# SENSORY AIDS

*Edited by*
Howard Freiberger, A.M.
Chief, Rehabilitation Engineering Service
Veterans Administration Prosthetics Center
252 Seventh Avenue
New York, N.Y. 10001

## Clinical Application Study of Reading and Mobility Aids for the Blind

**Eastern Blind Rehabilitation Center**
**West Haven VA Medical Center**
**West Spring Street**
**West Haven, Connecticut 06516**
**Don E. Garner, William R. De l'Aune, Ph. D., and Patricia D. Gadbaw**

### Technology Transfer Activities

*Polaroid Corporation*

In April of this year Dr. Gilbert Elchinger of the Advanced Development Group of the Polaroid Corporation visited the research department of the Eastern Blind Rehabilitation Center. Dr. Elchinger has been assigned to determine the feasibility of employing the new Polaroid sonar focusing module in a mobility device for the blind. He was currently involved with the implementation of such a system in a configuration appropriate for a blind quadriplegic patient who is confined to a motorized wheelchair in VA Medical Center, West Roxbury, Mass.

In consultation about this project with both the research and mobility staffs, it was emphasized that drop-offs were very critical environmental features for blind wheelchair users. Obstacle detecting beams for peripheral obstructions, and possible displays for that information, were also discussed. The research department also put Dr. Elchinger in contact with VAPC New York, because of their broad base of experience with motorized wheelchairs.

Dr. Elchinger brought with him a prototype cane-mounted sensor which provided upper body and head protection information to the user when the cane was employed in a normal fashion. The device was also capable of looking forward up to 30 ft, with a frequency/distance coded

auditory output, when it was held in an upright position and scanned.

A number of very innovative features were proposed, including an electronics and battery module mounted in a small package separate from the transducer and linked by radio transmission. This would allow the cane-mounted transducer to be very light, and would also help keep the batteries warmed by body heat in cold travel environments. Such a configuration would also allow the user considerable flexibility in the placement of the detector (i.e., it could be clipped onto a rigid cane, transferred to a folding cane, hand-scanned without a cane in a restricted environment, pinned to clothing, or worn as a medallion, etc.) Further reports on the progress of this device were promised.

*American Foundation for the Blind*

In June 1979, a meeting was held at AFB headquarters in New York, with Dr. Emerson Foulke and Dr. William De l'Aune as invited guests of Mr. Douglas Maure, Chief of Engineering in the Research Department of AFB. The two visitors were shown the prototype of the AFB mobile microprocessor mobility device. This experimental system uses the Polaroid sonar sensor as an environmental probe and contains sufficient microprocessor power to process and display the obtained data in a number of ways. The purpose of this meeting was to attempt to decide what software would be the most appropriate for the initial series of evaluations to be conducted at the VAMC in West Haven and the University of Louisville's Perceptual Alternatives Laboratories.

It was decided that a standard mode of obstacle detection, in which the device would warn the user of the presence of a reflecting object, would be desirable. The range of detection in this mode could be set at will by the experimenter. A distance indicating mode was also requested in which the distance/frequency relationship of an auditory or tactile output could be manipulated, as well as the overall range of detection. A "clear path" mode was proposed, in which the device would remain inactive unless it sensed the presence of osbstacles. Finally, a movement mode was planned, in which the device would remain silent unless the target object's distance to the user was decreasing at greater than a preselected rate. In this mode, the possibility of obtaining distance (pitch) and approach rate (pulse repetition rate) as an output was discussed. (A synthetically spoken output was also mentioned and will be provided as a user-selectable option.)

Because of the software dependence of the device, all of these modes can be evaluated and the device simply reprogrammed to perform either new tasks or modified versions of the original tasks in response to the ongoing evaluation. The first system should be available in a few months.

*Haskins Laboratories*

Dr. De l'Aune has been working with Dr. Terry Halwes of Haskins Laboratories in the synthesis of consonant-vowel stimuli with varying vowel onset delays. These stimuli are to be used in an auditory component of a NASA-funded project being conducted at Florida State University by Dr. Lloyd Elfner. Dr. De l'Aune considered his increased understanding of the capabilities of the Haskins facilities and the problems involved with synthetic speech to be the most valuable outcome of this involvement.

