which struck him in the head while he was riding in a military vehicle, resulting in blindness and the enucleation of both eyes.
HEALTH:	Subject in very good health.
MARITAL STATUS:	Married but no children.
EDUCATION:	Four years of high school but did not get a diploma. Completed GED Tests at the Rehabilitation Center and got Certificate (GED High School Equivalency Diploma).
MILITARY:	Army. Attained rank of Sp-4.
RESIDENCY:	Large metropolitan city in the midwest.
ADDITIONAL INFORMATION:	
1. Travel Habits	Subject travels to and from work using public transportation. The trip involves using buses and subway trains.
2. Changes in Background	Subject took course and qualified as a dark-room technician. A son was born to subject and his wife. He is presently employed as a dark-room technician in a hospital in the same metropolitan area in which he lives.
3. Psychological Test Result	WAIS IQ Average

TABLE 1 (cont'd)

BACKGROUND INFORMATION ON C-4 LASER CANE SUBJECTS

Subject **H2**

BIRTH DATE:	February 19, 1949
HEIGHT & WEIGHT	6' 1 1/2", 175 lbs.
DATE ADMITTED TO BRS FOR O/M REHAB TRNG:	November 6, 1970
DATE DISCHARGED:	April 28, 1971
DIAGNOSIS:	1. Penetrating and lacerating injuries of face and trunk as a result of combat duty in South Viet Nam. 2. Loss of vision, right eye, eye phthisical, light perception, left eye due to #1, resulting in blindness. Has a prosthetic right eye. 3. Partial arthrodesis and deformity of right little finger, status post-op.
ONSET OF BLINDNESS:	Subject was injured as the result of a mine explosion in South Viet Nam on September 16, 1970.
HEALTH:	Subject in good health.
MARITAL STATUS:	Single.
EDUCATION:	Completed the 10th grade but during his stay at the Rehabilitation Center, subject completed his GED Tests and got his GED High School Equivalency Diploma. He is now attending college.
OCCUPATION:	Musician. Played sax in a band for about eight years.
MILITARY:	Army. Inducted September 4, 1968, and discharged December 16, 1970. Attained rank of Sgt. E-5.
RESIDENCY:	Large metropolitan area in the midwest.
ADDITIONAL INFORMATION:	
1. Travel Habits	Subject uses public transportation to go to college classes.
2. Changes in Background	Subject underwent surgical procedures which resulted in the restoration of some useful residual vision. He married in 1972. Subject and wife moved from an apartment and bought a trailer in a more rural area. However, he still lives in same general metropolitan area. His wife is pregnant and the baby will arrive in early 1973.
3. Psychological Test Result	WAIS IQ Bright normal.

TABLE 1 (cont'd)

BACKGROUND INFORMATION ON C-4 LASER CANE SUBJECTS

Subject H3

BIRTH DATE:	December 11, 1941
HEIGHT & WEIGHT:	5' 11 3/4", 195 lbs.
DATE ADMITTED TO BRS FOR O/M REHAB TRNG:	July 31, 1968
DATE DISCHARGED:	November 20, 1968
DIAGNOSIS:	Injuries of head and eye, and flesh wounds of trunk. Loss of right eye and loss of vision of left eye, resulting in bilateral blindness.
ONSET OF BLINDNESS:	Subject was injured as the result of a mine explosion in South Viet Nam on December 4, 1967.
HEALTH:	Subject in very good health.
MARITAL STATUS:	Subject is married and has two children.
EDUCATION:	Subject received a B.S. in Biological Sciences prior to entering the Service. Currently doing graduate work in the Social Sciences which involves field work.
OCCUPATION:	Worked for a protection and security firm after discharge from the Rehabilitation Center.
MILITARY:	Officer in the Marine Corps.
RESIDENCY:	Large metropolitan city in the midwest.
ADDITIONAL INFORMATION:	
1. Travel Habits	Subject uses public transportation to go to college classes and to place of employment where he is doing his field work.
2. Changes in Background	Subject now working for a different agency in doing his field work.
3. Psychological Test Result	WAIS IQ Superior.

TABLE 1 (cont'd)

BACKGROUND INFORMATION ON C-4 LASER CANE SUBJECTS

Subject H4

BIRTH DATE:	February 3, 1929
HEIGHT & WEIGHT:	5' 2", 138 lbs.
DATE ADMITTED TO BRS FOR O/M REHAB TRNG.	February 9, 1952
DATE DISCHARGED:	September 11, 1952
DIAGNOSIS:	Bilateral blindness, both eyes enucleated. Subject has two plastic eyes.
ONSET OF BLINDNESS:	Subject was injured October 16, 1951, by a mortar shell in North Korea.
HEALTH:	Subject in very good health.
MARITAL STATUS:	Subject is married and has two children.
EDUCATION:	College degree in Social Work.
OCCUPATION:	Dark-room technician.
MILITARY:	Subject was a rifleman in the Army.
RESIDENCY:	Large metropolitan city in the midwest.
ADDITIONAL INFORMATION:	
1. Travel Habits	Subject uses public transportation to go across town to and from work. He also does considerable traveling in going shopping with his children and taking care of his personal and business needs.
2. Changes in Background	No significant changes since subject completed the training course.
3. Psychological Test Result	WAIS IQ Bright normal

TABLE 1 (cont'd)

BACKGROUND INFORMATION ON C-4 LASER CANE SUBJECTS

Subject P1

BIRTH DATE:	July 10, 1947
HEIGHT & WEIGHT:	6' 4", 180 lbs.
DATE ADMITTED TO BRS FOR O/M REHAB TRNG:	August 8, 1968
DATE DISCHARGED:	November 13, 1968
DIAGNOSIS:	Facial and eye injuries causing total blindness.
ONSET OF BLINDNESS:	Subject's injuries caused by grenade explosion sustained in combat in South Viet Nam on February 9, 1968.
HEALTH:	Good
MARITAL STATUS:	Married
EDUCATION:	College student at the time of training and follow-up program.
OCCUPATION:	Student
MILITARY:	Army
RESIDENCY:	Small western city
ADDITIONAL INFORMATION:	
1. Travel Habits	Travels daily to the campus several blocks away and around the campus to his various classes.
2. Changes in Background	Immediately following the training he transferred to another college in a different state. He got married on June 12, 1972, which was one week prior to the final home evaluation.
3. Psychological Test Results	WAIS IQ Very superior.

TABLE 1 (cont'd)

BACKGROUND INFORMATION ON C-4 LASER CANE SUBJECTS

Subject P2

BIRTH DATE	February 2, 1942.
HEIGHT & WEIGHT:	5' 6", 145 lbs.
DATE ADMITTED TO BRS FOR O/M REHAB TRNG:	June 30, 1971 Student had prior training at Hines V. A. in 1963 and had entered Western Blind Rehab. for a refresher program.
DATE DISCHARGED:	September 8, 1971
DIAGNOSIS:	Face and eye injuries.
ONSET OF BLINDNESS:	Auto accident in 1963. Subject was a passenger in a car which ran off the road.
HEALTH:	Good. Walks with a noticeable limp in his right leg; however, this did not impair his travel during lessons.
MARITAL STATUS:	Married
EDUCATION:	Two years of college
OCCUPATION:	Unemployed
MILITARY:	Air Force
RESIDENCY:	Small western city
ADDITIONAL INFORMATION:	
1. Travel Habits	He lives in a residential area that is six blocks from the downtown business area and travels several times a week to the business area using either a cane or a dog guide.
2. Changes in Background	He was a student when he was trained with the laser cane and graduated in June of 1972 just prior to the final evaluation. Presently he is seeking employment.
3. Psychological Test Results	WAIS IQ Superior.

TABLE 1 (cont'd)

BACKGROUND INFORMATION ON C-4 LASER CANE SUBJECTS

Subject P3

BIRTH DATE:	June 29, 1945
HEIGHT & WEIGHT:	6' 3", 235 lbs.
DATE ADMITTED TO BRS FOR O/M REHAB TRNG:	July 26, 1971 In 1969 - Student had prior training at West Haven, V. A.
DATE DISCHARGED:	August 31, 1971
DIAGNOSIS:	Trauma
ONSET OF BLINDNESS:	Subject was injured in Spring 1968 by an explosion while engaged in combat in South Viet Nam.
HEALTH:	Good during training. Following training some recurrence of seizures secondary to brain trauma. At the final evaluation the seizures were being better controlled by tranquilizers.
MARITAL STATUS:	Married
EDUCATION:	Two years of college.
OCCUPATION:	Student
MILITARY:	Marine Corps
RESIDENCY:	East coast city
ADDITIONAL INFORMATION:	
1. Travel Habits	Travels 5-6 hours a week on a college campus. Most of his travel is confined to the campus.
2. Changes in Background	Moved from Palo Alto, Cal., to East Haven, Conn., in April of 1972. Did not return to school until the Fall of 1972 and did little traveling as he did not live within traveling distance of destinations he had need of getting to.
3. Psychological Test Results	WAIS IQ Very superior.

TABLE 1 (cont'd)

BACKGROUND INFORMATION ON C-4 LASER CANE SUBJECTS

Subject P4

BIRTH DATE:	March 3, 1925
HEIGHT & WEIGHT:	5' 7", 172 lbs.
DATE ADMITTED TO BRS FOR O/M REHAB TRNG:	Prior instruction at Western Blind Rehabilitation in 1969. Prior instruction at Hines V. A. in 1950. Prior instruction at Perkins Institute in 1949.
DATE DISCHARGED:	August 30, 1972
DIAGNOSIS:	Occular damage.
ONSET OF BLINDNESS:	Subject was injured by an explosion which occurred while he was handling cargo in Port Chicago, 1944.
MARITAL STATUS:	Married
EDUCATION:	Presently enrolled in college.
OCCUPATION:	Student
MILITARY:	Navy
RESIDENCY:	Large west coast city
ADDITIONAL INFORMATION:	
1. Travel Habits	Travels to college and around the campus. The trip to school involves taking three buses. Occasionally travels to a nearby hamburger stand.
2. Changes in Background	Upon completion of the laser-cane training program he moved to a new home.
3. Psychological Test Results	WAIS IQ Very superior.

Chapter 2.

PROJECT PLAN AND TIMETABLE

INTRODUCTION

The complete program consisted of two parts--the training phase, lasting for one month, and the follow-up phase which extended over a period of one year. During the training program, effort was focused primarily on the task of acquainting each student with the characteristics of the laser cane under a variety of conditions. Some performance data were also gathered at this time but the main purpose of this data-collecting activity was that of a pilot run; to allow the research staff to gain experience in human performance measurements; and to explore and improve procedures which were extensively used in the second phase of the program. Additional secondary goals were to obtain some objective data which could reflect the functioning of the laser canes, to assess the subjects' ability to learn particular tasks and to gain some insight into the appropriateness of the teaching format. A description of the training procedures and the results of the preliminary measurements are given in Appendixes 1 and 2. The contents of these appendixes indicate that the level of effort involved was not small and unimportant. Nevertheless, the data obtained at this very early stage of the project have been set aside in favor of the more important data derived from the follow-up study. Thus this latter stage constitutes the major source of data on which the conclusions of this report have been based almost exclusively.

Frequent breakdowns were among the most disruptive and irksome problems that both the subjects and the research staff had to contend with during the program. In the first four months of the follow-up phase, a total of 38 breakdowns occurred. Twenty-one failures were caused by accidental damage, 11 were due to faults in electronic components, and 6 were caused by loose wires and misalignments. The reliability of the laser canes did show some improvement during the later months of the program, however. By March 1972 the failure rate had dropped to 4 per month and by August 1972, the rate fell still further to a little less than 2 per month.

The high failure rate had repercussions beyond the obvious inconvenience of often having less than the required eight canes in service. The loss of confidence that grew from the need to return canes sometimes led subjects to suspect failures when in fact none had occurred. Thus on a few occasions, canes were returned to the manufacturer and subsequently were found to be in normal working order. These experiences, in addition to remarks made by the subjects, clearly indicated to the evaluators that a generally prevalent low level of confidence in the laser cane must inevitably have taken a toll on the mobility performances that the subjects were able to achieve.

Another factor which contributed to the air of uncertainty surrounding the laser canes was their variability. Each cane appeared to have its idiosyncrasies. Hence, when a cane in process of repair was replaced by a spare, the subject had to spend time becoming accustomed to its special characteristics. Once again this may have detracted from the subjects' performances.

TRAINING PROGRAM

Table 2 shows the training timetable. The course began with an evaluation of each subject's long cane performance. All subjects were found to perform at levels below those that they had reached when they were originally discharged from their respective centers. However, a majority of the trainees were unaware of their errors in performing certain cane skills and had to be given a short refresher course.*

The remainder of the instruction consisted of a sequence of encounters in specially contrived laboratory environments followed by a series of journeys in residential and business settings. The laboratory training opened with a demonstration of each of the laser cane's three channels detecting hazards at head height, waist height, and foot level. These introductory lessons were followed by three formal test procedures (tests of Detection, Avoidance and Navigation, i.e., obstacle avoidance) which, although designed primarily for measurement, were found to be excellent training tools as well. Descriptions of these tests are given in Appendix 1. The journeys through normal streets were graduated in increasing difficulty and culminated in runs through crowded downtown districts. Details of representative routes are given in Appendix 2.

Instructors were aided by an FM transmitter attached to each laser cane to signal the output of the cane. They were thus able to observe the signals that the trainee was receiving as well as his response and were able to advise on whether the actions taken were appropriate.

The training program was conducted during the month of August and the first week of September 1971. At the end of that period the trainees returned to their homes and commenced a nine-month term during which frequent communication was established between them and the instructional staff.

FOLLOW-UP TIMETABLE

Table 3 shows the timetable of the follow up phase of the study in relation to the training program. The major features of the follow-up phase included repeated

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*For example, some subjects were not maintaining a correct (i.e., safe) arc width (probably because proprioceptive feedback is characteristically imprecise). Such a deterioration in performance could be offset by periodic retraining and there is good reason to believe that the rehabilitation agencies should be directing more attention to this problem.

"TIMETABLE OF INITIAL TRAINING PROGRAM" TABLE 2

LASER CANE EVALUATION

MONTH: AUGUST 1 — SEPTEMBER 3, 1971

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
[1] student arrival at blind centers	[2] orientation to center and program	[3] long cane and travel performance evaluation run one	[4] same as Tuesday run two	[5] general expl. of laser cane lab middle channel	[6] laser cane lab upper channel	[7] day off
[8] day off verbal WAIS test (psychological) given this week to students	[9] Laser Cane lab down channel	[10] lab all channels detection test	[11] lab all channels avoidance test	[12] obstacle test laser runs	[13] laser runs channel use rec.	[14] day off
[15] Starting the administration of the Rotter tests to the students	[16] laser runs	[17] laser runs	[18] laser runs	[19] laser runs channel use rec.	[20] laser runs obstacle test	[21] day off
[22] day off	[23] run one test long and laser cane	[24] run two test long and laser cane	[25] run two test long and laser cane	[26] extra testing time or for runs channel use rec.	[27] time spent for filming students on runs	[28] day off
	(peer group rating and subtask rating by eval. team)					
[29] day off	[30] extra time (used for catch up work) or for extra runs	[31] extra time (used for catch up work) or for extra runs	[1] extra time (used for catch up work) or for extra runs	[2] group meeting and final comments	[3] student departure date	[4]

VA FORM JUN 1953 7054 EXISTING STOCKS OF VA FORM 6-7054 FEB 1953, WILL BE USED. PROGRAM PLANNER 448190 Write days of month in the brackets

RUN A (PALO ALTO
[illegible]

BLOCK 1
EAST

BLOCK 2
EAST

BLOCK 3
EAST

BLOCK 4
SOUTH

[illegible]

[illegible]

[illegible]

[illegible]

TABLE 3

"TIMETABLE OF EVALUATION PROGRAM"

PERIOD	INSTRUCTIONS TO TRAINEES
August 1 September 3	Training programs at the VA facilities at Hines, Illinois and Palo Alto, California.
CHRONOMETRIC DEVICE fitted in last week of training	
September October (1 1/2 months)	Trainees encouraged to use laser cane exclusively. Telephone contact will be made during 2nd week at home (T1)
FIRST VISIT by O&M specialists (V1) to check timer and other details	
October November (1 1/2 months)	Encourage trainees to make exclusive use of the laser cane.
TELEPHONE INTERVIEWS with trainees who provide subjective reports (T2)	
December March (4 months	Trainees are asked to use the long cane and laser cane an equal amount.
SECOND TELEPHONE INTERVIEWS (T3)	
April May (2 months)	Trainees should use the cane of their choice.
SECOND VISIT by O&M specialists (V2)	

KEY: The symbols T1, T2, T3 and V1, V2 refer to a series of telephone calls and visits made by the O&M research staff. During these contacts the volunteer laser-cane users were asked a number of prearranged questions. A summary of the answers to these questions is given in Chapter 6.

BLOCK 1
WEST

BLOCK 2
WEST

BLOCK 3
WEST

BLOCK 4
SOUTH

BLOCK 5
SOUTH

BLOCK 6
EAST

BLOCK 7
EAST

BLOCK 8
EAST

telephone interviews with each trainee and the assignment of trial runs over familiar and unfamiliar routes (6-8 blocks in length) using the laser cane and the long cane in turn. During the telephone interviews, portions of the questionnaire included as Appendix 6 were administered together with instructions on ways of apportioning time between use of the long cane and the laser cane. Each trainee made four types of runs in an order specified by the latin squares for each center shown in Table 4, and while these runs were in progress videotape recordings were made primarily from a viewpoint behind the traveler. These tapes carried a sound track on which was recorded the output signals of the laser cane, and the ambient traffic noise. In addition, a commentary on the performance of the traveler was made by an O&M trained member of the evaluation staff on a separate tape recorder. The information from the video-and audio tapes constituted the data from which the staff later compiled the "Subtask Checklist" which is shown in full in Appendix 3.

It should be noted that, owing to the numerous breakdowns experienced with the laser canes, the planned timetable shown in Table 3 could not be followed by most of the subjects. As a practical matter, the subjects were actually instructed to use their laser cane whenever it was available and this stratagem allowed each volunteer to eventually accumulate the number of hours of experience called for in the original plan.

To complete the analysis of the videotaped performances, sixteen independent O&M specialists were asked to view a selected number of tapes and to rate various aspects of the subjects' travel behavior on a seven-point scale. Each specialist viewed 4 tapes--one of each type of run, the order of the sequence being varied (see Chapter 5), and recorded his scores in response to the list of questions which made up the "Task Rating Form" (see Appendix 4 and Chapter 3).

A subsequent assessment of the efficiency of the Task Rating Form used in conjunction with video recordings was made by sampling the opinions of the 16 O&M specialists. The replies showed that, although several improvements were possible, the procedures were thought, on the whole, to provide enough information to obtain an accurate assessment of a person's mobility skill. A copy of the questionnaire and an analysis of the replies are given in Appendix 5.

As indicated in Table 3, a chronometric device was fitted to all canes at the end of the training period. This was done in an effort to gauge the amount of use each laser cane received during the follow-up program. However, contrary to usual practice, each subject was told that a timer--the Curtis elapse-time indicator--had been fitted to his cane.* The vibration specification of the Curtis timers is said to exceed 20g at 2,000 Hz and the shock

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*The subjects were given this information primarily to avoid the risk of appearing to breach the trust which, in the interests of full cooperation, was maintained between the volunteer subjects and the O&M staff through an open information policy. It should be understood in this context that many of the subjects indicated that they did not relish having their performances examined, criticized and videotaped, and several indicated that they sometimes felt self-conscious when using the laser cane in public.