**Potential Cooperative Research Project Meetings**

*Teleflex, Incorporated*

Mr. Barry Barsky, new product engineer from Teleflex, has continued his efforts in the development of an auditory-output wristwatch for the blind (BPR, Spring 1979, p. 147). He has produced a functional prototype.

*Innovative Concepts Company*

Mr. Robert Sanford, president of Innovative Concepts, requested assistance in refining his proposal to utilize large-area Fresnel magnifiers as low vision aids. The large field of view, low cost, light weight, and portability of the sample lenses were greeted with great enthusiasm by the staff, especially when used in arm's length tasks. Suggestions for several types of mounting systems, and specifications of the types of tasks the devices were likely to be used in, were provided to Mr. Sanford.

*Georgia Institute of Technology*

Professor Leslie G. Callahan of the School of Industrial and Systems Engineering visited the research department of the Blind Center to discuss his ideas about using the pushbuttons on a telephone to communicate with a centralized computer system. This system would be capable of being as simple or as complex as the user wished, limited only by the number of code strings he desired to employ in his interactions with the central unit. Such a system could provide him with things as simple as information about his bank account or access to a personal directory, or could function as a highly sophisticated programmable calculator. A synthetically spoken output would be used in all cases.

*Texas Polytechnic and Research Institute*

Ms. Georgene M. Nielsen, manufacturing representative for the

Sensory Quill, a device developed at TP&RI, visited the center to demonstrate new materials upon which tactile drawings could be made with the device. Several other research proposals and prototype devices from TP&RI were discussed and demonstrated. A grant in which recreational aids were to be developed was examined. Audible targets for golf, basketball, and other aiming-type games were proposed through the use of a very small, inexpensive sound source developed by the Institute.

The prototype of a hand-held ultrasonic mobility device similar in concept to the Kay Torch was shown to the mobility staff. The "U-Guide" is similar in size to the Mowat Sonar Sensor, but provides the user with an auditory output in a frequency/distance code.

A TP&RI proposal to study optimum folding cane characteristics was discussed in great depth. The results of the recent Cooper Union project and of the AFB subjective evaluation of existing folding canes were brought to the attention of Ms. Nielson.

A reading stand for low vision patients was shown to the low vision staff and their comments solicited. A workable prototype incorporating most of their suggestions and the suggestions of clients using the initial device in the low vision clinic was supplied to the center a few weeks later. This stand was regarded very highly by both staff and patients. Ms. Nielson is seeking an appropriate marketing mechanism at this time.

**Meetings at which Blind Center Research Personnel Participated.**

1. *Journal of Visual Impairment and Blindness Editorial Advisory Board Meeting,* March, 1979, Chicago. The appointment of Dr. De l'Aune as a consulting editor for research of the Journal of Visual Impairment and Blindness was announced at this meeting, which was attended by Dr. De l'Aune.

2. *Seventh Annual New England Bioengineering Conference,* Troy, NY, March, 1979. Dr. De l'Aune presented a paper entitled "Project Involved with the Research and Development of Simulators of Auditory and Visual Impairment." which outlined the ongoing work on this project at the center. The paper was also published in the proceedings of the meeting.

3. *Low Vision Workshop,* Concord, NH, April, 1979. Ms. Patricia Gadbaw co-authored a paper with Mr. William Finn entitled "Basic Information for Ancillary Personnel Concerned with Low Vision Evaluations" and presented the material to the participants at this conference.

4. *AFB Research Seminar—Folding Canes,* New York, April, 1979. Dr. De l'Aune attended this seminar as an invited guest. The discus-

sants presented the results of the Cooper Union and the AFB folding cane evaluations, and also spoke of manufacturing difficulties involved with innovative device design.

5. *Workshop on Services for Deaf-Blind Persons,* Madison, Wisconsin, April, 1979. Dr. De l'Aune presented information on "The Problems of the Hearing Impaired Blind Adult." The text of this presentation will be published in an upcoming issue of the Journal of Blindness and Visual Impairment.