RUN 2 (PALO ALTO)
LASER CANE ROUTE

BLOCK 1
NORTH

BLOCK 2
NORTH

BLOCK 3
NORTH

BLOCK 4
WEST

BLOCK 5
SOUTH

BLOCK 6
SOUTH

[illegible]

BLOCK 8
EAST

TABLE 4

ORDER OF ASSIGNMENTS FOR SUBJECTS MAKING VIDEOTAPED RUNS

SUBJECT	FIRST RUN	SECOND RUN	THIRD RUN	FOURTH RUN
H1	Laser F	Laser UNF	Long F	Long UNF
H2	Long UNF	Long F	Laser UNF	Laser F
H3	Long F	Laser F	Long UNF	Laser UNF
H4	Laser UNF	Long UNF	Laser F	Long F
P1	Laser F	Long F	Laser UNF	Long UNF
P2	Long UNF	Laser UNF	Long F	Laser F
P3	Long F	Long UNF	Laser F	Laser UNF
P4	Laser UNF	Laser F	Long UNF	Long F

KEY: F - Familiar route. UNF - Unfamiliar route.

criterion to exceed MIL-STD-202, Method 205. However, while in normal use or while in air transit for repair, many canes received shocks sufficient to break the timer filaments and hence the time-in-use information was lost. Of the remaining seemingly intact units, the readings showed such wide variation that they had to be rejected as unreliable.

Chapter 3.

GENERAL DESCRIPTION OF METHODS

INTRODUCTION

Three distinct measuring procedures were used; one employed a specially designed document termed the "Subtask Check List" while the remaining two procedures were designed to gauge some of the more subjective features associated with mobility using a laser cane. These latter methods utilized a "Task Rating Form" and a "Questionnaire."

THE SUBTASK CHECKLIST

The primary vehicle for objective measurement was the Subtask Checklist (given in Appendix 3) which endeavored to record for analysis a number of the critical events which can occur during travel. Such events included body and/or cane contacts with obstacles, stops, hesitations and orientation errors, etc. These data were tabulated from the videotape and audio recordings, on a block-by-block basis, by O&M staff members who reviewed each traveler's videotaped journey using the long cane and the laser cane. An important prerequisite to the making and interpretation of such counts was the attempt to formulate clear and concise definitions of each of the critical events. For example, a "stop" was defined as "any situation where the traveler comes to a full and complete standstill. The only exception to this will be stops at curbs or alleyways." A full list of definitions is also given in Appendix 3.

In addition to the critical event counts, the Subtask Checklist provided space for recording the total travel time, the traffic conditions (whether heavy, medium or light) and the prevailing weather.

The data which were gathered on the eight subjects has been summarized in Table 5. Run A represents a laser cane run over a route familiar to the traveler. Run B represents a journey over a familiar route using the long cane. Run C represents a laser cane journey over an unfamiliar route and Run D is a long cane run--also over an unfamiliar route. Therefore in reading Table 5 for comparisons of laser cane and long cane performances one should look at A versus B, C versus D and perhaps A and C versus B and D.

THE TASK RATING FORM

The rating procedure was based on a document termed the Task Rating Form (reproduced in Appendix 4). This document posed two classes of questions to the O&M specialists who viewed the video recordings. Class 1 questions focused on specific components of a mobility performance. For example, these questions were concerned with assessing curb detection, obstacle avoidance and other similarly discrete skills. Class 2 questions were concerned with more global features and required an assessment of the safety of a traveler's

BLOCK 1
NORTH

BLOCK 2
NORTH

BLOCK 3
NORTH

BLOCK 4
[illegible]

BLOCK 5
SOUTH

BLOCK 6
SOUTH

[illegible] 7
[illegible]

[illegible]
[illegible]

TABLE 5

Subjects		Continuity of Travel: Hesitations – Block	Continuity of Travel: Hesitations – Street	Continuity of Travel: Stops – Block	Continuity of Travel: Stops – Street	Attempted Circumvention Without Contact: Block – Obstacle	Attempted Circumvention Without Contact: Block – Pedestrian	Attempted Circumvention Without Contact: Street – Obstacle	Attempted Circumvention Without Contact: Street – Pedestrian
1H	Run A	23	2	10	0	26	3	0	0
	" B	22	0	11	0	0	0	0	0
	" C	26	0	15	1	16	6	0	0
	" D	18	0	11	0	6	0	0	0
2H	Run A	0	0	0	0	6	1	0	0
	" B	0	0	0	3	0	0	0	0
	" C	2	0	0	0	3	1	0	0
	" D	0	0	3	1	0	0	0	0
3H	Run A	19	1	15	0	16	0	0	0
	" B	20	2	8	0	0	0	0	0
	" C	15	1	5	3	25	5	2	0
	" D	9	0	4	0	11	0	0	0
4H	Run A	19	2	14	1	26	9	0	1
	" B	11	1	4	2	6	2	0	0
	" C	24	2	23	1	18	5	0	0
	" D	23	1	13	0	1	3	0	0
1P	Run A	58	4	14	2	20	0	1	0
	" B	30	6	11	7	0	0	0	0
	" C	60	6	31	2	27	1	1	0
	" D	39	8	26	5	0	0	0	0
2P	Run A	39	4	10	1	20	1	0	0
	" B	30	4	6	6	0	0	0	0
	" C	47	4	11	2	15	2	1	0
	" D	61	4	21	3	1	0	0	0
3P	Run A	30	3	7	0	6	1	0	0
	" B	17	1	24	1	0	0	0	0
	" C	47	1	19	0	6	1	0	0
	" D	33	1	35	2	0	0	0	0
4P	Run A	41	1	17	2	6	0	0	0
	" B	22	1	15	0	0	0	0	0
	" C	38	3	24	2	3	0	0	0
	" D	20	5	8	2	0	0	0	0

TABLE 5 (cont'd)

Subjects		ATTEMPTED CIRCUMVENTION WITH CONTACT BLOCK						Street						CONTACT WITHOUT ATTEMPTED CIRCUMVENTION Block					
		Cane Contact Obstacle	Cane Contact Pedestrian	Body Contact Obstacle	Body Contact Pedestrian	Both Obstacle	Both Pedestrian	Cane Contact Obstacle	Cane Contact Pedestrian	Body Contact Obstacle	Body Contact Pedestrian	Both Obstacle	Both Pedestrian	Cane Contact Obstacle	Cane Contact Pedestrian	Body Contact Obstacle	Body Pedestrian	Both Obstacle	Both Pedestrian
1H	Run A	1	0	1	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
"	B	3	0	0	0	0	0	0	0	0	0	0	0	11	2	5	0	1	0
"	C	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
"	D	0	0	0	0	0	0	0	0	0	0	0	0	3	1	1	0	0	0
2H	Run A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
"	B	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
"	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
"	D	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0
3H	Run A	3	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
"	B	0	0	0	0	0	0	0	0	0	0	0	0	19	0	1	0	1	0
"	C	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
"	D	0	0	0	0	0	0	0	0	0	0	0	0	5	0	3	0	1	0
4H	Run A	7	0	4	0	2	0	0	0	0	0	0	0	1	0	2	0	2	0
"	B	0	0	0	0	0	0	1	0	0	0	0	0	8	0	12	0	7	0
"	C	2	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0
"	D	0	0	0	0	0	0	0	0	0	0	0	0	8	0	1	0	0	0
1P	Run A	1	1	1	0	0	0	0	0	0	0	0	0	15	0	6	0	1	0
"	B	0	0	0	0	0	0	0	0	0	0	0	0	19	2	12	0	1	0
"	C	1	0	0	0	1	0	0	0	0	0	0	0	6	0	1	0	5	0
"	D	0	0	0	0	0	0	0	0	0	0	0	0	15	1	1	0	3	0
2P	Run A	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
"	B	0	0	0	0	0	0	0	0	0	0	0	0	8	0	2	0	0	0
"	C	2	0	6	0	2	0	0	0	0	0	0	0	3	0	1	0	0	0
"	D	0	0	0	0	0	0	0	0	0	0	0	0	6	0	2	0	9	0
3P	Run A	4	0	1	0	0	0	0	0	0	0	0	0	11	0	1	0	1	0
"	B	0	0	0	0	0	0	0	0	0	0	0	0	24	1	4	1	0	0
"	C	3	0	1	0	0	0	0	0	0	0	0	0	22	0	0	0	1	0
"	D	0	0	0	0	0	0	0	0	0	0	0	0	29	0	3	0	2	0
4P	Run A	2	0	2	0	0	0	0	0	0	0	0	0	15	0	3	0	0	0
"	B	0	0	0	0	0	0	0	0	0	0	0	0	18	1	8	0	0	0
"	C	0	0	0	0	0	0	0	0	2	0	0	0	18	0	7	0	1	0
"	D	0	0	0	0	0	0	0	0	0	0	0	0	6	0	4	0	0	0

TABLE 5 (cont'd)

Subjects		CONTACT WITHOUT ATTEMPTED CIRCUMVENTION Street						ORIENTATION PROBLEM		RECOVERS FROM ORIENT.PR.		ASSISTANCE GIVEN		DEVIATION FROM ROUTE		DETECTS DOWN CURBS	
		Cane Contact Obstacle	Cane Contact Pedestrian	Body Contact Obstacle	Body Contact Pedestrian	Both Obstacle	Both Pedestrian	Blocks	Streets	Blocks	Streets	Blocks	Streets	Blocks	Streets	Yes	No
1H	Run A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
	" B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
	" C	0	0	0	0	0	0	3	0	3	0	0	0	0	1	6	0
	" D	0	0	0	0	0	0	1	1	0	0	1	0	2	1	8	0
2H	Run A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
	" B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1
	" C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0
	" D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2
3H	Run A	0	0	0	0	0	0	2	0	1	0	1	0	1	0	6	0
	" B	0	0	0	0	0	0	2	0	1	0	1	0	2	0	6	0
	" C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2
	" D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
4H	Run A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
	" B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
	" C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4
	" D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1
1P	Run A	0	0	0	0	0	0	1	0	0	0	0	0	0	0	6	0
	" B	7	0	0	0	1	0	0	0	0	0	0	0	0	0	6	0
	" C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
	" D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
2P	Run A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0
	" B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0
	" C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
	" D	0	0	0	0	0	0	2	0	2	0	0	0	0	0	6	0
3P	Run A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
	" B	3	0	0	0	0	0	1	0	0	0	0	0	0	0	5	0
	" C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
	" D	5	0	1	0	0	0	2	1	1	1	1	0	1	0	4	1
4P	Run A	0	0	0	0	0	1	1	0	1	0	0	0	0	0	7	0
	" B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0
	" C	0	0	0	0	0	0	1	0	0	0	1	0	1	0	6	1
	" D	2	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0

TABLE 5 (cont'd)

Subjects		PROGRESS ALIGN-MENT		START AT APP. TIME		VEERS ON STREET CROSSING			NEEDS ASST.ON CROSSING		CANE CONTACT WITH GUIDELINE		VEERS OFF TRAVEL PATH		TRAVEL TIME
		Yes	No	Yes	No	Towards Street	Away from Street	No	Yes	No	Towards Street	Away from Street	Towards Street	Away from Street	
1H	Run A	5	1	5	1	0	3	3	0	6	69	18	0	5	20
	" B	5	1	6	0	1	2	3	0	6	25	61	1	4	26*
	" C	6	0	6	0	0	1	5	0	6	27	27	2	0	25
	" D	6	0	6	0	0	1	5	0	6	25	47	2	2	23
2H	Run A	6	0	6	0	0	0	6	0	6	1	4	0	0	9
	" B	6	0	4	2	0	0	6	0	6	6	8	0	0	10
	" C	6	0	6	0	0	0	6	0	6	5	2	0	0	13
	" D	6	0	6	0	0	0	6	0	6	7	8	0	0	12
3H	Run A	5	1	6	0	0	3	3	0	6	31	47	0	4	20
	" B	6	0	6	0	1	1	4	0	6	30	46	3	1	22
	" C	3	3	6	0	1	1	4	0	6	19	61	2	2	20
	" D	3	3	6	0	2	2	2	0	6	23	82	1	4	18
4H	Run A	5	1	6	0	0	2	4	0	6	2	23	0	0	15
	" B	6	0	6	0	0	2	4	0	6	0	59	0	0	13
	" C	5	1	6	0	0	3	3	0	6	0	37	0	1	18
	" D	4	2	6	0	1	3	2	0	6	1	76	0	4	17
1P	Run A	6	0	6	0	0	3	3	0	6	35	61	1	2	25
	" B	6	0	5	1	0	1	5	0	6	40	78	0	1	19
	" C	6	0	5	1	1	2	3	0	6	68	63	3	3	23
	" D	5	1	6	0	0	2	4	0	6	46	84	1	1	20
2P	Run A	7	0	5	2	0	2	4	0	7	30	26	0	1	25
	" B	7	0	7	0	0	3	3	0	7	62	33	0	0	24
	" C	6	0	6	0	0	1	5	0	6	39	59	2	2	23
	" D	6	0	6	0	0	0	6	0	6	40	81	2	3	27
3P	Run A	3	2	6	0	0	3	2	0	5	19	28	0	3	23
	" B	5	0	4	1	0	3	2	0	4	120	43	3	2	23
	" C	4	2	6	0	0	3	3	0	6	38	94	1	0	26
	" D	5	0	4	0	0	4	0	0	4	25	124	0	2	32
4P	Run A	5	2	7	0	0	4	3	0	7	17	167	0	1	22
	" B	5	2	6	0	0	3	4	0	7	39	180	1	1	20
	" C	3	4	7	0	0	5	2	0	7	39	92	0	2	27
	" D	1	6	6	1	0	6	1	0	7	23	199	0	2	19

*Progress halted by playing children

performance and the confidence he exhibited. A total of 18 questions was included in the form, and associated with each question was a seven-point scale--7 representing an excellent performance and 2 an average performance. The prominence given to the above-average region of the scale reflected the initial selection criteria which specified that the subjects should be accomplished long-cane travelers of above-average ability.

Prior to using the Task Rating Form, each of the 16 raters was provided with a page of instructions. However, owing to time limitations, the raters did not have the opportunity to practice and gain experience in completing the form. In fact it became increasingly apparent as the project developed that, although the questions posed in the form related to factors which O&M instructors consider daily, the idea of examining each factor independently and relating it to an abstract level called the "average performance" was novel to most of the instructors. Thus the results shown in Table 6 contain some erratic entries which must presumably have been caused by inexperience. The data also contain two other sources of error which make the long cane and laser cane performances difficult to compare directly. These are, first, an apparent element of partisanship (revealed by analysis of the rating data, see Chapter 5) which tended to bias the raters' assessments towards those subjects who had received training from their centers, and second, an obvious and striking difference in the standard of "average performance" at the Hines and Palo Alto Centers. This latter effect has been brought out clearly in Table 6 by tabulating the rating given in each category by raters at Palo Alto side by side with the scores given by their opposite numbers at Hines.

THE QUESTIONNAIRE

The second subjective procedure was based upon a questionnaire which sought observations from the subjects which could lead to improvements in the design of the cane and also personal opinions which could reveal the value that each might place on his ownership of a laser cane. A complete list of the forty questions is given in Appendix 6 and a summary of the replies is given in Chapter 6 of this report. This same chapter includes lists of the suggested modifications which the subjects thought might lead to improvements in the performance of the laser cane.

Prompted by the high rate at which the laser cane developed faults during use, three so-called "bonus questions" were asked at the end of the study. These questions attempted to gauge the tolerance of the subjects to laser-cane failures, the annual cost they might be prepared to pay for maintenance and the delay they would be prepared to accept while the device was being repaired. With a warning to take some caution in making generalizations from these figures (particularly in the absence of information about each man's financial and domestic responsibilities), the replies to the bonus questions have been included in Appendix 6.

TABLE 6

HINES & PALO ALTO RATER SCORES OF VIDEOTAPES

	SUBJECT H1				SUBJECT H2			
ORDER OF RUNS	3	1	4	2	2	4	1	3
RUN	LONG F	LASER F	LONG UNF	LASER UNF	LONG F	LASER F	LONG UNF	LASER UNF
H - Hines P - P.A. RATERS	H-5 P-6	H-1 P-1	H-3 P-8	H-7 P-3	H-8 P-4	H-4 P-7	H-2 P-2	H-6 P-1
RATING QUESTION								
1	5 - 3	5 - 5	5 - 5	2 - 6	5 - 7	7 - 7	5 - 7	7 - 7
2	6 - 6	6 - 6	6 - 6	6 - 6	7 - 7	7 - 7	6 - 6	6 - 6
3	5 - 5	4 - 3	6 - 6	2 - 7	5 - 6	7 - 7	6 - 7	6 - 7
4	5 - 6	4 - 5	6 - 6	5 - 6	7 - 7	7 - 7	6 - 7	6 - 6
5	6 - 5	5 - 5	5 - 6	1 - 7	5 - 7	7 - 7	6 - 7	6 - 6
6	5 - 4	6 - 5	6 - 5	4 - 5	7 - 7	7 - 7	6 - 7	6 - 7
7	5 - 4	5 - 4	6 - 5	6 - 5	4 - 7	7 - 6	5 - 7	6 - 6
8	4 - 5	4 - 4	5 - 5	7 - 6	5 - 7	7 - 6	5 - 7	7 - 6
9	3 - 4	7 - 5	5 - 6	2 - 7	2 - 7	7 - 5	5 - 6	7 - 6
10	4 - 4	6 - 5	6 - 6	7 - 7	2 - 7	7 - 6	6 - 7	7 - 7
11	6 - 5	7 - 6	6 - 6	3 - 5	7 - 7	7 - 7	7 - 7	7 - 6
12	6 - 6	6 - 5	6 - 5	5 - 5	7 - 7	7 - 7	6 - 7	7 - 6
13	6 - 6	4 - 4	6 - 7	5 - 7	4 - 7	7 - 7	6 - 7	6 - 6
14	6 - 5	5 - 5	5 - 6	1 - 5	4 - 7	7 - 7	6 - 7	6 - 6
15	5 - 5	3 - 4	6 - 7	6 - 7	2 - 7	7 - 7	6 - 7	6 - 6
16	5 - 5	4 - 5	6 - 6	6 - 6	3 - 7	7 - 7	6 - 7	6 - 6
17	5 - 5	5 - 5	6 - 5	3 - 6	3 - 7	7 - 7	6 - 7	6 - 6
18	6 - 4	5 - 6	6 - 3	6 - 4	4 - 7	7 - 6	7 - 3	6 - 7

NB. The symbols H-1, H-2....H-8 and P-1, P-2....P-8 refer to the raters based at the Hines and Palo Alto VA Centers and should not be confused with the cane travelers indicated by the symbols H1, H2, P1, P2, etc.

TABLE 6 (cont'd)

HINES & PALO ALTO RATER SCORES OF VIDEOTAPES

	SUBJECT H3				SUBJECT H4			
ORDER OF RUNS	1	2	3	4	4	3	2	1
RUN	LONG F	LASER F	LONG UNF	LASER UNF	LONG F	LASER F	LONG UNF	LASER UNF
H - Hines P - P.A. RATERS	H-3 P-3	H-2 P-8	H-7 P-5	H-5 P-6	H-6 P-5	H-8 P-2	H-1 P-7	H-4 P-4
RATING QUESTION								
1	4 - 5	3 - 4	7 - 5	6 - 3	3 - 7	5 - 6	6 - 7	7 - 6
2	5 - 6	4 - 6	7 - 7	6 - 3	3 - 7	7 - 7	5 - 6	5 - 5
3	5 - 5	3 - 5	6 - 5	5 - 3	2 - 5	7 - 7	4 - 6	6 - 6
4	5 - 5	2 - 3	7 - 5	5 - 3	3 - 6	7 - 7	5 - 7	7 - 6
5	3 - 6	4 - 5	2 - 6	6 - 4	4 - 6	5 - 7	4 - 7	6 - 5
6	4 - 6	2 - 5	2 - 6	6 - 6	4 - 5	7 - 7	4 - 7	7 - 6
7	5 - 6	4 - 4	6 - 6	6 - 5	3 - 6	3 - 7	6 - 7	6 - 5
8	5 - 6	5 - 4	1 - 6	7 - 5	4 - 6	5 - 7	6 - 7	7 - 7
9	4 - 6	3 - 4	7 - 5	6 - 5	2 - 6	6 - 5	5 - 7	7 - 7
10	4 - 5	2 - 6	7 - 6	6 - 5	4 - 4	6 - 7	7 - 7	7 - 7
11	1 - 5	5 - 3	7 - 7	6 - 6	4 - 6	7 - 7	6 - 7	7 - 7
12	2 - 5	4 - 4	5 - 5	7 - 5	4 - 6	7 - 7	5 - 7	6 - 7
13	2 - 5	3 - 3	7 - 5	6 - 4	4 - 6	7 - 6	6 - 7	6 - 6
14	2 - 5	4 - 4	7 - 6	5 - 4	4 - 6	7 - 7	6 - 7	7 - 6
15	2 - 6	4 - 6	3 - 6	6 - 4	4 - 7	5 - 7	6 - 7	7 - 7
16	2 - 5	5 - 4	6 - 6	6 - 5	4 - 6	5 - 6	6 - 7	6 - 6
17	2 - 5	3 - 4	5 - 6	6 - 4	4 - 6	5 - 7	5 - 7	6 - 6
18	6 - 6	4 - 5	5 - 6	6 - 6	6 - 6	5 - 7	5 - 7	5 - 7

TABLE 6 (cont'd)

HINES & PALO ALTO RATER SCORES OF VIDEOTAPES

	SUBJECT P1				SUBJECT P2			
ORDER OF RUNS	2	1	4	3	3	4	1	2
RUN	LONG F	LASER F	LONG UNF	LASER UNF	LONG F	LASER F	LONG UNF	LASER UNF
H - Hines P - P.A. RATERS	H-4 P-2	H-5 P-5	H-8 P-3	H-1 P-7	H-1 P-8	H-7 P-4	H-6 P-6	H-3 P-5
RATING QUESTION								
1	7 - 7	4 - 6	2 - 6	6 - 7	6 - 4	3 - 6	5 - 5	6 - 7
2	7 - 7	6 - 6	3 - 6	6 - 7	6 - 6	1 - 7	6 - 6	7 - 7
3	7 - 6	5 - 5	3 - 7	3 - 7	7 - 5	2 - 6	6 - 6	6 - 6
4	7 - 7	5 - 7	7 - 7	4 - 7	7 - 4	5 - 7	4 - 4	7 - 6
5	7 - 7	5 - 6	2 - 7	5 - 7	7 - 5	1 - 6	6 - 5	6 - 6
6	7 - 7	6 - 7	2	4 - 7	7 - 6	6 - 7	5 - 5	7 - 6
7	7 - 7	5 - 7	4 - 7	6 - 7	5 - 4	2 - 7	5 - 5	6 - 7
8	7 - 7	3 - 6	2 - 5	6 - 7	6 - 6	1 - 7	4 - 5	7 - 6
9	7 - 6	4 - 6	2	5 - 6	5 - 5	1 - 7	4 - 5	6 - 5
10	7 - 6	6 - 7	2 - 6	6 - 7	6 - 6	2 - 7	3 - 4	6 - 6
11	7 - 7	6 - 6	7 - 7	7 - 7	7 - 6	7 - 7	4 - 6	7 - 6
12	7 - 7	5 - 6	7 - 7	6 - 7	7 - 5	7 - 7	5 - 6	7 - 6
13	7 - 7	6 - 7	4 - 7	6 - 7	7 - 6	7 - 7	5 - 6	7 - 6
14	7 - 7	5 - 7	4 - 7	6 - 7	7 - 5	6 - 7	5 - 4	7 - 6
15	7 - 7	6 - 6	2 - 6	3 - 7	7 - 6	3 - 7	4 - 5	7 - 6
16	7 - 7	6 - 7	3 - 7	6 - 7	7 - 5	6 - 7	5 - 5	6 - 6
17	7 - 7	5 - 6	3 - 6	5 - 7	7 - 5	5 - 7	5 - 5	6 - 7
18	7 - 7	5 - 7	4 - 6	5 - 7	6 - 4	6 - 6	6 - 6	6 - 7

TABLE 6 (cont'd)

HINES & PALO ALTO RATER SCORES OF VIDEOTAPES

	SUBJECT P3				SUBJECT P4			
ORDER OF RUNS	1	3	2	4	4	2	3	4
RUN	LONG F	LASER F	LONG UNF	LASER UNF	LONG F	LASER F	LONG UNF	LASER UNF
H - Hines P - P.A. RATERS	H-7 P-7	H-3 P-3	H-5 p-1	H-2 P-2	H-2 P-1	H-6 P-6	H-4 P-4	H-8 P-8
RATING QUESTION								
1	1 - 7	2 - 5	5 - 3	3 - 7	4 - 5	4 - 7	7 - 7	1 - 6
2	2 - 7	2 - 7	6 - 4	4 - 7	5 - 6	4 - 6	7 - 7	5 - 4
3	1 - 5	1 - 4	4 - 1	3 - 7	4 - 5	3 - 6	5 - 5	2 - 4
4	1 - 6	2 - 5	3 - 1	4 - 7	4 - 5	4 - 6	5 - 7	4 - 4
5	1 - 6	2 - 6	6 - 2	3 - 7	6 - 6	4 - 6	6 - 7	4 - 5
6	1 - 5	3 - 2	6 - 2	4 - 7	6 - 6	5 - 6	7 - 7	3 - 5
7	1 - 6	2 - 5	4 - 3	3 - 6	3 - 6	4 - 6	5 - 7	2 - 6
8	2 - 6	2 - 6	6 - 5	2 - 7	3 - 7	4 - 6	4 - 7	4 - 6
9	1 - 6	2 - 5	5 - 4	3 - 6	3 - 6	5 - 6	6 - 7	2 - 4
10	1 - 4	1 - 5	6 - 5	4 - 7	5 - 6	5 - 6	6 - 7	2 - 4
11	1 - 6	1 - 6	1 - 1	5 - 7	7 - 7	4 - 6	7 - 7	2 - 3
12	1 - 6	2 - 5	5 - 2	5 - 7	5 - 6	4 - 6	7 - 7	2 - 4
13	1 - 6	2 - 6	5 - 2	3 - 7	5 - 7	5 - 6	7 - 7	3 - 7
14	2 - 6	2 - 5	4 - 1	5 - 7	5 - 6	4 - 6	6 - 7	3 - 5
15	1 - 7	2 - 6	5 - 1	5 - 7	4 - 5	5 - 6	4 - 7	2 - 6
16	1 - 6	2 - 5	4 - 2	4 - 7	4 - 6	5 - 6	5 - 7	3 - 5
17	1 - 6	2 - 5	4 - 1	4 - 6	5 - 6	4 - 6	6 - 7	2 - 4
18	5 - 6	6 - 6	6 - 6	4 - 7	5 - 6	6 - 6	5 - 7	4 - 5

Chapter 4.

ANALYSIS OF SUBTASK CHECKLIST DATA

INTRODUCTION

The data derived from the Subtask Checklists are contained in Table 5. At first glance they reveal a preponderance of zero entries which are brought about in part by the fine breakdown of tasks and contingencies and also, in some degree, by the skill of the travelers. Nevertheless, the fact that the subjects performed so well with either cane provides scant encouragement to the statistician because there remain relatively few columns which contain a sufficient number of entries to analyze.

PROBLEMS OF ANALYSIS

Before formally analyzing any data, an important consideration to be borne in mind is that each occasion on which a subject was tested, either with the long cane or the laser cane, was an essentially different experiment. As far as the objective measures are concerned, this makes the data not directly internally comparable, i.e., the measures as given are, generally, dependent on the particular environment and conditions under which each excursion was made. One subject, for example, encountered children playing during one of his trials. Trials do vary as to the density of pedestrians, traffic and unforeseen incidents--even for a single traveler. Each subject therefore had to cope with a different environment entirely, although the O&M specialists who conducted the trials tried to make every journey as similar in character as possible.

Thus we must reluctantly conclude that only measures which can be normalized (i.e., made more or less independent of the circumstances and environment of the trials), can be usefully analyzed by a formal statistical procedure. For example, a circumvention can only be attempted if an opportunity exists and subject opportunities may be more frequent on some occasions than on others. However, the frequency of such opportunities is reflected in the total number under heading of "attempted circumvention with and without contact" plus "contact without attempted circumvention". Another example is that of "orientation problems," which do not necessarily occur, but the ratio of recoveries to problems might have been useful had there not been so few problems at all.

The possibility of using a ratio for variables under the headings "proper alignment," "start at appropriate time," "veers on street crossings," "need assistance on crossing," for example, occurs to one. In the first two cases, one is deterred by the plentiful number of zeros. In the last case, performance was uniformly excellent. However, in the case of veers we used "number of no veers," (this section deals with street-crossing veers) since, except for subjects P3 and P4, the total number of opportunities was always 6 (no doubt it would have been better to normalize the data for subjects P3 and P4 to equivalent "no veers" on 6 performances; but the influence of such a procedure on the conclusions would have been only slight).

It is apparent from the data that the amount of "cane contact with guideline" depends too much on an individual's cane technique and the prevailing traffic to make an analysis across subjects possible. Subject H2 was clearly benefited by his partial recovery of sight, while subject P3 was not feeling well. Questions left unanswered include the reason for the heavy veering tendency of subjects H4 and P4. "Veers off travel path" and "continuity of travel" exhibit the same trends and it is unfortunate that no suitable normalizer was recorded.

ANALYSIS

The videotaped performances of the 8 subjects were obtained under four sets of conditions labeled A-D and referred to here as "treatments."

A. Laser cane in familiar environment.

B. Long cane in familiar environment.

C. Laser cane in unfamiliar environment.

D. Long cane in unfamiliar environment.

The following variables were analyzed:

(i) "Attempted circumventions (of obstacles and pedestrians) with and without contact" on blocks only, in the form

$$\log\left\{\frac{\text{no. without} + 0.5}{\text{no. with} + 0.5}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (1)$$

(0.5 is added to avoid division by zero. The log transform is used with the objective of improving the shape of the distribution by avoiding a long right tail.)

(ii) "Contacts avoided and contacts made" (of all types) in the form

$$\log\left\{\frac{\text{contacts avoided} + 0.5}{\text{all contacts} + 0.5}\right\} \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

In both (i) and (ii), the value of the variable increases as performance improves.

(iii) Number of "no veers" on street crossing.

The results are summarized in Table 7. The analysis assumes the model described in Chapter 5 but without the rater effects or interactions which are considered there. "Treatments" refer to the combination of cane (whether laser-cane or long-cane) and the familiarity of the run (i.e., whether it was made over a familiar route or unfamiliar route). The last column (a) gives (conservatively) the level of significance reached.

TABLE 7

Attempted circumventions with and without contact (log transformed, see (1))

Source	df	Mean Square	F	α
Subject locations	1	1.720	4.86	0.1
Subjects	6	0.354	3.46	0.05
Order of runs	3	0.271	2.65	0.1
Treatment type	3	1.069	10.46	0.005
Locations X order	3	0.295	2.88	0.1
Locations X treatment	3	0.145	1.41	
Error	12	0.102		

$R^2 = 0.882$

Treatment contrasts:

Laser - Long $t_{12} = 4.75$ (significance level p = 0.001)

Unfamiliar - Familiar $t_{12} = 1.84$ (significance level p = 0.10)

Location effect (Hines) = 0.23

TABLE 7 (cont'd)

Contacts avoided and contacts made (log transformed, see (2))

Source	df	Mean Square	F	α
Subject locations	1	6.723	16.66	0.01
Subjects	6	0.404	4.22	0.025
Order of runs	3	0.424	4.44	0.03
Treatment type	3	5.771	60.35	0.001
Locations X order	3	0.125	1.31	
Locations X treatment	3	0.236	2.48	0.1
Error	12	0.096		

$R^2 = 0.962$

Treatment contrasts:

Laser - Long $t_{12} = 12.48$ (significance level $p = 0.001$)

Unfamiliar - Familiar $t_{12} = 3.70$ (significance level $p = 0.005$)

Location effect (Hines) = 0.21

TABLE 7 (cont'd)

Number of "no veers" on street crossing

Source	df	Mean Square	F	α
Subject locations	6	8.00	1.25	
Subjects	1	6.417	5.31	0.01
Order of Runs	3	2.083	1.72	
Treatment type	3	0.75	0.62	
Locations X order	3	0.25	0.21	
Locations X treatment	3	0.833	0.69	
Error	12	1.271		

$R^2 = 0.793$

CONCLUSIONS

Variables (i) and (ii) are obviously dependent on one another, and therefore their indications are similar. We note that:

(a) Hines-trained subjects appear to avoid contact more successfully than Palo Alto-trained subjects (this may, of course, be an observer-induced effect).

(b) Subjects vary considerably in their ability to avoid contact.

(c) Experience in the experimental situation (order of runs) has some bearing on avoidance.

(d) The type of cane and type of environment are very important. Performance improves with the laser cane and when in an unfamiliar environment.

Variable (iii) shows no significant effect of any interest--we expect that subjects are significantly different from each other.

The following general conclusion can be drawn from an inspection of the data.

If one looks at the "attempted circumvention without contact" columns--in particular the "block-obstacle" column--it is obvious that all subjects avoid obstacles better when they attempt to do so with the laser cane (compare Run A with Run B, and Run C with Run D). From the sparseness of non-zero data under "attempted circumvention with contact," it appears that the subjects rarely attempted a circumvention without accomplishing it. Only subject H1 ever attempted a circumvention with the long cane in which he did not avoid contact, and no subject from Palo Alto ever attempted a circumvention with the long cane at all.

Now consider the data on "continuity of travel." If one uses the "Hesitations-block" column to form ratios of the number of hesitations with the laser cane to the number of hesitations with the long cane in either familiar or unfamiliar terrain, we find that only two of the resulting 16 ratios are less than 1 (note that we add 1 to all entries to avoid division by zero, forming the ratios (Run A + 1)/(Run B + 1) and (Run C + 1)/(Run D + 1) The chance of this occuring at random (if one assumes no differences between canes) is less than 0.004. On the other hand, the same procedure applied to the "Stops-block" column yields 5 ratios less than 1, which should not be regarded as surprising. Evidently more hesitations occur when the laser cane is used than when the long cane is used but not necessarily more stops. One also notices that the Hines-trained subjects appear to hesitate less often than the Palo Alto subjects, even when the scores of Subject H2 are ignored. However, the Hines subjects do not stop much less frequently. Their average rate is similar to the Palo Alto group, although the Palo Alto subjects show some high scores which increase the variability of their data.

Repeating this procedure for "Cane contact with guideline", it seems that the laser cane is not better than the long cane in avoiding contact with the guideline toward the street, but it seems to be better away from the street (1 ratio out of 16 greater than 1). With "veers off travel path", a delicate situation emerges: 8 of the "towards" ratios and 5 of the "away" ratios are 1.00. When these entries are removed from the data, the laser cane performance does not appear to be different from the long cane performance as far as veers are concerned; but we note the number of veers is in most cases extremely low.

Chapter 5.

ANALYSIS OF TASK RATING DATA

INTRODUCTION

This chapter analyzes the data contained in Table 6 which were compiled from the Task Rating Forms completed by 16 mobility specialists.

The gathering of these data from the videotaped recordings of 32 journeys was adopted in an effort to reduce the effects of observer bias. However, only one attempt could be made to videotape each particular journey (or treatment) and, as has been pointed out before, this did not make allowance for "bad days." Additional factors which may have influenced day-to-day performance were learning effects and a progressive lessening of camera consciousness and associated tension. To avoid the bias these trends might introduce, it was therefore decided to vary the order of the treatments according to a Latin Square design for each set of subjects from each training center.

In deciding the number of raters to be used, the relevant considerations were:

(i) limitations on the number of mobility specialists available at each location, and

(ii) the fact that if each rater were to view all 32 tapes, he would have to spend 16 hours of his time. Not only would this have been an imposition, but it is questionable that consistent standards could have been maintained for so long. Thus raters were only asked to view a limited number of tapes.

It was decided that eight raters could be found at each location and that it was reasonable to ask each to view four tapes. Thus each videotape could be viewed twice. It was intended that each rater would see two subjects from each center, one performance under each of the four treatments, and one performance at each possible time (order in sequence of runs). Also each performance would be seen by a rater from each center. The resulting design is given in Table 8.*

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*It will be seen that the objective of having each rater view one performance at each possible time was not realized, owing to an error in copying, so that H-1 saw two 3rd runs and no 4th run and H-2 saw two 4th runs and no 3rd run. The effect of this error was judged to be unimportant.

The order of presentation of tapes to the raters was also considered. A situation in which the treatments are presented in the same order, or the times presented in the same order, should be avoided. A scheme for the order of presentation was drawn up where each treatment was presented equally often in each position of the order of presentation, and the times were mixed up, if not balanced, in a pseudo-random manner.

THE MODEL

The resulting design is an extremely complex incomplete design and a rigorous statistical analysis of a full model which accounted for all factors: subjects, subject locations (i.e., training centers, Hines and Palo Alto), treatments, times (order of runs), raters, rater locations and rater-viewing order, along with the appropriate interactions, would be impossible. We adopted the following simplified model:

Y_{ijktr} = the observation on the jth subject from location i on treatment k at time t as judged by the rater from location r.

$$i = 1, 2;\ j = 1,..4;\ k = 1,..4;\ t = 1,..4;\ r = 1,2.$$

$$Y_{ijktr} = \mu + \alpha_i + b_{j(i)} + K_k + \tau_t + \theta_r + (\alpha K)_{ik} + (\alpha\tau)_{it} + (\alpha\theta)_{ir} + (K\theta)_{kr} + (\tau\theta)_{tr} + \varepsilon_{ijktr} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

b's and ε's are assumed to be independent random variables with zero means and variances σ_b^2 and σ^2 respectively. The fixed effects are assumed to sum to zero on all subscripts, e.g.,

$$\sum_i \alpha_i = 0,\ \sum_k K_k = 0,\ \sum_i (\alpha K)_{ik} = \sum_k (\alpha K)_{ik} = 0 \ . \ . \ . \ . \ \text{etc.}$$

These assumptions are consistent with the usual assumptions of analysis of variance. It is usual also to assume that the random variables are normally distributed. Since the ratings were made on a seven-point scale and there was some a-priori reason to believe that the distributions would be skewed, we could not honestly assume this. However, the procedures of analysis of variance are fairly robust.

It should be understood that the model described by (1) applies to the scores on one item (out of the 18 on the score sheet). It is not advisable to analyze the full set of data as an 18-variate multivariate analysis of variance because

(i) the correlation structure of the ε's is not known, though one can assume high correlation between responses of the same rater on a single performance,

(ii) multivariate techniques are not particularly robust,

TABLE 8

HINES SUBJECTS

ORDER OF RUNS	H1	H2	H3	H4
	A H-1 P-1	D H-2 P-2	B H-3 P-3	C H-4 P-4
	C H-7 P-3	B H-8 P-4	A H-2 P-8	D H-1 P-7
	B H-5 P-6	C H-6 P-1	D H-7 P-5	A H-8 P-2
	D H-3 P-8	A H-4 P-7	C H-5 P-6	B H-6 P-5

PALO ALTO SUBJECTS

ORDER OF RUNS	P1	P2	P3	P4
	A H-5 P-5	D H-6 P-6	B H-7 P-7	C H-8 P-8
	B H-4 P-2	C H-3 P-5	D H-5 P-1	A H-6 P-6
	C H-1 P-7	B H-1 P-8	A H-3 P-3	D H-4 P-4
	D H-8 P-3	A H-7 P-4	C H-2 P-2	B H-2 P-1

Treatments A, B, C, D.

Hines Raters H-1,.... H-8; Palo Alto Raters P-1,.... P-8.