6. *AAWB Seminar on Diabetes,* Newton, Mass., March 1979. Dr. De l'Aune chaired a session on technology and the blind diabetic, and Ms. Gadbaw served as a program chairperson and a member of the planning committee.

7. *AAWB Seminar on Perception,* Newton, Massachusettes, May, 1979. Ms. Gadbaw served on the planning committee of this meeting.

8. *American Foundation for the Blind, Special Research Meeting,* New York, June 1979. Dr. De l'Aune was an invited discussant in a meeting arranged for Dr. Osamu Sueda of the Department of Biological Engineering, Osaka University, Japan. Dr. Sueda is in the forefront of efforts in Japan to develop a braille production system based on minicomputers and microcomputers. He is also investigating tactile television displays for the blind. His paperless braille system features capabilities for full page displays.

## Ongoing Research Activities

*Visual and Auditory Impairment Simulation Project*

This project is proceding according to plan. An outline of its progress was presented in March at a meeting referred to in the previous section.

Telephone conferences were held with the consultants and the design of the simulators was agreed upon. The low vision simulators are being fabricated by Dr. Randall Jose, Chief of the William Feinbloom Vision Rehabilitation Center of the Pennsylvania College of Optometry. Mr. Richard Koch, electronic consultant from Lynbrook, New York, is constructing the auditory impairment simulators. Both systems should be available for evaluation in the Fall of this year.

In a related project, a paper on the effects of hearing aids on the ability of blinded veterans to localize noise stimuli was written by Mr. Bruce Bergen, a work study graduate student in the research department, and has been accepted for publication in the Journal of Visual Impairment and Blindness.

*New York Association for the Blind Cooperative Personality Study*

The first batch of data from Minnesota Multiphasic Personality

Inventories (MMPI) and California Psychological Inventories (CPI) administered to congenitally blind clients at the Lighthouse was analyzed by means of the EBRC computer programs. Marked differences in test results were noted between those of the EBRC's adventitiously blinded clients and those from this sample. Further analysis is underway along with continued data acquisition.

*Beliefs About Blindness*

Drs. Walter Needham and Marjy Ehmer have been recently exploring the applicability of Albert Ellis' Rational Emotive Therapy model to the blind center's clients' adjustment to blindness. In this model one's irrational beliefs about his life situation can lead to emotional turmoil.

To quantify the extent of such irrational beliefs about blindness, Drs. Needham and Ehmer compiled a listing of those they observed in several years of interviews with newly blinded patients. A paper based on this initial study has been accepted for publication in the Journal of Visual Impairment and Blindness. From this listing a questionnaire was developed in which the respondent was given the option of five responses ranging from strong agreement to strong disagreement on forty statements concerning beliefs about blindness. It is hoped that eventually such a questionnaire may prove to be useful as a diagnostic tool. Dr. De l'Aune is currently involved in the statistical analysis of large amounts of data from blind clients, blind professionals, and sighted people both familiar and unfamiliar with the problems of blindness.

*Mobility Questionnaire*

Responses to a mobility questionnaire have been computer-coded for 161 clients. The questionnaire was refined after evaluation of the responses to an initial mobility questionnaire study. The responses will be computer analyzed for the type of travel environment, the recency of last travel, the destination of last travel, the types of aids used, the perceived usefulness of mobility training, the stated reasons for traveling, the stated reasons for not traveling and the respondent's impression of his own need for further training. Relationships between these factors will also be studied.

*Visual Pathology Code*

A two-digit code for the primary cause and a two-digit code for the presenting cause of blindness was developed by Ms. Gadbaw. The system is being evaluated at the center by Optometric and Low Vision

Clinic staff. This coding is expected to have a great impact on the computerization of low-vision data.

*Reading Program*

In conjunction with Instructional Communications Technology, Ms. Gadbaw is developing a reading program in the hopes of training clients with extreme field restrictions to track more efficiently in reading situations. It is hoped that the skills gained from this effort will provide a basis upon which skills in mobility tasks can be increased.