(iii) it is unlikely that any more information would be revealed than in doing 18 univariate analyses, and

(iv) the programming requirements for these calculations would have been beyond the available resources.

DATA ADJUSTMENTS

Each rater had to score each of 17 mobility performance characteristics on a seven-point scale. Since the subjects were all judged to be above average, a score of two was designated as an average performance. The first 12 questions referred to specific aspects of cane techniques and the next five to more general impressions about performance. An 18th question concerned the quality of the videotape and its usefulness for the purpose, and is not really related to other questions.

One rater had some difficulty in rating and omitted five scores – two each on variables 6 and 9 on the same tapes and one on variable 18. The missing observations on variables 6 and 9 were estimated from the general level of the other scores given by that rater for that performance, and the fluctuations of the other rater's scores for that same performance. The missing value for 18 was supplied by considering the rater's response on his other scores for variable 18. This procedure is admittedly unorthodox, but the classical procedures would be extremely complex in the case of this design and an intelligent guess usually serves quite well in that the conclusions are negligibly affected.

Another problem was the fact that one of the subjects regained partial use of one eye before the field trials took place. The raters were not informed of this, however. To eliminate this subject entirely from the data would have made analysis very difficult. Furthermore, compared to other subjects' good performances, his scores were not obviously extraordinary, especially since he was evidently inclined to be overconfident and careless in technique. Therefore, his data were left intact, in the belief that the removal of the "subject effect" would take care of the problem.

RESULTS

The computational results of the analysis are summarized in Tables 9* and 10. The estimates of most interactions have been omitted because such interactions are in general, not significant and uninformative.

The F-ratios given in Table 10 are the ratios of the Effect or Interaction mean square to the Error mean square, except in the case of the

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*α_1 = Location effect for Hines subjects = α_2

θ_2 = Location effect for Palo Alto raters = θ_1

TABLE 9

CLASS ONE QUESTIONS

Estimates		1 Line of travel	2 Detects curbs	3 Crosses streets	4 Auditory Information	5 Non-auditory Information	6 Information from device	7 Long cane technique	8 Appropriate speed	9 Avoids cane contact	10 Avoids body contact	11 Maintains orientation on prescribed route	12 Solves orientation and mobility problems	Average 1 - 12
Mean	μ	5.20	5.72	4.94	5.34	5.25	5.42	5.20	5.31	4.98	5.39	5.70	5.63	5.34
Subject location	α_1	.17	.19	.34	.25	.09	.11	.20	.25	.27	.36	.23	.13	.22
Times	τ_1	-.27	-.28	-.19	-.34	-.19	-.23	-.20	-.25	-.11	-.52	-.64	-.69	-.33
	τ_2	.17	.22	-.13	-.16	0.0	.02	.23	.63	.08	.36	-.58	-.13	.06
	τ_3	.36	.53	.38	.28	.25	.02	.05	0.0	.27	.36	.55	.31	.29
	τ_4	-.27	-.47	-.06	.22	-.06	.20	-.08	-.38	-.23	-.20	.67	.50	-.01
Treatments	κ_1	-.20	.09	-.06	-.03	.19	-.05	-.27	.06	-.48	-.70	-.14	-.19	-.15
	κ_2	-.27	-.16	-.25	-.16	-.02	.08	-.33	-.50	-.11	-.14	.05	-.06	-.17
	κ_3	.23	.16	.25	.09	0.0	-.23	.30	-.31	.33	.30	.11	.13	.11
	κ_4	.23	-.09	.06	.09	0.0	.20	.30	.75	.27	.55	.02	.13	.21
Rater location	θ_2	.58	.44	.53	.34	.69	.36	.61	.72	.64	.52	.30	.25	.50
Subjects b (H)	1	-.88	.09	-.53	-.22	-.34	-.53	-.41	-.56	-.38	-.13	-.44	-.25	-.38
	2	1.13	.59	1.09	1.03	1.03	1.22	.59	.69	.38	.38	.94	1.00	.84
	3	-.75	-.40	-.65	-1.22	-.84	-1.03	-.15	-.69	-.38	-.63	-.94	-1.13	-.73
	4	.50	-.28	.09	.41	.16	.34	-.03	.56	.38	.38	.48	.38	.28
b (P)	1	.59	.47	.78	1.28	.59	.44	1.25	.31	.53	.84	1.28	1.00	.78
	2	.22	.22	.91	.41	.09	.81	.13	.19	.03	-.03	.78	.75	.38
	3	-.91	-.66	-1.34	-1.47	-1.03	-1.56	-1.25	-.56	-.72	-.91	-1.97	-1.38	-1.15
	4	.09	-.03	-.34	-.22	-.34	.31	-.13	.06	.16	.09	-.09	-.37	-.01
Subj.Loc.× Rater Loc. $(\alpha\theta)_{11}$		.33	.28	.19	.19	.03	.02	.39	.41	.27	.27	.17	.13	.22
Treatment Contrasts:														
(Laser-Long) Fam.		-.06	-.25	-.19	-.13	-.38	.13	-.06	-.56	.38	.56	.19	.13	-.02
(Laser-Long) Unf.		0.0	-.25	-.19	0.0	0.0	.44	0.0	1.06	-.06	.25	-.13	0.0	.09
(Laser-Long)		-.06	-.50	-.38	-.13	-.38	.56	-.06	.50	.31	.81	.06	.13	.07
Unf. - Fam.		.94	.13	.63	.38	0.0	-.06	1.19	.88	1.19	1.69	.19	.50	.64
Type X Fam.		.06	0.0	0.0	.13	.38	.31	.06	1.63*	.44	-.31	-.31	-.13	.11
Time Contrasts														
Linear		.19	.25	.88	2.13*	.63	1.31	.19	-1.00	-.19	.94**	5.06°°	4.00°°	1.16
Quadratic		-1.06*	-1.5°	-.50	-.25	-.5	-.06	-.56	-1.25°	-.69	-1.44	.06	-.38	-.68

°Significant at 2 1/2% °°Significant at 1%

*Significant at 10% **Significant at 5% level

TABLE 9 (cont'd)

CLASS ONE QUESTIONS

Estimates	1 Line of travel	2 Detects curbs	3 Crosses streets	4 Auditory Information	5 Nonauditory Information	6 Information from device	7 Long cane technique	8 Appropriate speed	9 Avoids cane contact	10 Avoids body contact	11 Maintains orientation on prescribed route	12 Solves orientation and mobility problems	Average 1 - 12
Multiple Correlations R^2 = Proportion 4 Variance explained by regression	.54	.51	.52	.54	.44	.46	.60	.69	.54	.57	.63	.62	.5[illegible]
Error Mean Square σ^2	2.29	1.69	2.43	2.10	2.70	2.44	1.57	1.43	2.22	2.12	2.18	1.47	1.27
Subject σ^2 error b	.39	.01	.58	.87	.24	.75	.42	.16	0.0	.11	1.11	.83	.44

TABLE 9 (cont'd)

CLASS TWO QUESTIONS

Estimates		Relaxed & Confident	Sensitivity to informational changes	Travels safely	Travels efficiently	Total performance	Videotape rating
Mean	μ	5.66	5.41	5.34	5.45	5.22	5.67
Subject location	α_1	0.0	.06	.28	.14	.16	- .11
Times	τ_1	- .59	- .41	- .41	- .52	- .47	- .23
	τ_2	- .03	- .41	.34	.11	- .09	.20
	τ_3	.41	.53	- .03	.17	.34	.08
	τ_4	.22	.28	.09	.23	.22	- .05
Treatments	κ_1	- .09	- .16	- .09	- .27	- .03	.08
	κ_2	- .22	.09	- .09	- .02	- .03	.14
	κ_3	.22	.09	- .22	.05	.03	- .30
	κ_4	.09	- .03	.41	.23	.03	.08
Rater location	θ_2	.41	.41	.75	.48	.53	.23
Subjects b (H)	1	- .03	- .72	- .25	- .22	- .38	- .56
	2	.97	- .78	.63	.78	1.00	.19
	3	-1.28	- .84	-1.00	- .72	-1.00	- .06
	4	.34	.78	.63	.16	.38	.44
b (P)	1	.72	.91	.44	.94	.69	.22
	2	.72	.53	- .56	.68	.81	.09
	3	-1.66	-1.34	- .81	-1.44	-1.48	- .03
	4	.22	- .09	- .19	- .19	- .06	- .28
Subj. loc. × Rater loc. $(\alpha\theta)_{11}$		.25	.06	.13	.20	.09	.17
<u>Treatment Contrasts</u>							
(Laser-Long)Fam.		- .13	.25	0.0	.25	0.0	.06
(Laser-Long) Unf.		- .13	- .13	.63	.19	0.0	.38
Laser-Long		- .25	.13	.63	.48	0.0	.44
Unf.-Fam.		.63	.13	.38	.56	.13	- .44
Type × Fam.		0.0	- .38	.63	- .06	0.0	.31
<u>Time Contrasts</u>							
Linear		2.88°	3.00°	1.13	2.31**	2.5**	.44
Quadratic		- .75	- .25	- .63	- .56	- .50	- .56
	R^2	.63	.59	.53	.66	.58	.36
Error mean square	σ^2	1.55	1.75	2.36	1.15	1.69	1.17
Subject error	σ^2_b	.89	.68	.21	.63	.71	0.00

"Subject location" effect (α in (1)), where theory requires that this ratio be relative to the "subject" mean square. Because of the missing observations, the number of degrees of freedom associated with the error mean square in variables 6 and 9 should possibly be reduced, but this does not have a profound effect on the results.

Since the "treatments" are of principal interest in this study, we examined five specific contrasts between them:

(i) (Laser-Long) Familiar, i.e., $K_2 - K_1$

(ii) (Laser-Long) Unfamiliar , i.e., $K_4 - K_3$

(iii) (Laser-Long) i.e., $(K_2 + K_4) - (K_1 + K_3)$

(iv) Unfamiliar - Familiar, i.e., $(K_3 + K_4) - (K_1 + K_2)$

(v) Type X Familiarity interaction, i.e. $(K_4 + K_1) - (K_2 + K_3)$

The Scheffé multiple-comparisons procedure was used to gauge whether any of these quantities was statistically significantly different from zero. From Table 9 it is obvious that the results were disappointing. Only the Type X Familiarity interaction appears significant, at only the 10% level, for variable 8 - travel at appropriate speed. This seems hard to interpret. Table 10 also indicates that treatment effects are significant, at the 10% level, for variable 10 - avoiding body contact; but the contrasts do not indicate precisely what is important, although they point towards the influence of familiarity of the territory in increasing body contacts.

In order to study the "time effects" for possible trend, we use contrasts of the time effect estimates which represent the linear and quadratic components of regression of τ_1, τ_2, τ_3, τ_4 on 1, 2, 3, 4; i.e., we pretend the times are equally spaced:

(i) Linear $(3\tau_4 + \tau_3) - (\tau_2 + 3\tau_1)$

(ii) Quadratic $(\tau_1 + \tau_4) - (\tau_2 + \tau_3)$

These two contrasts are the only ones we intend to consider and they are orthogonal. Therefore, a t - test can be used on each, rather than a multiple comparisons technique.

From Table 9 we see significant linear increasing trends for variables 4 (auditory information), 11 (maintaining orientation), 12 (solving O&M problems), 13 (relaxed and confident travel), 14 (sensitivity to informational changes), 16 (efficient travel), 17 (total performance). Thus it appears that, in general, these characteristics improve with practice, at least over the short term in the experimental situation.

Significant negative quadratic trends, indicating curvature up and then down, are shown by variables 1 (maintaining line of travel), 2 (detection of curbs), 8 (traveling at appropriate speed), and 10 (avoiding body contact). Thus it appears that these characteristics tend to improve and then deteriorate over the short term in the experimental situation. One wonders why 11 (maintaining orientation) improves while 1 (maintaining line of travel) improves and then deteriorates. Otherwise, one may ask what underlying property discriminates between the two types of variables--those which improve steadily and those which improve and then deteriorate.

Table 10 shows that the most consistently nonzero effect is the "Rater location." Palo Alto raters tend to be more generous than the Hines raters in scoring. This is obvious on scanning the data. Although the "Subject locations" do not appear to have any significant effect, it is worth noting that the α_1's are all positive, indicating that the Hines subjects may have a slight edge on the Palo Alto subjects.

The only interaction which occasionally shows a high degree of statistical significance is the Subject-location × Rater-location interaction. The constraints on the values of the: $(\alpha\theta)_{22}$ as defined by the model demand that $(\alpha\theta)_{11} = -(\alpha\theta)_{12} = -(\alpha\theta)_{21} = (\alpha\ )$, so we give only the $(\alpha\theta)_{11}$'s., which are all positive. Thus it appears that there is a tendency for raters to favor subjects from their own location.

The subjects themselves contribute quite substantially to the variation. The individual contributions are given in Table 9 and are seen to be fairly consistent across variables. We notice that subject H2, who regained partial vision in one eye, does very well, but he is not obviously better than subject P1 when one considers each relative to the average performance in his group. If H2's performance were far superior to the rest of his group one would expect that the values of b_{1j} for $j = 1, 3, 4$ (the other members of the group) would be small and tending to be negative; but H3 appears at least as poor as H2 is good. Likewise, the performance of P1 is balanced by that of P3. Indeed P3 may be pulling the average of the Palo Alto group down, affecting the value of $\alpha_2 = -\alpha_1$. Adjusting for group difference by adding α_1 to the Hines group estimates and subtracting α_1 from the Palo Alto group estimates does create a difference between them. The question arises whether the Hines group is inherently better (at getting high scores) than the Palo Alto group or if the difference (if any) lies in the training and follow up at the two centers.*

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*We remind the reader that the estimates of α_1 do not give any strong support to the hypothesis that $\alpha_1 \neq 0$, other than a consistently positive value across variables.

TABLE 10

CLASS ONE QUESTIONS
ANALYSIS OF VARIANCE

Source	DF	F 1	2	3	4	5	6	7	8	9	10	11	12	Ave.
Subject locations	(1,6)	.35	1.29	1.08	.44	.12	.09	.54	1.48	2.44	2.78	.32	.12	.64
Times	(3,36)	.70	1.99	.43	.68	.20	.21	.36	2.22	.34	1.43	3.66**	3.03**	.79
Treatment	(3,36)	.52	.21	.29	.11	.14	.23	1.20	3.41**	1.02	2.27*	.08	.26	.44
Rater locations	(1,36)	9.33°°	7.25°	7.44°°	3.60*	11.22°°	3.38*	15.13°°°	23.17°°°	11.81°°	8.04°°	2.59	2.72	12.49°°
Subjects w. locations	(6,36)	2.37*	1.03	2.90°	4.30°°	1.71	3.46°°	3.14°	1.90	.84	1.41	5.07°°	5.49°°°	3.71°°
SL × Time	(3,36)								2.16	2.25*				
SL × Treat-ment	(3,36)										2.39*			
SL × RL	(1,36)	3.01*	3.00*					6.22°	7.40°°	2.03	2.13			2.47
Time × RL	(3,36)								2.26*					
Treatment × RL	(3,36)													

Omitted values are < 2.0

CLASS TWO QUESTIONS
ANALYSIS OF VARIANCE

Source	DF	13	14	15	16	17	Ave.
Subject locations	(1,6)	0.0	.04	1.25	.20	.21	.84
Time	(3,36)	1.9	2.11	.66	1.67	1.24	.47
Treatment	(3,36)	.39	.13	.52	.59	.01	.54
Rater locations	(1,36)	6.80°	6.03	15.25°°°	12.97°°°	10.66°°	2.98*
Subject w. location	(6,36)	5.60°°°	4.09°°	1.72	5.36°°°	4.32°°	.77
SL × Time	(3,36)						
SL × Treatment	(3,36)		2.71*		2.86*		
SL × RL	(1,36)	2.57			2.28		
Time × RL	(3,36)	2.11					
Treatment × RL	(3,36)						

TABLE 11

CLASS ONE QUESTIONS
RATER EFFECTS

		1	2	3	4	5	6	7	8	9	10	11	12	Ave.
(Mean														
Residuals)	H-1	.42	-.22	-.52	.58	.08	-.22	.42	.34	.45	.56	.33	.11	.10
	2	-.42	-.16	-.11	-.86	.42	-.41	-.48	-.47	-.33	-.44	.30	-.23	-.27
	3	-.11	-.16	.59	.47	-.19	.42	.33	.38	.08	-.33	-.95	-.50	.00
Raters	4	1.45	.91	1.28	1.09	1.00	.98	1.14	.69	1.39	.98	.92	.69	1.04
	5	.98	1.00	.93	.13	1.78	1.48	.61	.88	.48	1.14	.52	1.00	.91
	6	-.23	-.50	-.44	-.94	.21	-.61	-.17	-.13	.02	-.02	-.52	-.63	-.33
	7	-.55	-.81	-1.28	-.03	-2.41	-1.11	-.36	-1.16	-1.08	-.30	-.55	-.34	-.83
	8	-1.55	-.06	-.47	.72	-.91	-.55	-1.48	-.53	-1.02	-1.61	-.05	-.09	-.63
	P-1	-.80	-.72	-1.56	-1.34	-1.31	-.98	-.73	-.56	-.70	-.45	-.95	-1.28	-.95
	2	.30	.25	.59	.56	.63	.80	.64	.69	.39	.17	.17	.59	.42
	3	.48	.63	1.13	.50	1.28	-.52	.23	.19	.55	.20	.33	-.06	.41
	4	.52	.63	.25	.69	.22	.39	.70	.69	1.33	1.05	.55	.56	.63
	5	.27	.50	-.50	0.0	.13	.23	.27	.06	-.08	-.05	.20	-.06	.08
	6	-.83	-.72	-.16	-.41	-.56	-.30	-.61	-.44	-.39	-.67	.58	.31	-.35
	7	.83	.31	.59	.94	.38	.70	.48	.06	.33	-.04	.52	.84	.49
	8	-.76	-.88	-.34	-.94	-.75	-.33	-.98	-.69	-.64	-.20	-1.39	-.91	-.73
Mean squares	df													
Rater	14	2.70	1.66	2.88	2.48	4.54	2.35	2.20	1.52	2.31	2.12	1.92	1.79	1.64
Residual	22	2.04	1.71	2.14	1.86	1.52	2.50	1.17	1.37	2.17	2.11	2.35	1.27	1.03
$F(14,22)$		1.32	.97	1.34	1.33	2.98	.94	1.88	1.11	1.06	1.01	.82	1.41	1.60
	R_r^2	.749	.700	.741	.751	.805	.660	.816	.821	.724	.738	.753	.799	.796

TABLE 11 (cont'd)

CLASS TWO QUESTIONS
RATER EFFECTS

		13	14	15	16	17	18
(Mean Residuals)	H-1	- .17	.13	- .44	.03	.09	.08
	2	- .45	0.00	.38	.03	- .03	- .52
	3	- .56	- .56	- .16	- .67	- .38	.64
Raters	4	1.13	1.25	1.16	.89	1.13	.20
	5	1.13	.94	1.50	.89	1.13	.08
	6	- .75	- .31	- .06	- .08	- .19	.11
	7	.03	- .50	-1.15	- .05	- .72	.36
	8	- .34	- .94	-1.22	-1.02	-1.03	- .95
	P-1	-1.03	-1.13	-1.81	- .80	-1.16	.36
	2	.50	.19	.56	.55	.47	- .02
	3	.88	.63	.81	.33	.50	- .30
	4	.25	.88	.75	.61	.69	.73
	5	- .38	- .03	- .06	.02	.31	.33
	6	- .41	- .34	- .69	- .33	- .31	- .55
	7	.50	.50	.38	.45	.78	.64
	8	- .31	- .69	.06	- .83	-1.22	-1.20
Mean square	df						
Rater	14	1.87	2.09	3.49	1.57	2.51	1.37
Residual	22	1.35	1.54	1.64	.90	1.18	1.06
F(14, 22)		1.39	1.35	2.12*	1.75	2.13*	1.30
	R_r^2	.805	.779	.802	.841	.821	.649

The variance due to subjects alone, i.e., σ_b^2 can be estimated from the "Subjects within locations" mean square and the Error mean square. These estimates are given in Table 9. An estimate of 0.0 results when the corresponding F ratio is less than 1.0.

The values of the multiple correlation, R^2, given in Table 9, represent the proportion of variation accounted for by fitting the model (1). The best value is 0.69 and the worst, disregarding variable 18, is 0.44. The fit is not very good and we speculate that this is due to the fact that we have not taken out a "Raters within locations" component. This cannot be done exactly, but an approximate procedure estimates the individual "Rater effect" by averaging the residuals from the fit of model (1) to the data, for each rater. The results are given in Table 11. A high degree of consistency for each rater across variables may be seen. A "Raters within locations" mean square and a new Error mean square has been computed and an approximate F ratio is shown. The results suggest wide variation in the raters' assessment of variable 5 (use of nonauditory information) and possibly variable 15 (travels safely) and 17 (total performance). It is seen, therefore, that the values of R^2 obtained on eliminating the additional rater component are substantially improved, but the error mean square remains about the same.

The entire set of calculations was repeated for the average score on the "Class one questions." This might serve as a summary score. The same tendencies are reflected in the estimates, but the detail is obscured, as is any indication of specific significant effects. For example, no significant trend is indicated in the estimates of time effects. Comparison of the error mean square for this average score and the 12 individual error mean squares indicates a very high average correlation coefficient between the variables--about 0.58 if the "Rater" component of variance is not removed, and about 0.52 if it is. The difference in the two estimates is probably due to estimation error.

Variable 18 (videotape rating) needs to be considered separately since it is not a mobility rating. In fact, there is no reason why model (1) should apply, unless the raters are highly influenced, in rating 18, by the previous 17 scores they have given. The estimates for variable 18 do not follow the same tendencies established by variables 1-17, :α_1 is negative and the only negative treatment effect is K_3. The individual subject effects are quite small: there is a slight correlation between the variable-18 values and the "average of 12" values, and the signs of the values are the same in both cases. Only the "Rater Locations" effect appears significant--at the 10% level: thus indicating that Palo Alto raters were less critical of the tapes than were the Hines raters.

Chapter 6.

SUMMARY OF REPLIES TO QUESTIONNAIRE

INTRODUCTION

The questions comprising the follow-up questionnaire were administered in batches at prescribed intervals through the follow-up period. The point in time at which a particular question would be posed was listed against that question by means of a simple code. Thus the symbols T1, T2 and T3 associated with a question served to indicate that it should be asked during one or more of the telphone interviews. Similarly the symbols V1 and V2 referred to questions to be asked during visits made by the O&M research team.

The objectives of the questionnaire were two-fold; first to provide an insight into the subjective factors governing user acceptability; second to gather suggestions for the structural improvement of the laser cane. A total of 40 questions were posed. The replies to the questions are summarized in the following section.

THE REPLIES

Q1. Is the process of learning to use the laser cane, in your view: very easy, fairly easy, difficult, or very difficult? (T2, T3, V2)

> Initially six subjects answered "fairly easy" and two subjects answered "very easy." One of the latter changed his opinion to "fairly easy."

Q2. How would you rate your confidence in the device: very high, high, low, or very low? (T1, T2, V1, T3, V2)

> Replies to this question usually fell in the "high" or "very high" category although opinions fluctuated toward the lower categories when failures and malfunctions occurred.

Q3. Do you find the device comfortable to use? Please explain. (T1, V1, T3, V2)

> All of the subjects replied "yes" consistently, but some qualified their opinions with remarks to the effect that the diameter of the cane shaft required some time to get accustomed to and that the position of the tactile stimulator could be improved. Three subjects pointed out that the laser cane was more difficult to handle in areas with grass lines or cracked sidewalks because the tip caught too easily in the cracks, etc.

Q4. When using the laser cane, how, in your opinion, does it compare with the long cane in the following areas? (V1, T3, T2)

a) Weight

b) Balance

c) Touch

d) Position in which the device is held

i) All but one of the subjects said that they were aware of the heavier weight of the laser cane; but the majority claimed that they were able to adjust to the weight, given time. Two subjects indicated that the weight reduced maneuverability in some situations.

(ii) Replies to this question showed some evidence of instability. Some subjects rated the balance as fair-to-good. Three subjects preferred the long cane.
Four subjects concluded that there was little difference. One subject thought that the laser cane had superior balance.

(iii) Opinions on touch also fluctuated. The majority, however, appeared to favor the long cane or later took the position that the two canes were much the same. One subject concluded that the laser cane was superior.

(iv) The angle at which a cane is held can depend on the grip. Subjects with small hands or short fingers adopted unusual grips in order to reach the tactile stimulator and consequently had a tendency to hold the cane at an acute angle with respect to the ground. In one case, this was thought to be the reason why waist-high obstacles were missed.

Q5. Is the device reasonably durable? (T3, V2)

The subjects who experienced the most failures consistently responded "no." Those who experienced the least difficulty said "yes." Several subjects thought that the cane was structurally strong enough to withstand normal collisions with obstacles, although at the same time expressing doubts about its electronic durability.

Q6. Is the device reasonably maintenance-free? (V1, T2, T3, V2)

Most of the subjects were emphatic in their opinion that the device in its present form was not "reasonably maintenance-free." These opinions reflected the frequency of cane breakdowns that they had experienced. Two subjects who encountered few problems answered "yes" to the question.

Q7. Do you feel relaxed using the laser cane? (V1, T2, T3, V2).

All subjects consistently responded that they were relaxed using the laser cane. Five subjects felt it took a while, after returning home, to achieve relaxed travel. One subject expressed his concern for the safety of the cane in congested areas.

Q8. Do you feel as relaxed as you do when using your long cane or collapsible cane? (V1, T2, T3, V2)

All subjects stated consistently that they were as relaxed with the laser cane as with the long cane. Several subjects stated that they were more relaxed with the laser cane than with the long-cane, particularly on unfamiliar territory.

Q9. Are the audible signals easily interpreted? (T1, V1, T2, T3, V2)

In total agreement all subjects responded "yes" the audible signals were "easily interpreted." On several occasions a subject qualified his answer stating "under most circumstances." The most commonly mentioned situations that presented signal interpretation difficulties were areas with heavy pedestrian traffic, overpowering auto traffic noise, and after rain storms. These situations created an overabundance of signals, masked signals or meaningless information.

Q10. Do you have any difficulty telling the difference between the audible signals of the laser cane? If so, which one(s) confuse you? (T1, V1, T2, T3, V2)

Most of the subjects consistently reported they had "no difficulty" distinguishing the audible signals of the laser cane. However, a few stated that the Middle-and Lower-channel frequencies "appeared to be too close together."

Q11. Can you readily feel the tactile stimulator? If not, does it require undue concentration? (V1, T2, T3, V2)

Almost all of the subjects stated "yes" consistently. One subject, whose opinion fluctuated, owned a cane which had a weak tactile stimulator. One subject could feel the stimulator through medium thick gloves during winter. Others mentioned that without gloves in winter their fingers "got numb from the weather" and they experienced difficulty with the tactile stimulator. A side comment that two subjects made was that they found it difficult to maintain finger contact with the stimulator when weather conditions were humid or cold. Only one of the subjects felt that the tactile stimulator, with the exceptions listed, required undue concentration.

Q12. Which signal, audible or tactile, do you prefer to use for the Middle Channel? If you have preferences, under what circumstances do they apply? (V1, T2, T3, V2)

Two subjects preferred the tactile stimulator when it could be used. Four subjects preferred the audible signal outdoors and the tactile signal indoors, especially in pedestrian traffic, while two subjects almost exclusively preferred the audible signal. Qualifying statements often pointed to situational preference and a desire for both types of signals.

Q13. Does your index finger ever become fatigued or numb to the tactile stimulator? If so, under what circumstances? (T1, V1, T2, T3, V2)

Several subjects said that they initially experienced fatigue and numbness, however, toward the end of the program all subjects answered "no." The only qualification to that answer was that in very cold weather the hand would get numb due to the cold, and then it was difficult to feel the signals.

Q14. Which channel do you use the most? The least? (V1, T2, T3, V2).

All subjects consistently agreed that the Middle Channel was used the most. Three subjects stated the Upper Channel was the least used, while five subjects used the Lower Channel the least.

Q15. Are there any occasions on which you do not respond to the signals of the laser cane. If so, under what circumstances do you not respond? (V1, T2, T3, V2)

All subjects answered "yes" to the first part of this question. In situations such as heavy pedestrian traffic, narrow corridors, crowded buildings, elevators and highly familiar routes, the subjects largely ignored the laser signals.

Q16. With reference to question 15, what objects do you fail to respond to? V1, T2, T3, V2)

Lists of objects included clusters of bicycles, crowds of pedestrians, objects close to buildings, and garbage cans. Subjects finding themselves among objects of this type would ignore laser signals--particularly those arising from the Lower Channel and adopt conventional long-cane touch technique.

Q17. In which situations do you feel that the cane is most useful to you? (V1, T2, T3, V2)

All of the subjects said that the laser cane was most useful in unfamiliar areas. Some subjects listed the locating of edges--building lines, elevated platforms, etc. Others mentioned conditions of light pedestrian traffic and loud noise.

Q18. For what particular purpose is each channel most useful?
&
Q19. For what objects is each of the three channels most useful? (V1, T2, T3, V2)

All subjects agreed that the Upper Channel was useful for the detection of overhanging branches, signs, etc. Some subjects monitored objects at the side of the travel path, rolling their wrists, on occasion. One subject gauged the distance of pedestrians or obstacles by reacting to the signals with a stop response. Two subjects stated that they seldom used the Upper Channel in their home areas, while two others utilized it as a secondary warning system or scanning system for side openings.

The Lower Channel was utilized regularly by only two subjects, the purpose being to detect elevated train platform edges and shoreline them. Their comments on the Lower Channel were quite favorable. The remaining subjects had little use for the channel with the exception of detecting a known flight of stairs. None of the subjects interviewed said that the Lower Channel was useful for detecting curbs. The subjects all consistently listed use for the Middle Channel basically as an obstacle detector, with the most frequently mentioned obstacles being poles, parking meters, pedestrians, and building fronts. The amount of benefit received by the users in pedestrian traffic was said to be related to the number of pedestrians, although dense crowds generated more signals than could be usefully distinguished. The next most important use of the Middle Channel was split between providing a directional-change indication and scanning for landmarks. The most commonly mentioned objects which could be detected were bushes, light posts, building fronts and off-sidewalk landmarks along routes. At least three subjects also located openings with the channel.

Q20. Do you feel that the range at which it is possible for you to detect objects with each channel is adequate? (T2, V2)

Four subjects consistently responded "yes." Two subjects wanted the range of the Middle Channel extended and two subjects wanted an extension of two more feet in the range of the Upper Channel. Also, at least one subject wanted a few extra feet added to the range of the Lower Channel. One subject found the present setting of 14 feet on the Middle Channel difficult to utilize in narrow indoor quarters or complex outdoor environments.

Q21. Do you find the laser cane more useful in a familiar environment or in an unfamiliar one? (T3, V2)

Regardless of how much the subjects traveled in unfamiliar areas, all consistently stated they found the laser cane more useful in an unfamiliar area.

Q22. What general differences in technique or utilization do you note with the device in familiar and unfamiliar environments? (T3, V2)

With the exception of minor differences in technique such as slowing the pace, widening cane arc or rolling the wrist to scan peripheral travel areas, the same cane technique was used by all subjects. In an unfamiliar area, scanning movements were common, with the cane thrust farther forward. All subjects consistently agree that, in familiar areas, prior knowledge reduces the amount of information from the device which is used. All subjects also agree that they pay more attention to the laser signals if they are in an unfamiliar area. Responses to this question were only moderately consistent in specifics but quite consistent in theme.

Q23. Does the device provide more aid to you in orientation or in the recognition of landmarks in familiar areas than the long cane? (T2, T3, V2)

Most subjects were consistently quite positive that the laser cane was "more helpful" in the described areas than the long cane. One subject, when first questioned, said "no."

Q24. Does the device aid you in orientation or in the recognition of useful landmarks in unfamiliar areas; how does this capability compare with that provided by your long cane in unfamiliar areas? (T2, T3, V2)

Most of the subjects consistently agreed that the laser cane was more effective than the long cane in orientation and in the recognition of landmarks in an unfamiliar area. One subject changed his response to "no" on the last interview, stating the long cane was more helpful due to its physical contact with objects which enabled the user to identify the objects. With laser beam contact, this advantage is lost because the beams are unable to convey information about texture.

Q25. Does the laser cane or its signals create any confusion in orientation procedures or hinder use of environmental information? (T1, V1, T2, T3, V2)

Seven subjects consistently answered "no" while one subject qualified his statement by pointing out that the combination a high noise level and busy traffic created a situation in which "one could easily become confused." Another subject said that the laser cane frequently attracted enquiries from the public and in the process of replying he could lose his sense of direction.

Q26. Does the laser cane give reliable and useful direct travel path information? (T1, V1, T2, T3, V2)

Consistently the responses of the four subjects were quite positively "yes," with qualifying statements relating to the Lower Channel.

Q27. Does the laser cane appear, at times, to be giving inexplicable signals? (T1, V1, T2, T3, V2)

As expected, there were inconsistent responses by all eight subjects during various segments of the follow up program. Primary reasons were malfunctions and difficulties with the Lower Channel.

Q28. Can you readily react to the tactile and/or audible signals of the device? (T1, V1, T2, T3, V2)

All subjects consistently responded "yes" with no qualifying statements.

Q29. Can you readily determine the direction and width of objects with the laser cane while traveling at your normal gait? (T1, V1, T2, T3, V2)

The majority replied that at their normal gait they could determine the direction of objects, but not the width, unless the objects were quite large. Several qualifying statements by students indicated that the dimension of width was difficult to ascertain at normal walking speeds, particularly in the case of obstacles such as bicycles and glass doors. One subject stated consistently, with some qualification, that he could detect both direction and width.

Q30. Can you roughly estimate your distance from a detected object soon enough to take the proper action? (T1, V1, T2, T3, V2)

Almost all of the subjects consistently replied "yes," while two subjects responded "yes, most of the time" during early interviews. On the last interview, one subject said "not on everything" because he felt that the detection range varied according to the type of obstacle detected with his cane.

Q31. Do you feel your line of travel has improved using the laser cane in comparison with your usual line of travel when using your long cane? (T2, T3, V2)

Six subjects consistently replied "yes" while two subjects consistently answered "no." One subject thought that the laser cane improved his line of travel considerably while another thought that his long cane travel was straighter because he plowed ahead in blissful ignorance of the margin by which he was missing obstacles.

Q32. Do you feel your speed of travel has been changed by using the laser cane as compared to your usual rate using the long cane? (T2, T3, V2)

This question was inconsistently answered by six subjects while the remaining two subjects consistently answered "no." Four subjects for the most part, and specifically on the last interview, answered "yes," claiming a slight increase in speed with the laser cane. No subject reported that the laser cane decreased his travel speed.

Q33. Do you feel that, compared to your long cane, the laser cane provides you with any added information or a state of well-being that enables you to perform differently when traveling? (T3, V2)

The majority of the eight subjects commented that they "felt more comfortable" traveling with the laser cane. All subjects listed the early-warning nature of the device and fewer collisions with obstacles as very highly valued benefits of the laser cane. Several subjects also stressed that the additional detection range of the beams adds a convenience factor in searching for landmarks or scanning the environment. One subject commented that he sometimes could create a crude picture in a known environment using the laser cane.

Q34. Are you relaxed while using the laser cane and its signals? (T1, V1, T2, T3, V2)

Toward the end of the follow-up program all subjects responded "yes" consistently to this question. However, in earlier answers some subjects indicated that the pressure to attend to laser signals made them feel tense. One subject indicated that he feared damage to the cane and was tense and apprehensive while traveling.

Q35. Does the laser cane or its signals cause you to become uncomfortable when you are around people? Do you feel the same or differently with the long cane? (T3, V2)

Five subjects responded "no" and three subjects answered "yes." One subject felt more comfortable with the laser cane because he thought that the audible signals reduced the number of collisions he made with alert pedestrians and another subject stated that, with the exception of the fact that people looked at him, he felt better with the laser cane. Two subjects said that they felt more uncomfortable and self-conscious when in the company of other people because the audio signals attracted attention. All answers for each subject were consistent.

Q36. Is the frequency or range of your travel influenced in any way when the laser cane is available? (T3, V2)

The answers given to this question on two occasions were not always consistent. At the last interview, however, most of the subjects replied "no" to the question. Three subjects responded "no" throughout the follow up interviews. For the most part, these subjects needed to travel to get to school, to work or to conduct personal business rather than for leisure.

Q37. Do you make any modifications of your conventional long-cane technique when using the laser cane? (T1, V1, T2, T3, V2)

All subjects were quite consistent in stating that, basically, their cane technique was the same with the laser cane as with the long cane. Three subjects held the laser cane closer to their bodies with bent elbows. All subjects, at times, adopted the new technique of rolling the wrist to scan the side of their path or to locate openings. In addition, all subjects reported that they carried out more scanning movements to utilize the sensing capability of the device, when attempting to locate desired landmarks. One subject developed the new technique of holding the cane in the perpendicular plane to ascend and descend stairs and further extend his use of the laser beam.

Q38. What improvements or modifications, if any, would you like to see incorporated in the present laser cane? (T3, V2)

All subjects agreed quite strongly that basically they desired a more durable and reliable cane. The suggested improvements, both mechanical and electronic, are listed below in order of frequency.

A. Increased durability and reliability of the cane.

B. Smaller diameter of crook and less bulky packaging.

C. Decrease in weight of cane.

D. Increased durability of controls against accidental breakage (dropping).

E. Relocation of controls for utilization by cane hand only while traveling.

F. More durable lower shaft.

G. Move tactile stimulator closer to end of crook.

H. Strengthen tactile stimulator.

I. Add abrasive surface or grip to cane since hands in humid or rainy weather slip out of position.

J. Add finger guard or pad so one knows if he is holding cane in proper position to receive the tactile stimulation. (One subject complained that he had cut his finger twice on the tactile stimulator.)

Q39. What additional information would you like to add to this interview? (T1, V1, T2, T3, V2)

The majority of the answers to this question were usually given in response to other questions. Additional comments were concerned with repair problems associated with the canes and with the various personal adjustments that must be made in order to utilize the laser cane and its signals effectively. Several subjects required a period of months to accomplish the adjustment task, with one subject once hovering on the brink of returning his cane.

One subject commented that he preferred the long cane in snow and wet weather while another thought that he was a more confident traveler with the laser cane and became disorientated less frequently. The provisions for separating the upper and lower sections of the cane drew criticism because it was thought to be unnecessarily difficult to realign the components correctly when assembling. A subject from Palo Alto reported that he had given demonstrations of the laser cane to several groups and organizations.

Q40. Would you like to continue to use the laser cane? Can you give a rough percentage estimate of the extent to which you would like to use the laser cane in the future? (T3, V2)

All subjects were quite consistent in answering this question affirmatively over the course of the follow up period. Five subjects said that they would use the cane 100% of the time in lieu of the long cane, except on occasions when they are accompanied by a sighted guide. One subject stated that he would use the laser cane 95% of the time, but added no qualifying conditions. Another subject stated that in his small college town he does not have as much use for the laser cane as he might in other areas. All subjects were strong in their positive opinions of the laser cane, although quite concerned about its breakdown frequency.