**Clinical Application Study of Mobility Aids for the Blind**

**Central Rehabilitation Section for Visually Impaired and Blinded Veterans**
**Hines VA Medical Center**
**Hines, Illinois 60141**
**John D. Malamazian and Leicester W. Farmer**

This reporting period began with a visit by peripatologist Judy Sharko, Orientation and Mobility representative for Nurion, Inc., which manufactures the Laser Cane. Mrs. Sharko made the trip to Hines to demonstrate the first Laser Cane (the N-6 Model) produced by the new company and to have Mr. Leicester W. Farmer evaluate the cane.

In March, four Nurion N-6 Laser Canes were delivered to Hines from Nurion and underwent evaluation by Mr. Farmer. The Nurion cane was also evaluated and field-tested by two veterans who have been using Laser Canes since 1971 in the Chicago area.

The upper portion of the Nurion Laser Cane looks like the Bionic Instruments Laser Cane. The Nurion Cane is slightly heavier and shorter than the Bionic Cane, but none of the users have been able to notice any difference. The lower shaft of the Nurion Cane is considerably thinner and more tapered from top to bottom than the lower shaft of the Bionic C-5 Cane; it is not apparent whether this makes any difference at all.

There have been some problems with the quick disconnect extension at the bottom of the upper portion of the cane; two of these extensions have broken off from the new canes, thus indicating a possible weakness in this area. The company has identified the cause of the problem and feels that it has instituted measures which will remedy this situation. Also, when the lower shaft is attached to the upper portion by means of the quick disconnect, the shaft tends to bend slightly to the right as a rule. This has no apparent effect on the [illegible]

cane or its operation by the user but it is something that must be corrected in the next production lot, if only for cosmetic reasons.

The Bionic C-5 Cane had a projecting screwhead immediately below the range switch, which was used by one of the veterans to locate the range control switch; the screw on the Nurion Cane is less prominent and the veteran misses the reference point. The on/off switch for the Nurion Cane is not rounded as is the switch for the C-5 Cane. It has some rough edges which are abrasive to the fingers when the cane sticks in the grass or along a rough, broken pavement.

One of the N-6 Canes failed to detect objects on short range when used in bright sunlight. The cause of the problem has been pinpointed and the company has corrected this situation.

Initial reports from two experienced users give the Nurion Laser Cane high grades in performance and sturdiness of construction. The tactile stimulator is easier to feel (one user had no trouble feeling it through gloves), the down channel seems to be more sensitive than in the Bionic C-5, and the thumb-wheel volume control is easier to manipulate.

The audible levels on the N-6 Cane have come in for some opposing viewpoints by the users and Mr. Farmer. One traveler likes the loudness of the N-6 better than his C-5. He reports that he could still hear the signals while waiting at a railroad crossing for a train to pass. This seemed especially true for the down channel. However, another user feels that although the audible signals of the N-6 Cane are louder than those for the C-5, he does not like the pitches of the forward and down channels because the pitches do not seem as attention-getting. The volume might be greater but for him it lacks intensity and the signals seem to be more easily absorbed in the environment; Mr. Farmer also prefers the audible signals of the C-5 Cane. He feels that more confusion in trying to distinguish the signals of the N-6 canes (particularly between the up and forward channels) is possible with the current sound levels of this device. However, both the above consumer and Mr. Farmer like the up channel signals of the N-6 Cane better than those of the C-5 unit. The pulse repetition rate of the N-6 Cane is 80 pulses per second.

One of the greatest concerns of persons involved with electronic travel aid programs, after considerations of cost benefit and training are resolved, is to what degree (and how long after training) are the travel aids used by the trainees? Mr. Farmer conducted a survey of the veterans who have been trained at Hines to use the Laser Cane and reported his findings in a report to the Veterans Administration. A summary of the results of that survey, which was conducted in May 1979, follows.