SUMMARY OF SUGGESTED MODIFICATIONS

The summary provided here is concerned with recommended modifications which extend beyond the minor changes which were implemented both prior to and during the study. These are divided into three parts. Part (i) lists those made by the eight subjects. Part (ii) contains the recommendations and observations which were put forward both by the subjects and the O&M specialist colleagues of the research staff. Part (iii) concludes with a summary of the observations and recommendations agreed to by the O&M research staff. Each part reflects the topics of special interest to the group involved. No ordering in terms of importance has been attempted and no value judgments are implied by the presentation of these proposals in three parts.

Part (i) Recommendations made by subjects

1. A Palo Alto subject suggested making a one-piece cane instead of the present two-piece one.

2. All Palo Alto subjects advocated elimination of the Lower Channel.

3. The lower shaft sometimes rotates out of the correct position and makes it difficult to align the upper and lower shafts correctly for proper cane tip orientation. A Palo Alto subject suggested that an eccentric coupling concept might be used to solve this problem. A Hines subject suggested that the junction of the upper and lower shafts could be connected by a triangular-shaped union which he thought would be easier to sense than the two raised dots which are used to indicate the correct alignment.

4. Some subjects claimed that the Lower Channel signal was too loud and tended to mask the other channels. They suggested that the loudness level should be reduced.

5. It was suggested that a prescription cane should be made available with only Upper and Middle channels available. In addition, the upper signal should be softer than the middle signal.

6. Two of the subjects complained that the grip was too large for people with small hands.

7. One subject recommended putting a raised ring around the tactile stimulator so the index finger would not rest against it. He felt that this would enable the finger to be more sensitive to the movement of the tactile stimulator when it is activated.

8. Another subject suggested that the Lower Channel components should be located at the bottom of the cane and that they should be made to function more accurately.

9. It was suggested that a zippered cover for the cane be made, particularly for the upper shaft.

10. The Hines subjects recommended retaining the present Forward or Middle Channel detection range.

11. The Hines subjects recommended retaining all three channels but wanted all to be more reliable.

12. The screws holding the cane together tend to come loose and one of the Palo Alto subjects carries a screwdriver with him to tighten them. He therefore suggested that a setting compound be used to prevent the screws from rotating under vibration.

13. Some of the subjects thought that the upper and lower shaft of the cane did not fit as snugly as it should and suggested that this feature should be improved.

14. At least one subject reported that when the cane first returns after being repaired, the tactile stimulator vibrates strongly, but gradually loses its effectiveness as time passes.

15. One Hines subject stated that since in hot, humid weather his hands perspire freely, an abrasive surface should be provided around the grip to keep the cane hand from slipping.

16. This same subject recommended positioning all the controls in such a way that they can be operated with the cane hand while he is moving.

17. A Palo Alto subject recommended recessing the tactile stimulator.

Part (ii) Recommendations and observations made by subjects and O&M specialists

1. The reliability and durability of the laser cane must be improved and the breakdown frequency must be reduced.

2. The cane should be more streamlined and the weight and diameter of the upper shaft reduced.

3. The amplitude of vibration of the tactile stimulator must be made more uniform across canes and the stimulator must be relocated higher up the shaft to accommodate persons with smaller hands.

4. The present Range-Setting Control sticks out too far from the cane shaft and is vulnerable when the cane falls. It is recommended that the controls on future canes be made flush with the shaft, or recessed, to eliminate or reduce the possibility of breakage due to falling.

5. Future canes must be weather-proofed so that they will work when it rains.

6. A very high degree of quality control must be the rule with future canes.

7. There was unanimous agreement that the protruding prism associated with the Upper Channel must be eliminated.

Part (iii) Recommendations and observations made by O&M researchers

1. Future laser canes should not be made of boron because this material is not as safe as we would wish. In accidents involving collisions and broken shafts, the filaments which appear at the break are dangerous.

2. Consideration should be given to redesigning the entire outer shell of the cane because it has lacked durability when under mechanical stress and when dropped.

3. Unless the Lower Channel is made more reliable and stable and can give useful and dependable information, it seems that it should be eliminated or made optional.

4. An acceptable battery lifetime may be shorter than has hitherto been thought necessary. A two-hour battery lifetime is sufficient if spare batteries can be carried.

5. Provision for attaching a good telemetry system, including an earphone for the purpose of monitoring, should be included when the laser cane is manufactured.

6. The audio outputs should be investigated to determine which frequencies are most compatible with traffic patterns and less likely to be masked by traffic sounds.

7. The use of quick-charge batteries should be investigated and adopted if practical.

8. Removable rather than sealed batteries should be used, if practical.

9. A charging unit which can be plugged into an auto cigarette lighter receptacle might be produced as optional equipment.

10. The battery tester on the present cane is a useful tool but could be even more useful if it were made to indicate low voltage automatically by means of an audio or tactile signal or both.

11. Some future canes must be built for left-handed as well as right-handed users.

12. A vibratory system activating the entire crook of the cane or upper shaft should be investigated as a superior substitute for the tactile stimulator.

Chapter 7.

CONCLUSIONS

INTRODUCTION

In this the concluding chapter, we gather together the main findings which have emerged from the evaluation study. It will be recalled that the Subtask Checklist and the Task Rating Form did not entirely meet our expectations and that the data were insufficiently reliable to allow us to draw firm conclusions. Inadequate control made a contribution to some of the difficulties experienced with the rating methods. For this failure the panel must accept much of the responsibility, although, under the circumstances, it is unlikely that a group of part-time, widely scattered researchers of varying experience could have foreseen all of the pitfalls that had to be avoided. Nevertheless, however vexing they may be, these shortcomings should not be allowed to disguise the fact that the laser cane did not stand out as a travel aid strikingly more effective than the long cane and hence any differences which may have been present in the data were easily masked by other factors. To the credit of the metrically based procedures, it must be noted that, at the very least, the time spent in carrying them out gave the evaluators ample opportunity to observe the traveling subjects in a wide variety of surroundings and to discuss thoroughly with them their impressions and opinions of the laser cane. From these encounters, numerous valuable insights and tangible proposals were developed which have been recorded in this report.

The other sources of data which have contributed to our conclusions include the opinions expressed by colleagues of the O&M research staff and of course those of the panel members. In addition we have utilized the replies obtained from our Subject Questionnaire and the repair records which were kept on the ten laser canes. Also not overlooked are such observations as the fact that, at the end of the program, all eight subjects continued to use their laser canes although one of the volunteers returned his cane some months later. The obvious implication of this statement could be countered by arguing that, like the Victorian aspidistra, the laser canes were retained primarily as conversation pieces. However, the frequently expressed distaste of most subjects at the idea of being closely observed (particularly by strangers) while using the laser canes, leads one to think that they do not relish any notoriety that the canes may attract.

Drawing, therefore, upon all of these sources, we submit the following as the major findings of this evaluation study, listed under three subheadings:

Utility of the Laser Cane

1. On the basis of both the observational, subjective and objective data the overall mobility performance of above-average long-cane travelers is only marginally improved if the laser cane is used.

2. The laser cane is most effective in two principal situations:

   (a) in moderate density urban traffic along familiar routes provided that the cane's acoustic signals are not masked by traffic noise

   (b) in unfamiliar urban areas with low traffic activity.

3. The laser cane is least effective:

   (a) in residential areas whether familiar or unfamiliar to the traveler

   (b) in the high density, very noisy traffic conditions which prevail downtown during big city rush hours

   (c) in the confined conditions prevailing in the interiors of buildings, elevators and crowded corridors.

4. The blind users place a higher value on their ownership of a laser cane than their performance gain would appear to justify. A corollary of this observation is that laser-cane users believe that their performances with the laser cane are better than the assessments of skilled mobility trainers would indicate.

5. There is no evidence which would indicate that the availability of the laser cane significantly increased the travel frequency of the subjects.

Structure of the Laser Cane

1. The next batch of canes* should be designed to achieve a considerably higher standard of reliability than prevailed in this study. Specifically, it is recommended that the first few C-5 models should be subjected to a regime of environmental testing with the objective of achieving the expectation of a minimum-time-between-failure of not less than six months.

2. The structural modifications listed earlier in this report should be given careful consideration. From this list four proposals are repeated here for special emphasis.

   (a) The lower shaft should be made from a stronger, less brittle material.

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*An order for 35 C-5 laser canes was placed with Bionic Instruments, Inc., before the preliminary evaluation program was completed.

(b) The lower shaft should be keyed with the body of the laser cane so that the two components can be easily and precisely reconnected.

(c) The optical component housing should be made smaller and less vulnerable to damage.

(d) The Lower Channel should be re-engineered to achieve its design goals of reliably detecting down curbs.

3. User efficiency would be increased if the tactile stimulator could be redesigned to increase its ability to capture the traveler's attention. A vibrating handle is a possible solution, if the power demands it would make can be met.

RECOMMENDATIONS FOR THE FUTURE

1. Plans should be laid well in advance to ensure that the maximum amount of information can be gathered from the next batch of 35 laser canes when they become available.

2. Consideration should be given to conducting the next evaluation trial with subjects who fall into the categories of poor traveler, novice traveler, and good long-cane traveler, respectively.

3. In future studies more training time should be allocated and the training regimen should be very carefully planned to increase efficiency.

APPENDIXES

CONTENTS

		Pages
Appendix I	PRELIMINARY DATA COLLECTION	73
	Detection Test	
	Avoidance Test	
	Obstacle Course Test	
	Channel Use Recording	
	O&M Task Rating Scale	
	O&M Subtask Check List	
Appendix II	LESSONS USED IN TRAINING	124
	Pre-Course Evaluation of Long Cane Skills	
	Introduction to C-4: Upper,Middle & Lower	
	Detection Drill	
	Obstacle Course Drill	
	Residential Travel in Maywood: Lesson Plans	
	Chicago Loop Travel: Lesson Plans	
Appendix III	SUBTASK CHECKLIST	160
	Introduction	
	Guidelines for Completing the Subtask Checklist	
	Critique	
	The Checklist Data Sheet (Table A29)	
Appendix IV	TASK RATING FORM	170
	Introduction	
	Instructions Given to Raters	
	Critique	
	The Task Rating Form (Table A30)	
Appendix V	RATER QUESTIONNAIRE	176
	Introduction	
	Utility of the Videotapes	
	Efficiency of the Rating Form	
	Value of the Laser Cane	
	Rater's Rating of Himself	
	Quantitative Summary	
Appendix VI	SUBJECT QUESTIONNAIRE	190
	Introduction	
	Questions	
	Bonus Questions	
	Critique	

Appendix I

PRELIMINARY DATA COLLECTION

INTRODUCTION

During the training program objective data were collected and recorded on a pilot basis for the purpose of assessing the performance of the laser cane, the subjects' ability to learn particular tasks, and the appropriateness of the teaching format. The data-collection procedures were directed primarily at early skill acquisition and incidentally carried the benefit of providing additional practice with the device.

Six different evaluation procedures were used at various stages of the training program. The overall intent of these procedures was to gain an insight to progressively more complex aspects of device utilization. Thus after an initial 5-8 hour introduction to the three channels of the devices, a detection test, an avoidance test, and an obstacle-course test were administered. Further into the program (2nd, 3rd, and 4th weeks) three Channel Use Recordings were made as the subjects traveled in various environments. At the end of the fifth week, performance ratings of the subjects, traveling with the long cane and the laser cane over four routes, were conducted by a panel of O&M specialists who observed the runs. During these runs assessments of specific mobility subtasks and critical travel events were made by two investigators according to a checklist.

In this appendix each testing procedure is outlined and discussed separately. The impressions and recommendations of the testing team are also included. Several improvements in procedure were incorporated into the follow-up program and are discussed more completely in later appendixes.

Of the fifty or so hours spent on the training course, seven hours were specifically used for testing. Three hours were occupied on the dual tasks of recording data and providing the subjects with routine travel lessons. In general the above-average travelers employed in the project completed the various tasks somewhat faster than anticipated. It is conceivable that, in the absence of any testing procedures, the instructional time for good long-cane travelers may fall around forty hours or less. Less capable subjects may dictate more extensive training. A totally open-ended program, allowing for individual differences, would of course be ideal. However, from the results of the tests which were administered and the comments obtained from students and from instructors, it appears that the instructional material developed in this study was both useful and appropriate.

DETECTION TEST

METHODOLOGY

The purpose of the detection test was to measure the detection range of the Middle Channel of the laser cane while recording each subject's ability to perceive the audio and tactile information display and respond to it appropriately. The test was administered after 5-8 hours of initial instruction and was conducted in a controlled environment.

The test area was an outdoor asphalt parking lot. A portion of the lot 110 feet by 65 feet was utilized with the placement of two vertical poles 15 feet apart connected by a cord strung at shoulder height. The cord acted as a guideline in aiding the subject to walk in a straight line from pole to pole by loosely grasping the cord in the left hand while utilizing the laser cane in the right hand. The subjects practiced using the rope guideline prior to testing.

The subjects were asked to walk from pole to pole at their own rate of speed using the laser cane in the conventional Touch Technique and to stop when they perceived a signal (audio or tactile) from the device indicating that the beam had detected an obstacle. Randomly selected obstacles were positioned at various distances along the path. The ten obstacles were positioned so their largest detection surface faced the travel path. The ten obstacles were:

Code Number	Color	Composition	Size
1. Garbage Can	Tan	Metal	32 gallon
2. Ladder	Brown	Wood	6 foot
3. Box	Brown	Cardboard	36 x 18 inches
4. Bicycle	Green	Metal	24 inches
5. Waste Receptacle	White/Olive	Metal	34 x 18 inches
6. Clothes Tree	Gray	Metal	1" square 66" high
7. Person	White Shirt Dark Pants	Natural	6 foot
8. Shrubbery	Green	Natural	Medium Size
9. Vertical Pole	Silver	Metal	1 1/2"dia. 36" high
10. Lattice Surfaced Wall	Tan	Wood	4'x 4'section

Each subject was given two random trials at each obstacle using the tactile stimulator and two trials at each obstacle using the audio signal from the Middle Channel of the cane. The beam range was set at maximum (12 - 14 feet). A total of forty trials per subject were recorded on data forms (Table A1). Two measurements in inches were recorded on each trial which terminated in the subject either responding to a cane signal by stopping, or making cane contact with the obstacle.

The first measurement was the distance in inches from the tip of the laser cane to the obstacle when the warning signal was first heard on a special monitoring device used by an investigator. The purpose of this measurement was to record the distance at which the laser beam detected various obstacles and the exact distance from the obstacle that the subject first received the warning stimulus. The second measurement was the distance between the cane tip and the obstacle measured when the subject had made a complete stop. The two measurements represent a detection range measurement for the device and the subject's reaction distance to the stimulus.

TABLE A1

DETECTION TESTS: MIDDLE CHANNEL ONLY
(Setting at far range. All measurements in inches)

DATE ________________

TIME ________________

OBSTACLES

		1	2	3	4	5	6	7	8	9	10
AUDIBLE TRIAL 1	M. D.										
	S. D.										
AUDIBLE TRIAL 2	M. D.										
	S. D.										
TACTILE TRIAL 1	M. D.										
	S. D.										
TACTILE TRIAL 2	M. D.										
	S. D.										

M. D. = Monitor detection (Distance of cane tip from obstacle when monitor indicates that signal has been transmitted.)

S. D. = Subject detection (Distance of cane tip from obstacle when subject stops or checks his forward pace.)

RESULTS

In Table A2, the detection distances measured in inches per obstacle and individual are listed, with each distance representing the mean of the combined audio and tactile trials. Only trials where both the laser cane and the subject responded were computed in the means. There were some individual differences in detection ability between the laser canes used by different subjects. Subject P2 utilized a cane that originally had the best detection ability, averaging 102 inches for all trials, while the cane of Subject P3 averaged only 57 inches. The mean detection range for all canes was 79 inches per trial.

TABLE A2

MEAN DETECTION DISTANCES (INCHES) - DETECTION TEST - ALL TRIALS

Subject	Obstacle										All Obstacles
	1	2	3	4	5	6	7	8	9	10	
H1	71	57	98	112	99	21	87	83	42	92	79
H2	76	71	84	74	85	45	66	83	54	71	71
H3	81	117	107	77	106	49	85	94	57	102	88
H4	55	45	88	79	92	28	64	73	41	70	63
P1	95	62	117	72	80	64	97	112	74	114	89
P2	108	79	128	84	104	80	98	126	85	129	102
P3	65	28	92	29	38	30	61	70	32	100	57
P4	80	76	119	91	100	85	88	106	75	110	96
All Subjects	79	67	104	77	88	50	89	93	58	98	79

The detection distances also reflected some variation with respect to the types of obstacles detected. The furthest obstacles detected (3,5,8,10) were the cardboard box, waste receptacle, shrubbery, and the lattice-surfaced wall. Obstacles (2,6,9) which were detected at the shortest distances were the ladder, clothes tree, and the vertical pole.

Category A of Table A3 shows that the laser canes detected target obstacles and provided signals successfully on 314 trials from a total of 320 trials. Moreover, of the 314 laser-cane signals, the subjects responded to 302. As a group the subjects responded slightly better to the audio signal than to the tactile. The mean group reaction distance was 15 inches per audio trial compared to 21 inches per tactile signal. The subjects failed to respond to 2 audio trials and 10 tactile trials. On the whole, in the controlled testing situation, the short reaction distances and the low number of non-responses appear to indicate good man-machine integration. From these results it is apparent that, with a minimum amount of instruction and practice, the subjects were able to perceive the warning stimuli generated by the device.

TABLE A3

CANE AND SUBJECT DETECTION RESPONSES - DETECTION - GROUP DATA

Category	H1	H2	H3	H4	P1	P2	P3	P4	Total	Total Trials
A. Number of trials laser cane did not detect obstacle	0	0	0	0	2	0	3	1	6	(320)
B. Number of trials Subject did not respond to audio signal	0	0	0	1	0	0	1	0	2	(158)
C. Number of trials Subject did not respond to tactile signal	0	0	0	1	0	0	4	5	10	(156)
Subject mean reaction distance (inches for audio trial)	9	19	16	19	12	12	13	17	Mean = 15"	
Subject mean reaction distance (inches for tactile trials)	6	19	18	20	18	16	20	49	Mean = 21"	

COMMENTS

During the administering of the test, noticeable differences among the canes were observed. Several of the subjects throughout this and subsequent testing commented at some point on the variability among the tactile stimulators of various canes. Some canes transmitted the tactile signals with a greater amplitude than others. Another point observed was that some subjects at times in the testing displayed improper cane hand position. Ideally, the laser cane should be held with the cane hand centered directly in front of the midline of the subject's body. This position affords the furthest detection range. If the cane is positioned to either side of the midline, reduced range and incorrect obstacle localization results. On several occasions this was observed during the testing and, in subsequent portions of the follow-up program, this continued to be observed.

AVOIDANCE TEST

METHODOLOGY

Following the detection test,an avoidance test was given which assessed the performance level achieved by subjects in circumventing selected obstacles in a controlled environment. It is well known that even when an instrument which can detect objects and enable the subject to avoid contact is available it is not always used. The laser-cane traveler may seek contact deliberately to acquire more knowledge of the object and the environment in general or, in cases where known landmarks exist, provide confirmation of their location. Other reasons for contact may vary from lack of attention to inaccurate interpretation of the information. Early experience with the laser-cane demonstrated several of these reasons for contacts. However, whatever he should choose to do with the information, a traveler should be confident that once having detected an object with his mobility aid, he can circumvent it if he so desires. In addition,it is of some importance that a subject, in the final analysis, be able to function with a device at close to his normal travel speed.

The successful avoidance of an obstacle can be seen as being dependent upon four factors:

(i) The detection of an obstacle at a sufficient distance to enable the subject to react to the signal in time,

(ii) An accurate percept of the distance and position of the obstacle in relation to the subject's direction of motion,

(iii) An appreciation of the dimensions of the obstacles, and

(iv) The subject's ability to make a rapid mental assessment of these factors and, after avoiding the obstacle, resume the original line of travel.