### Review of the Laser Cane Program Since 1971

1. 20 veterans have been admitted to the Blind Center at Hines for training with the Laser Cane since 1971.
2. One veteran could not participate in the program because his cane technique, and basic orientation and mobility skills, were just too poor.
3. One veteran received training with the Laser Cane for 6 weeks but still was unable to learn to use the cane adequately and safely.
4. Eighteen veterans have successfully completed training with the Laser Cane since 1971.
5. Eleven veterans have been using the Laser Cane for periods of from 2 to 8 years; these are all current users. Nine of the 11 users use their Laser Canes as their primary travel aid every day and the remaining two use their Laser Canes at least three times per week.
6. One veteran lost the hearing in one ear and now uses a dog guide; he was one of the first 4 trained in 1971.
7. One veteran returned the Laser Cane (he was also one of the first 4 trained) and was trained to use the Sonicguide—which was then lost in a fire that destroyed his home. In the fall of 1978 he requested another Laser Cane but none were available at that time.
8. One veteran died only a few months after returning home with his Laser Cane.
9. Four veterans were trained to use the Laser Cane in 1977 but did not receive Laser Canes because a fire destroyed the Bionic Instruments, Inc. factory that year, and no Laser Canes were produced again until the first quarter of 1979.

The four last-mentioned veterans have all returned to Hines for a refresher course with the N-6 Laser Canes lasting from 3 to 5 days and have been issued Laser Canes.

Another veteran was admitted to Hines for training with the Mowat Sensor and the Lindsay Russell Pathsounder.

### U-Guide Travel Aid

During this reporting period D. Reginald Traylor, Ph. D., visited Hines to introduce the U-Guide travel aid to the research team. Dr. Traylor is President of Traylor Enterprises, Inc. which is the manufacturing part of Texas Polytechnic & Research Institute, San Antonio, Texas. The U-Guide is a hand-held device approximately 4 x 2 x 1¼ inches. It has an audible output which is heard by means of an earphone. This device affords the user information about distances involved between the user and the target through signal pitch — high

pitch for far objects and low pitch for near objects. Dr. Traylor discussed standards to specify function, capacity, and performance of the U-Guide and other travel devices with the research personnel. He also introduced the Audibee, a Frisbee-like flying disc. It contains microminiature electronic components and a sound source and is designed to be used by blind and partially sighted persons.

### Other Activities

Mr. Farmer conducted a 3 weeks electronic travel-aids course (from May 28 to June 15, 1979) and certified (under the authority of Western Michigan University), four Orientation and Mobility Specialists to teach the Mowat Sensor, Nottingham Obstacle Detector, and the Sonicguide. The course was held at Centre Louis-Hebert. Two of the students were from Institut Nazareth et Louis-Braille, Longueuil, Quebec. Familiarization with the Lindsay Russell Pathsounder and the Laser Cane was given. The principles, function, and uses of light probes were also covered in the course.

This reporting period marked the end of a 22-week course on "Basic Electricity, Electronics and Instrumentation," given at Hines. The course ran from November 1, 1978 to May 24, 1979 and was especially designed to meet the needs of the Hines Blind Center staff. The series of lectures, presented in excellent fashion by Dr. Kenneth W. Haag, assistant chairman of the Electrical Engineering Department, Illinois Institute of Technology, Chicago, Illinois, were stripped of as much of the highly technical language of the engineering community as possible. The information proved very beneficial and was most appreciated by the Hines Blind Center staff.

## Clinical Trials of Reading Machines for the Blind

**Central Rehabilitation Section for Visually Impaired and Blinded Veterans**
**Hines VA Medical Center**
**Hines, Illinois 60141**
**John D. Malamazian, Harvey L. Lauer, and Leonard Mowinski**

### The Reading Aids Program

This project is concerned with the clinical evaluation of reading machines and other communication aids for the blind. There are two full-time staff members, Harvey Lauer and Leonard Mowinski.

An audible output for the Optacon (a tactile-output reading machine) has been built to Mr. Lauer's specifications. This first effective bimodal reading aid for touch and hearing was designed by Ber-

nard Vecerek of Illinois Institute of Technology, (I.I.T.) with the cooperation of the Optacon's manufacturer, TSI. The first 12-tone model was well-accepted by reading-aid users, and the code may be incorporated in the hand scanner being designed for the Kurzweil Reading Machine (KRM). A 24-tone model is being tested at Hines. Prototypes will soon be available for other centers.

Messrs. Lauer and Mowinski wrote two articles. The first is "Communication Aids for the Blind" which is to be published in Blindness 1979, the annual publication of the American Association of Workers for the Blind. The second is "Personal Reading Machines for the Blind, Report to Consumers and Developers." It includes a report on the evaluation of the 12-tone audible attachment for the Optacon. The above documents, as well as updated articles on speech compressors and calculators for the blind are available from the Hines Blind Center.

Mr. Lauer spent a week at Kurzweil Computer Products, Inc., conferring with personnel regarding design of the hand scanner and other new products. He also spent a day at ARTS Associates which is developing braille, large-print, and talking computer terminals.

Mr. Mowinski, in collaboration with staff at the three VA Blind Rehabilitation Centers, wrote "The Reading Machine Program for Blinded Veterans." It describes the Optacon training program and describes requirements for acceptance at the three centers. The document is available from any of the centers and is being published in the BVA Bulletin. A similar paper is being prepared regarding the Kurzweil Machine.

Mr. Lauer wrote: "Findings and Recommendations on the Synthesized Speech Program of the Kurzweil Machine." It has been shared with the makers of reading machines.

Pursuant to the need for computer terminals by blind people in professional and clerical occupations, a Diablo Model 1620 printer terminal was purchased. It was very successfully interfaced with the ELINFA Portable Braille Recorder, which acts as a braille terminal. This provides a braille output typewriter with text editing capability. The KRM will also be interfaced to function as a talking terminal. Test interfacing will soon be done with computers and terminals at the Hines Data Processing Center and the Western Blind Rehabilitation Center by phone. A cooperative arrangement is also underway with the new Rehabilitative Engineering Research and Development Center at Hines.

The research staff participated in the KRM optical character recognition study coordinated by Dr. Goodrich at the Western BRC. A report of the results can be obtained from Dr. Goodrich. Clinical

evaluation of the KRM was continued, with emphasis shifting to the new desktop Model III. The machine is being tested, and veterans are being taught to use it.

## Clinical Application Study of Reading and Mobility Aids for the Blind

**Western Blind Rehabilitation Center**
**Palo Alto VA Medical Center**
**3801 Miranda Avenue**
**Palo Alto, California 94304**
**J. Kenneth Wiley, Gregory L. Goodrich, Ph. D., Richard R. Bennett, and H. Stanton Paul**

### Evaluation of the 2nd Generation Kurzweil Reading Machine

During the current reporting period, all visually impaired staff of the WBRC completed familiarization and training in the use of the KRM. In addition, demonstrations of the KRM were made during February at the Exploratorium in San Francisco, as part of a feature program on blindness, and during March at the VA Medical Center, Palo Alto, "Handicapped Week" program. A demonstration of the KRM text-to-speech capabilities was conducted in February and attended by Dr. Vernon Nickel and Mr. Frank Coombs of the VA Rehabilitative Engineering Research and Development Service, Washington, D.C., Mr. Howard Freiberger, VA Prosthetics Center, New York, Mr. Loyal Apple, Executive Director, American Foundation for the Blind, and representatives from Kurzweil Computer Products and Tektronix, Inc.

The WBRC's evaluation of the 2nd generation KRM had five specific goals: (i) evaluate the reliability and assess the repair rate of the KRM, (ii) evaluate the effectiveness of the KRM within the context of a BRC, (iii) develop selection criteria and training procedures for the target population, (iv) interface with on-going evaluations at other centers, and (v) assess the KRM's ability to interface with other computer systems.

The electronic functioning of the KRM from January through June 1979 was satisfactory with two exceptions. In March the unit began functioning in a mode characterized by scanning and inputting to memory, but no voice output. If recalled from memory the scanned material would be read, but could not be accessed directly during scanning. This "bug" could usually be corrected by reloading the program. KCP reported that they had not previously encountered the problem so a service representative was dispatched. The repair effort

on the KRM was not successful but it was decided to let the machine continue temporarily to see if the problem would remain, correct itself, or worsen. To date the problem persists with occasional "silent" readings, but no change from its previous pattern. The second problem occurred in May when a bearing assembly in the scanner became faulty with the result that the scanner would not calibrate. That fault was corrected by KCP service personnel.