The avoidance test was given in the same outdoor area as the previous test and the same ten obstacles were used. (See Table A4.)

The obstacles were randomly spaced about the practice area. Each subject individually was given two trials per obstacle, using the tactile stimulator on one trial and the audio system on the other for a total of twenty trials. All three channels were used with the Middle Channel set at the "far" range. The trials required the subject to use the laser cane in the conventional Touch Technique manner and to walk across the practice area attempting to detect, avoid, and circumvent an obstacle without any physical body or cane contact. A sound source (radio) was placed opposite the traveler and switched on for a minute to provide the subject with an indication of the direction he should take. Unless the subject deviated from his collision course with the obstacles no additional sound clue was provided. During these trials, the radio was placed at various distances behind the obstacles to ensure that the subjects would not be able to guess the distance of any of the obstacles. The distances between obstacles and their order of presentation were varied to prevent test learning. All subjects were permitted to travel at their own travel speeds. A trial terminated when a subject either successfully detected and circumvented an obstacle or made body or cane contact with it. There was no predetermined order of selecting obstacles resulting in varied approach distances and irregular patterns of approach around the practice area. All of the avoidance trials were monitored by an investigator with a telemetry system. Several dummy trials in which no obstacles were used were introduced from time to time. The use of the telemetry monitor determined whether or not the laser beam had detected an obstacle, and provided the subject with a signal. If, on occasions, the subject drifted off course and missed the obstacle, or the laser cane failed to detect the obstacle, no record of the trial was made and the test was repeated again later.

The scoring for the trials consisted of marking one of three defined categories. A "yes" for a successful trial (circumventing an obstacle without any contact), "CC" for an unsuccessful trial (making cane contact while attempting to circumvent an obstacle), "BC" for an unsuccessful trial (making body contact while attempting to circumvent an obstacle. It was possible to score a "CC" and "BC" for the same obstacle if both occurred.

Two conditions were required before the subjects were scored on a trial;

(i) The telemetry system must have verified that the laser cane did in fact provide the subject with a signal.

(ii) The subject must have verified he received the signal by motioning with his left hand to inform the scorer. The individual results were recorded on the data sheet shown in Table A4.

RESULTS

Table A5 contains the individual results of the avoidance test for the eight subjects. In varying degrees, the individuals performed at adequate skill levels for beginning students. Subject P2 had the best combined trials score with only two cane contacts out of his twenty, while subject P3 made the most contacts with six cane contacts and one body contact in his trials. As a group the subjects averaged 4.5 contacts over twenty trials. In trials comparing the use of the audio versus the tactile signal the subjects showed little difference in performance levels. As a group, as seen in Table A6, the subject performance level was only slightly improved when the audio system was used. The combined trials for the group showed that they were successful in 124 trials out of a total of 160 trials (i.e., 78% of the time).

OBSTACLE COURSE TEST

METHODOLOGY

To conclude the performance testing of the subjects during the initial phase of instruction, an obstacle course test was administered. The procedure followed the avoidance tests and preceded the start of training in residential areas.

TABLE A4

DATA SHEET FOR AVOIDANCE TEST

STUDENT -- H1 H2 H3 H4 P1 P2 P3 P4 ALL CHANNELS USED

DATE ______________ MIDDLE CHANNEL RANGE AT FAR

OBSTACLES	AUDIO TRIAL 1		TACTUAL TRIAL 2	
1. ASH & GARBAGE CAN				
2. WOODEN 6' LADDER				
3. CARDBOARD BOX				
4. GREEN 24" BICYCLE				
5. METAL RECEPTACLE				
6. CLOTHES TREE				
7. PERSON				
8. SHRUBBERY				
9. VERTICAL METAL POLE				
10. WOOD LATTICE SURFACE				

SYMBOLS USED

YES = Correct Response - Circumventing obstacle without contact of any sort.
CC = Incorrect Response - Making cane contact while attempting to circumvent obstacle.
BC = Incorrect Response - Making body contact while attempting to circumvent obstacle.

(BOTH CC AND BC CAN BE SCORED ON SAME OBSTACLE IF THE OCCURRENCES TRANSPIRE)

GROUND RULES

1. ALL CHANNELS ARE TO BE USED. THE MIDDLE-CHANNEL RANGE IS TO BE SET AT "FAR."
2. Trial 1 involves the use of all channels. The Middle Channel signal to be specified as audio only. (The student will not be allowed to use the tactile stimulator.)
3. Trial 2 involves the use of all channels with the Middle-Channel signal being displayed only by the tactile stimulator. (Turn off student's Middle-Channel audio switch.)
4. Two conditions must be met before a student can be scored when attempting to avoid and circumvent an obstacle (if not, repeat the test):
   a. The student must hear or feel signal. This he shows by flipping his wrist to let the scorer know.
   b. A research team member, via the monitoring system, must have heard that the cane provided the student a signal.

TABLE A5

INDIVIDUAL DATA - AVOIDANCE TEST

OBSTACLES		1	2	3	4	5	6	7	8	9	10	TOTAL SUBJECT CONTACT
SUBJECT												
H1	AUDIO	X	X	X	X	X	CC	X	X	X	X	1
	TACTILE	X	CC	X	X	X	CC	X	X	X	CC	3
H2	AUDIO	X	CC	X	X	X	CC	X	X	X	X	2
	TACTILE	X	X	CC	X	X	X	X	X	X	CC	2
H3	AUDIO	X	X	CC	X	X	X	CC	X	X	X	2
	TACTILE	X	X	X	CC	X	CC	X	CC	X	X	3
H4	AUDIO	X	CC	X	X	X	CC	X	X	X	BC	3
	TACTILE	X	X	CC	X	X	X	X	X	CC	X	2
P1	AUDIO	X	X	X	CC	CC	X	X	X	X	X	2
	TACTILE	X	X	CC	X	X	X	X	X	CC	X	2
P2	AUDIO	X	X	X	X	X	X	X	X	X	X	0
	TACTILE	X	X	X	CC,BC	CC	X	X	X	X	X	2
P3	AUDIO	X	X	X	CC	CC	X	X	X	X	X	2
	TACTILE	CC	X	X	CC,BC	CC	X	X	CC	X	X	4
P4	AUDIO	X	X	X	CC	CC	X	X	X	X	X	2
	TACTILE	X	X	X	BC	X	CC	X	X	X	X	2
TOTAL OBSTACLE CONTACT		1	3	4	7	5	6	1	2	2	3	

CC = CANE CONTACT
BC = BODY CONTACT
X = SUCCESSFUL TRIAL

TABLE A6

AVOIDANCE TEST - GROUP DATA

	Successful Trials	Unsuccessful Trials Cane Contact	Unsuccessful Trials Body Contact
Audio Trials 80	66 (83%)	13 (16%)	1 (1%)
Tactile Trials 80	58 (73%)	19 (24%)	3 (3%)
Total Trials 160	124 (78%)	32 (20%)	4 (2%)

The obstacle course tests were conducted on the same outdoor practice area as the previous tests. The asphalted area was marked with a 30 foot by 90 foot grid. The ten obstacles used in the previous tests were then arranged in a specified pattern (see Table A7). Three different starting positions were chosen. Each subject began from each randomly selected starting position twice, once with the long cane and once with the laser-cane to make a total of six trials.

At the beginning of the test, each subject was instructed that his task was to walk as directly as possible towards the sound source and to locate it by physical contact. The subject was informed that he would encounter a number of obstacles along the way and that he was to walk around them with as little physical contact as possible and proceed towards the sound source. He was told that he could transverse the course at his own speed, although, he was asked not to stop along the route. The student was also instructed that, on the Middle Channel, he may use either the tactile or audio output or both. The Middle Channel was set at its "far" range.

A data form (Table A8) containing a schematic diagram of the obstacle course was used for each trial. The travel path of each subject was drawn in by an observer; body contact with an obstacle was recorded by the notation "BC" and cane contact by the notation "CC." The subject's total travel time (the time which elapsed from the time he started moving to the time he physically contacted the sound source) was recorded although a fast time was not the primary objective of the trial.

RESULTS

The individual results of the subjects are shown in Table A9. Subject H1 recorded the test trial performances with the laser cane by transversing the course without contact in all three trials. Subjects H3, H4, P1, P3 recorded small improvements with the laser-cane, and Subjects H2, P2, P4 scored about the same amount of contact with either device. Using the laser cane the subjects recorded nine perfect runs out of the twenty-four total trials to only one with the long cane. Table A10 contains the group results showing the total number of contacts with the long cane to be about twice that of the laser-cane, while the laser cane trials averaged seven seconds more per trial.

CHANNEL USE RECORDING

METHODOLOGY

During the second, third, and fourth weeks of training, recordings were made of the subjects using the laser cane in an attempt to assess man-machine factors. The channel-use recordings attempted to measure the magnitude, distribution, and utilization of the signals generated by the laser cane over typical travel routes.

Each subject was monitored once a week for three weeks while traveling during a regular lesson. Recordings were made during the second, third, and fourth week on:

(i) a residential travel route,

(ii) a combined residential--light business travel route,

(iii) a business travel route.

The subjects were aware that the recordings were being made and were allowed to choose whatever laser-cane setting they felt to be necessary.

The laser-cane signals were monitored via a telemetry system enabling the investigator to record each signal and observable subject response. The subject response was assessed according to three defined categories of "appropriate," "inappropriate," and "no-response" on the data form shown in Table A11. A "no response" resulting in a body or cane contact was recorded with a "C". As a group, the subjects traveled 240 blocks while crossing 240 streets on these runs. The mean signal input per run of ten blocks was 358 signals. It was found that the subject received about 35 signals per block distributed among the three channels as follows; four signals on the low channel, 26 signals from the middle channel, two from the upper channel, and two combination signals. The lowest number of signals generated in a run was 146 signals, the highest was 986 signals, and the median was 347 signals.

RESULTS

Table A12 contains the group data for all the recordings. The results show that most subjects were observed to respond appropriately to signals about 50 percent of the time. An exception was the down channel which was ignored almost 80 percent of the time.

COMMENTS

The administration of the channel use recording procedure posed several difficulties to the investigators. The results should be viewed as crude, indicators rather than exact statements. The rapidity of signal generation, spurious signals due to malfunctions and weakly defined response categories made very accurate data difficult to obtain. Coupled with these problems was the inherent difficulty of observing slight behavioral changes in skilled performance.

In general, the data show that the subjects were obliged to process a considerable signal load during their travel. With the exception of the lower channel, the subject either responded "appropriately" to the signal or did not respond at all. Very few "inappropriate" responses were recorded. Interestingly, whether the subject responded inappropriately or not at all, very few physical contacts were made.

ORIENTATION AND MOBILITY TASK RATING SCALE

METHODOLOGY

At the end of the training program the travel performance of the subjects was rated by a group of Orientation and Mobility Specialists on four travel routes. On two of these routes the subjects used the laser cane and on two comparable routes the long cane was used. All four routes, labeled A through D, were eight blocks in length and included eight street crossings. Routes A and B passed through areas that contained four residential blocks and four blocks containing light business. Routes C and D passed through heavy downtown urban areas. The long cane was employed on routes A and D and the laser cane on routes B and C.

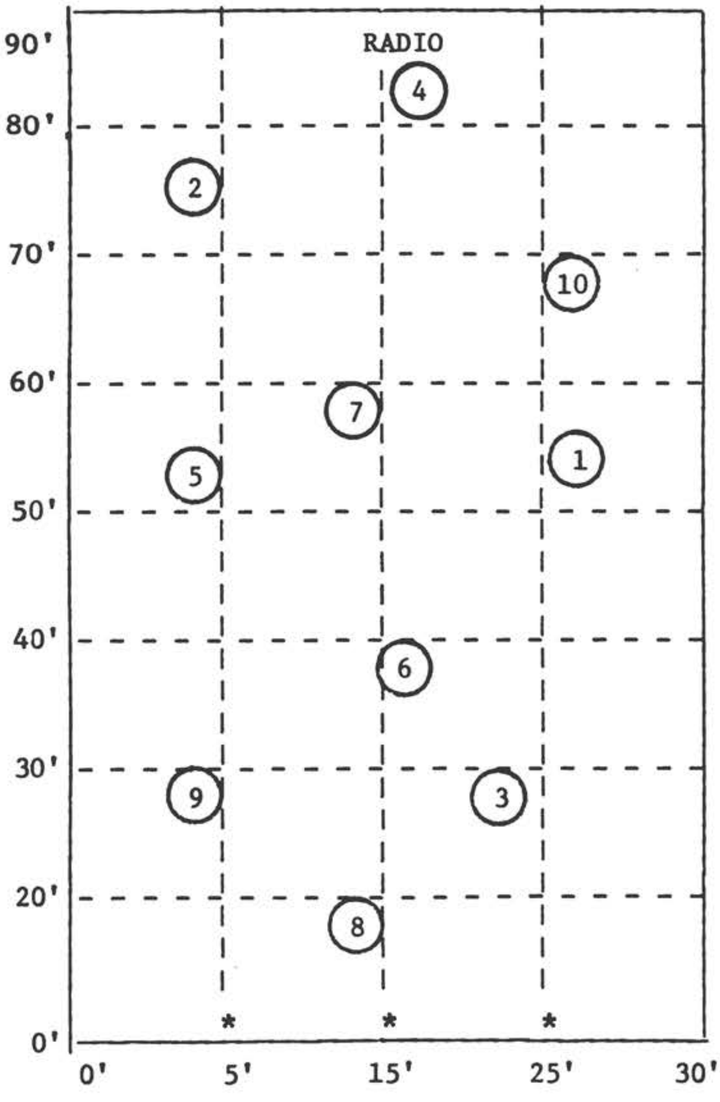
The subjects were not familiar with any of the chosen routes prior to undertaking the evaluation runs but, just before setting out, were informed verbally about the pattern of the run and the distance to be traveled. The names of streets, landmarks, or compass directions, however, were not given. The subjects were assured that on any occasion on which assistance might be required, it would be provided by one of the investigators and they were asked not to accept any assistance from the general public. Any subject who became disoriented and was unable to gain his orientation within five minutes was provided with assistance. Also in situations in which a subject's personal safety was in jeopardy, or a wrong turn or route reversal was made, assistance was given by the investigators.

The O&M raters followed the progress of each subject and, on the conclusion of his run, marked an O&M Task Rating Scale Form (Table A13). The rating scale contained eleven questions divided into two categories. Category one contained eight questions dealing with specific characteristics of travel performance, while category two contained three questions asking for judgments on the subjects overall performance. For each question, the rater judged the performance on a five-point scale whose extremes were labeled "very well" and "very poorly." The rating scale and the questions were discussed with each rater prior to his observations to ensure that he fully understood each question. All raters were instructed to mark each performance separately and to main uniform criteria. All rating forms were completed immediately following each observation and returned to an investigator.

TABLE A7

OBSTACLE COURSE TEST

STANDARD PLACEMENT AND DIMENSIONS



*Quasi-random starting points for 3 trials with each cane.

OBSTACLES

1. Ash and garbage can
2. Wooden 6' step ladder
3. Cardboard box
4. Green 24" bicycle
5. Metal waste receptacle
6. Clothes tree
7. Person (wearing dark pants and white shirt)
8. Shrubbery
9. Vertical metal pole
10. Wood lattic surface

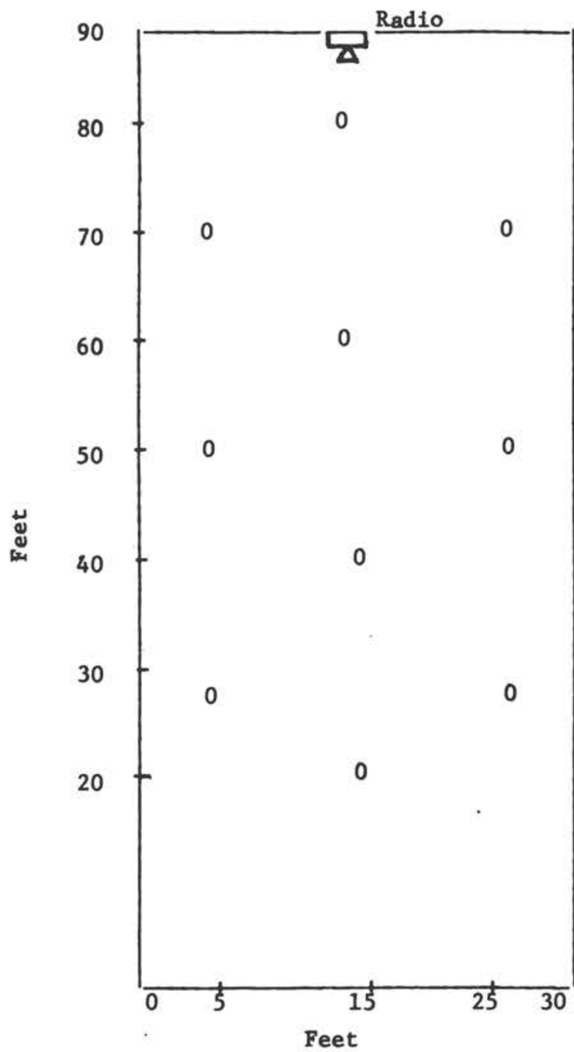
TABLE A8

OBSTACLE COURSE TEST

Student -- H1 H2 H3 H4 P1 P2 P3 P4 Long Cane Trial -- 1 2 3

Date ________________ Laser Cane Trial -- 1 2 3

Middle Channel Preference: Audible ____ Tactile ___ Both ___



	LONG CANE TRIALS			LASER CANE TRIALS		
	1	2	3	1	2	3
Body Contact (BC)						
Cane Contact (CC)						
Time						

TABLE A9

INDIVIDUAL DATA - OBSTACLE COURSE TEST

	LONG CANE			LASER CANE		
	CANE CONTACT	BODY CONTACT	TIME (SECONDS)	CANE CONTACT	BODY CONTACT	TIME (SECONDS)
SUBJECT H1						
TRIAL 1	1	0	41	0	0	65
TRIAL 2	2	0	39	0	0	42
TRIAL 3	1	0	35	0	0	45
SUBJECT H2						
TRIAL 1	1	0	27	1	0	29
TRIAL 2	1	0	22	1	0	35
TRIAL 3	2	1	30	1	0	28
SUBJECT H3						
TRIAL 1	1	1	34	2	0	44
TRIAL 2	1	0	30	0	0	33
TRIAL 3	2	0	34	0	1	34
SUBJECT H4						
TRIAL 1	2	1	30	0	1	30
TRIAL 2	1	0	30	0	0	33
TRIAL 3	1	0	28	1	0	31
SUBJECT P1						
TRIAL 1	2	0	30	0	0	34
TRIAL 2	2	0	27	1	0	33
TRIAL 3	1	0	27	1	0	33
SUBJECT P2						
TRIAL 1	1	0	28	1	0	34
TRIAL 2	1	0	28	0	0	30
TRIAL 3	0	0	26	0	0	29
SUBJECT P3						
TRIAL 1	1	0	27	0	0	38
TRIAL 2	3	1	36	1	0	36
TRIAL 3	2	1	33	1	0	38
SUBJECT P4						
TRIAL 1	2	1	33	1	0	51
TRIAL 2	1	0	31	1	0	47
TRIAL 3	1	0	29	1	0	47

TABLE A10

OBSTACLE COURSE TEST - GROUP DATA

Trials (48)	Long Cane (24)	Laser Cane (24)
Perfect Trial Without Contact	1	9
Body Contact with Obstacles on Trials	6	2
Cane Contact with Obstacles on Trials	33	14
Total Contact with Obstacles	39	16
Average Time per Trial (seconds)	30	37

An interesting point to note is that the most commonly contacted obstacle with either cane was the bicycle which was positioned in front of the sound source. This presented repeated problems to all subjects. In the 24 trials with the laser cane, contact was made with the bicycle 11 times and only 5 times with 3 other obstacles. In the 24 long-cane trials the subjects contacted the bicycle 21 times and made contact with 4 other obstacles 18 times.

COMMENTS

The small number of contacts per trial was to a large extent attributable to faults in the construction of the maze pattern. Two of the starting points on the course left fairly open alleys through the maze to the sound source. This factor, in addition to the subjects' demonstrated ability to learn the maze pattern, caused the number of contacts to be quite low, and so reduced the efficiency of the test. A more difficult randomized maze pattern with occasional changes to alternative patterns would have improved the effectiveness of the testing procedure.

TABLE ALL

CHANNEL USE RECORDING

DATE & WEEK ________________

STUDENT H1 H2 H3 H4 P1 P2 P3 P4

TYPE OF AREA ____________________(general category)

NUMBER OF BLOCKS __________________________

NUMBER OF STREET CROSSINGS ________________

CHANNEL	APPROPRIATE RESPONSE	INAPPROPRIATE RESPONSE	NO RESPONSE*
LOWER			
MIDDLE			
UPPER			
COMBINATION			

*Mark a no response that results in a cane or body contact with a " C ".

TABLE A12

LASER CANE SIGNAL INPUT AND UTILIZATION - GROUP RESULTS - CHANNEL USE TESTS

	SIGNAL RESPONSE AND CONTACT							
	PERCENT OF TOTAL SIGNAL INPUT	TOTAL NUMBER OF CHANNEL SIGNALS	APPROPRIATE RESPONSES	INAPPROPRIATE RESPONSES	CONTACT FOLLOWING INAPPROPRIATE RESPONSES	NO RESPONSES	CONTACT FOLLOWING NO RESPONSES	TOTAL CONTACTS
CHANNEL SIGNAL								
LOWER	11%	999	196 (20%)	27 (2%)	0	776 (78%)	0	0
MIDDLE	76%	6461	3024 (47%)	241 (4%)	16	3196 (49%)	241	257
UPPER	9%	776	432 (56%)	35 (5%)	0	299 (39%)	2	2
COMBINATION	4%	367	177 (48%)	50 (14%)	6	140 (38%)	5	11
TOTAL NUMBER OF SIGNALS		8593	3829	353	22	4411	248	270
PERCENT OF SIGNAL INPUT	100%	44%		4%	.2%	51%	3%	3%

TABLE A13

ORIENTATION & MOBILITY TASK RATING SCALE

DATE ______________________________

STUDENT ____________________________

RUN _____A_____B____C____D_____________

EVALUATOR __________________________

CATEGORY ONE

1. Uses environmental information __________

   A. very well |—+—+—+—| very poorly

   B. If not sufficient information available to rate mark X here ____

2. Travels in straight line __________

   A. very well |—+—+—+—| very poorly

   B. If not sufficient information available to rate mark X here ____

3. Crosses streets __________

   A. very well |—+—+—+—| very poorly

   B. If not sufficient information available to rate mark X here ____

4. Maintains orientation __________

   A. very well |—+—+—+—| very poorly

   B. If not sufficient information available to rate mark X here ____

5. Detects curbs __________

   A. very well |—+—+—+—| very poorly

   B. If not sufficient information to rate mark X here ____

6. Solves orientation and travel problems _____

   A. very well |—+—+—+—| very poorly

   B. If not sufficient information available to rate mark X here ____

TABLE A13 (cont'd)

7. Avoids bodily contact ______________

   A. very well |———+———+———+———| very poorly

   B. If not sufficient information available to rate mark X here _______

8. Uses mobility aid ________________

   A. very well |———+———+———+———| very poorly

   B. If not sufficient information available to rate mark X here _______

CATEGORY TWO

Indicate the performance levels you feel the traveler has exhibited in all his O&M tasks, on a scale ranging from "Excellent" down to "Poor."

1. Travels safely __________________ excellent |———+———+———+———| poor

2. Travels effectively _____________ excellent |———+———+———+———| poor

3. Total O&M performance ___________ excellent |———+———+———+———| poor

TABLE A14

RATING QUESTIONNAIRE CLASS ONE	1	2	3	4	5	6	7	8
RATER	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
SUBJECT								
H1 RUN A	3 3 3 3	3 4 3 2	3 3 3 3	3 3 3 3	3 4 4 3	3 4 3 3	4 3 5 4	3 4 4 4
" B	4 4 4 4	4 4 4 4	4 3 4 4	4 4 4 3	5 4 5 5	4 4 4 4	5 3 5 5	5 4 5 5
" C	4 3 4	4 3 4	4 4 4	4 4 3	4 5 5	4 3 4	4 4 4	4 5 4
" D	4 3 4	4 3 4	4 3 4	4 3 4	4 4 4	4 4 4	3 3 4	4 5 4
H2 RUN A	4 4 3 4	5 4 4 4	4 3 4 4	3 4 3 3	5 4 5 5	4 4 4 2	3 3 5 3	5 4 5 5
" B	4 4 4 4	5 4 5 5	4 4 4 4	4 4 5 4	5 4 5 5	3 4 4 4	5 3 5 5	5 4 5 5
" C	4 4 4 4	4 4 4 4	4 4 4 4	3 4 5 3	5 5 5 5	5 5 5 4	4 4 5 5	4 5 5 4
" D	4 5 4 4	4 5 4 4	4 4 3 4	4 5 4 4	5 5 5 5	4 5 4 4	4 4 4 4	4 5 5 5
H3 RUN A	4 3 4 4	4 4 4 4	4 3 4 4	4 4 5 4	3 3 3 3	5 4 5 5	4 3 4 4	4 3 5 4
" B	3 3 3 3	3 3 4 3	3 3 4 3	3 4 4 3	3 3 3 2	3 4 4 3	5 3 5 5	3 4 5 3
" C	3 4 3 2	3 4 3 2	3 4 3 3	3 4 3 2	4 5 4 4	3 4 3 2	3 3 3 3	2 4 3 2
" D	3 4 3 4	3 4 3.3	3 4 3 3	3 4 3 3	3 4 4 4	3 4 4 4	3 3 3 3	4 4 4 4
H4 RUN A	4 4 4 4	4 5 4 4	4 4 3 4	4 5 5 4	4 4 4 4	4 4 4 4	5 4 5 5	4 4 5 4
" B	4 4 4 4	4 5 4 4	5 4 3 4	4 5 5 5	4 4 4 5	4 4 4 5	4 4 5 5	4 5 5 4
" C	5 5 4 5	5 5 4 5	5 5 4 4	5 5 5 5	5 4 5 5	5 5 5 5	4 5 5 5	4 5 5 5
" D	5 5 5 5	5 5 5 4	5 5 5 4	5 5 5 5	5 4 5 5	5 5 5 5	4 3 5 4	5 5 5 5
P1 RUN A	5 5 5	5 5 4	5 4 5	5 5 5	5 4 4	5 5 5	5 4 4	5 5 5
" B	3 4 4	4 5 4	3 4 5	3 5 3	5 5 3	4 5 3	4 3 3	3 3 5
" C	4 5 4	4 4 4	3 4 3	5 5 5	5 5 5	5 4 3	4 4 4	4 5 4
" D	4 5 5	4 4 4	4 5 4	5 5 5	5 5 5	4 4 3	3 4 4	4 5 5
P2 RUN A	4 5 5	5 4 4	2 4 5	4 5 4	5 5 5	5 5 3	5 4 4	5 5 5
" B	5 5 5	5 5 4	4 5 4	5 5 5	4 3 4	5 5 3	4 4 4	5 5 5
" C	5 4 5	5 5 5	4 4 5	5 4 5	5 5 5	5 4 3	5 5 5	5 5 5
" D	5 5 5	4 5 4	5 5 5	5 5 5	5 5 4	5 5 3	4 5 4	5 5 5
P3 RUN A	4 5 5	4 5 4	5 5 5	5 5 4	5 5 5	5 5 3	4 5 4	4 5 4
" B	2 4 4	5 5 5	4 5 5	2 4 3	5 5 5	2 4 3	5 5 5	4 4 4
" C	5 4 5	5 5 5	4 4 5	3 5 4	5 5 5	3 5 3	4 4 5	4 4 4
" D	3 4 2	4 5 4	3 4 4	5 5 4	5 5 5	3 4 3	5 5 4	4 4 4
P3 RUN A	4 5 4	4 5 4	4 5 5	4 5 4	5 5 5	4 5 5	4 4 4	5 5 4
" B	4 4 4	5 4 4	3 4 4	4 5 4	5 5 5	4 5 3	4 4 5	5 5 4
" C	5 5 5	5 5 5	4 5 5	4 5 4	5 4 5	4 5 3	5 5 5	5 5 5
" D	5 5 5	4 5 4	5 5 5	5 5 5	5 5 5	5 5 3	5 5 4	5 5 5

TABLE A14 (cont'd)

RATING QUESTIONNAIRE CLASS TWO	1	2	3
RATER	1 2 3 4	1 2 3 4	1 2 3 4
SUBJECT			
H1 RUN A	4 4 4 5	3 4 3 2	3 3 3 3
" B	5 4 4 5	5 4 5 4	4 5 5 5
" C	3 4 4	4 4 4	4 3 4
" D	3 4 4	4 4 4	4 4 4
H2 RUN A	3 3 4 3	5 5 5 4	4 4 5 4
" B	5 3 4 4	5 4 5 5	5 4 5 5
" C	4 4 5 5	4 4 5 5	4 4 5 4
" D	4 5 4 4	4 5 5 4	4 5 5 4
H3 RUN A	3 2 3 3	4 4 4 4	4 4 5 4
" B	3 3 3 3	3 4 4 3	3 4 4 3
" C	3 4 3 2	3 4 3 2	3 4 3 2
" D	3 4 3 3	3 4 3 3	3 4 3 3
H4 RUN A	4 4 5 4	5 5 5 5	4 5 4 4
" B	4 4 5 4	5 5 5 5	4 5 4 4
" C	4 5 5 4	4 5 5 5	4 5 5 5
" D	4 4 5 4	4 5 5 4	4 5 5 5
P1 RUN A	5 5 5	5 4 5	5 5 5
" B	3 3 5	3 4 4	3 4 4
" C	4 4 4	4 5 4	4 5 4
" D	5 5 5	4 5 5	4 5 5
P2 RUN A	3 5 5	4 5 5	4 5 5
" B	4 5 5	5 5 4	5 5 4
" C	5 5 5	5 5 5	5 5 5
" D	5 5 5	5 5 5	5 5 5
P3 RUN A	4 5 5	5 5 5	4 5 5
" B	4 4 5	2 4 3	3 4 3
" C	4 5 4	4 4 4	4 4 4
" D	4 5 4	4 4 4	4 4 4
P4 RUN A	4 5 5	4 5 5	4 5 5
" B	4 5 5	4 5 4	4 4 4
" C	5 5 5	4 5 5	4 5 5
" D	4 5 5	4 5 5	4 5 5

RESULTS

The results of the rating are contained in Table A14. Unfortunately, during their work, several raters did not follow the scoring procedure of marking one of the five points on the scale and instead made marks in between the scale points. These incidents were handled by recording the next highest point on the scale. In addition, each rater was given an alternative option to answering every question. This option stated that if insufficient information was available with which to answer a question an "x" could be marked instead of the usual marks. When the results were collected to form Table A14 a neutral score of three was given for each "x".

From these rating data it can be seen that, in general, the subjects' performance scores were fairly consistent. The subject as a group did quite well with either aid, and on many occasions received the highest possible score with both aids. With the exception of Subject H1 who obtained considerably higher performance scores using the laser cane in the residential--light business area, no general travel improvement with the laser cane over the long cane emerges from the individual results. Isolated higher scores appear in the laser cane data of Subjects H3, P1 and P3. However, a relatively uniform distribution of scores is evident (see Table A15) if the data of the eight subjects are pooled.

TABLE A15

O&M RATING SCALE RESULTS - ALL QUESTIONS - GROUP DATA

Runs	Incidents of Improved Scores (Long Cane)	Incidents of Improved Scores (Laser Cane)	Incidents of Identical Scores
Residential-Light Business Routes	75	74	159
Urban Downtown Routes	50	42	205
All Routes	125	116	364

In examining both category one and category two questions, the most significant variation in scores occurred in connection with question seven. On this question the raters scored several subjects higher when using the laser cane in avoiding bodily contact (while traveling in all areas) than when using the long cane.

Agreement between the raters observing the same performance was surprisingly high considering the nature of the task and the individuality of human judgment.

All raters observing the same performance gave identical scores 92 times out of a possible 352 times to several questions. It also should be mentioned that some other questions did show that there were substantial differences of opinion among the raters.

ORIENTATION & MOBILITY SUBTASK CHECKLIST

METHODOLOGY

During the four assessment runs, while the O&M raters were observing the subjects' performance, investigators (O&M specialists) scored an O&M Subtask Checklist (Table A16 and A17) for each run. The O&M Subtask Checklist was composed of two parts each scored by a different observer. The purpose of the checklist was to assess travel performance in terms of a number of discrete subtasks. The checklist for Scorer 1 specified critical travel events related to the subject's line of travel, veering, and orientation problems. The scoring procedure for recording performance at these critical points was either a numerical total, indicating frequency of occurrence, or a yes-no response indicating occurrence or nonoccurrence. Table A18 details the complete scoring procedure. At the completion of each run, Scorer 1 also indicated the time of day that the run took place and the subject's total travel time.

Scorer 2 indicated the type of weather during the run, the density of automobile and pedestrian traffic, and any unusual occurrences during the run in addition to his assessment of particular subtasks. He was also responsible for the subjects' safety during the runs. Since the scoring had to be completed during live observation the scope and complexity of the subtasks specified in the checklist was kept to workable proportions.

RESULTS

The results obtained from the subjects are contained in Table A19. Each specific subtask is discussed separately.

A. Obstacle Negotiation:

1. Cane Contact

During runs in residential-light business areas (runs A & B) the subjects averaged 9 cane contacts with obstacles while using the laser cane and 17 contacts while using the long cane. Seven of the eight subjects recorded fewer cane contacts with obstacles when using the laser cane in the same type of area. Subject H1 recorded the same number of cane contacts with either cane. The decrease in cane contacts when using the laser cane varied with individuals with six subjects (H2, H3, H4, P2, P3, P4) showing a reduction of fifty percent or more. The number of cane contacts made with pedestrians during the residential--light business runs totaled two with long cane to one with the laser cane.

The subjects achieved less dramatic reductions in cane contact with obstacles when using the laser cane in the downtown urban areas, runs C and D. They averaged 17 cane contacts with obstacles using the laser cane to 22 cane contacts with the long cane. The highest individual reduction in cane contacts was achieved by Subject H3 who made 10 fewer contacts with obstacles while using the laser cane. The major area of improvement in urban downtown performance lay in the reduced number of cane contacts with pedestrians, although the number of incidents was high with either cane (totals were laser cane 63, long cane 108). Overall, the subjects averaged 8 cane contacts with the laser cane to 14 cane contacts with pedestrians while using the long-cane. Subjects H1, H2, H3, and H4 all recorded reduced cane contact, while subjects P1, P2, P3, and P4 recorded either the same number or slightly fewer cane contacts with the long cane.

2. Body Contact

The results show that the differences in number of body contacts varied with the type of route traveled. In the residential--light business areas (runs A and B) the number of body contacts with obstacles showed a significant difference between the long cane and laser cane. In the case of figures for body contacts with pedestrians the magnitudes in residential areas are so small that no conclusion can be drawn. However, in urban downtown areas many more body contacts with pedestrians are made yielding totals of 9 contacts for the laser cane and 24 contacts for the long cane.

Subjects H1, H2, H3, P1, P2 and P3 made fewer body contacts with obstacles while using the laser cane, while Subject H4 made the same number as he did when using the long cane in the residential--light business area. The number of body contacts with pedestrians for routes A and B did not differ. In this travel area the subjects averaged 2 fewer body contacts with obstacles when using the laser cane. The subjects achieved little difference in performance with respect to body contacts with obstacles in the runs C and D, averaging 1 or less with either cane.

The number of body contacts made with pedestrians (long cane 2, laser cane 1) was quite small on routes A and B. In the urban downtown areas, Subjects H2, H4, and P4 recorded a reduced number of body contacts with pedestrians when using the laser cane. Subjects H1 and P1 showed no change, and Subjects H3, P2, and P3 reduced the number of body contacts with pedestrians using the long cane.

The group totals for each category of obstacle negotiations are recorded in Table A20. In reviewing the obstacle negotiation results the advantage of the laser cane can be seen as enabling a reduction of the number of incidents of cane and/or body contacts.

The laser cane is more effective as an obstacle detector in residential--light business areas where it reduces contact in general and in the urban downtown areas where the major benefit lies in the reduction of cane and body contact with pedestrians.

TABLE A16

ORIENTATION & MOBILITY SUBTASK CHECKLIST

SCORER 1

DATE ____________________ BLOCKS IN RUN____________________

STUDENT __H1__H2__H3__H4___P1__P2__P3__P4 NUMBER OF STREET CROSSINGS ______

RUN ______A______B_____C______D________ NUMBER OF PENSION AREAS ________

BLOCK

SCORER 1

1. BREAKS STRAIGHT LINE TRAVEL ______________________________

1	3	5	7
2	4	6	8

2. VEERS OFF TRAVEL PATH ______________________________

1	3	5	7
2	4	6	8

3. RECOVERS FROM ORIENTATION PROBLEMS ______________________________

1	3	5	7
2	4	6	8

STREET CROSSING
SCORER 1

1. DETECTS DOWN CURBS ______________________________

1 2	3 4	5	6	7	8

2. PROPERLY ALIGNS FOR CROSSING ______________________________

1 2	3 4	5	6	7	8

3. STARTS CROSSING AT CORRECT TIME ______________________________

1 2	3 4	5	6	7	8

4. NEEDS ASSISTANCE TO COMPLETE CROSSING ______________________________

1 2	3 4	5	6	7	8

+ or - scoring for number 3 under Block and numbers 1,2, & 3 under Street Crossings. All other categories are scored by using a vertical line for each response.

TABLE A16 (cont'd)

ORIENTATION & MOBILITY SUBTASK CHECKLIST FORM

SCORER 1

END OF RUN

SCORER 1

1. TRAVEL TIME ____________________

STARTING TIME ____________
FINISH TIME ____________
TOTAL TRAVEL TIME ____________

2. TIME OF DAY ____________________

AM	NOON	PM
8____	____	1____
9____		2____
10____		3____
11____		4____
		5____

TABLE A17

ORIENTATION & MOBILITY SUBTASK CHECKLIST FORM

SCORER 2

STUDENT ____H1____H2____H3____H4____ P1____P2____P3____P4

RUN _____A_____B_____C_____D

DATE ______________________

BLOCK

SCORER 2

1. MAKES CANE CONTACT (Collision) ______________________

	1	2	3	4	5	6	7	8
Obstacle								
Pedestrian								

2. MAKES BODY CONTACT (Collision) ______________________

	1	2	3	4	5	6	7	8
Obstacle								
Pedestrian								

STREET CROSSINGS

1. MAKES CANE CONTACT (Collision)______________________

	1	2	3	4	5	6	7	8
Obstacle								
Pedestrian								

2. MAKES BODY CONTACT (Collision)______________________

	1	2	3	4	5	6	7	8
Obstacle								
Pedestrian								

3. VEERS ON STREET CROSSING______________________

	1	2	3	4	5	6	7	8
Towards parallel traffic								
away from parallel traffic								

TABLE A17 (cont'd)

END OF RUN

SCORER 2

1. PEDESTRIAN TRAFFIC ON RUN ______________________________

Heavy ________
Medium ________
Light ________

2. AUTOMOBILE TRAFFIC ON RUN ______________________________

Heavy ________
Medium ________
Light ________

3. WEATHER DURING RUN ______________________________

Sunny ________
Overcast ______
Raining _______

4. UNUSUAL OCCURRENCES (if any)

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