The KRM has received only limited use by WBRC personnel. It is hypothesized that two factors account for this fact. First, all professional staff at the WBRC have previously developed successful means of accessing printed material necessary for their professional careers: these means include sighted readers and the use of braille and recorded material. Second, the KRM's ability to read material is limited by the type style of the material and the quality of print. Specifically, as the quality of print is decreased the intelligibility of the output decreases. Therefore, many of the day-to-day materials relevant to staff members (e.g., memos, carbon copies, patient files, etc.) are not readable on the machine. The problem is compounded by the complex formats the material is printed in (e.g., columns, pictures or graphs on page, multiple type styles per page, etc.) since these are not easily handled by the machine.

Preliminary work on developing training techniques for instructing veterans in the use of the KRM has begun: however, this work has concentrated on general techniques rather than specific training items. In part this has been necessitated by modifications KCP intends to make on the 3rd generation of the machine. The exact nature of these modifications is not yet known.

The WBRC has cooperated extensively with KRM evaluations at the EBRC and CBRC. This cooperation has allowed for comparisons between the VA's two 2nd generation and one 1st generation KRM. The comparison indicates similar performance characteristics between the machines, in particular the two 2nd generation KRM's. A study of the optical character recognition error rate of the devices (using three type fonts and 5 methods of reproducing material) indicates the machine performs relatively well on different type styles. However, unless printed material is of relatively high quality (e.g., carbon ribbon typing) the machines' recognition qualities would not be sufficient for many types of reading. That is, the error rate would be expected to exceed 5 percent for many photocopies, memos, carbon copies and similar types of correspondence. A further limitation for the KRM user is the difficulty of coping with columns, pictures, and figures embedded in text. It appears that, unless the user's reading needs were largely confined to books, the current KRM's (and software pro-

grams) would read only about 20-to-50 percent of the necessary material.

The "learning" feature of the KRM was also evaluated in the cooperative work by the three BRC's. In general, the learning feature improves optical character recognition in the KRM. In normal practice, at least one page of text (in a single type style) must be read before learning approaches an optimum level. The average improvement in optical character recognition accuracy was over 20 percent.

These results have been communicated to Kurzweil Computer Products, which has already begun incorporating improvements in a 3rd generation device. These improvements include improved software, a graphics tablet device to control scanner position, and an improved computer, as well as other changes. The VA has purchased two 3rd generation machines for further evaluation.

One of the most exciting aspects of the WBRC's KRM evaluation has been the exploration of the versatility of the KRM in interfacing with other computer systems. Using a Tektronix 4051 graphic system, appropriate software, and the KRM, Mr. Bennett was able to demonstrate that a visually impaired user can rapidly and easily access information stored on computer tape, add to the information, delete information and control the output of the computer either in a voice mode (KRM) or on a computer printer (Diablo Hyterm Printer). A wide range of educational and employment opportunities could be opened to the blind through such access. These would obviously include employment in computer programming, but could also include such diverse occupations as banking, accounting, reservation clerk, word processor, claims representative, and administration. Such occupations are becoming heavily dependent upon access to computers.

### ELINFA Digicassette

Evaluation of the Digicassette continued. Previous difficulties with the braille display have apparently been resolved. Among the uses of the ELINFA were a series of cassette letters sent to a deaf blind ELINFA user at Hewlett Packard's Santa Rosa facility. The ELINFA was perhaps the best means of correspondence with this individual, and since he had recently purchased an RS-232 braille-to-ASCII conversion unit from ELINFA, the WBRC's 4051 computer was interfaced directly to the ELINFA. This proved to be an extremely efficient means of communication. An attempt was also made to interface the Kurzweil Reading Machine with the ELINFA (which would have provided a direct reading ability to the deaf blind individual); however, the KRM in use at the WBRC does not have the capability of transmitting (at least in its present configuration).

### Optacon

During the current reporting period five veterans were evaluated for Optacon training. In accordance with center policy, formal training was postponed until all had completed the rest of their training at the WBRC.

### Tonal Display for Optacon

In May, a "black box" tonal package for use with the Optacon was received from Mr. Harvey Lauer. The device (developed by researchers at the Illinois Institute of Technology) adds a 12-tone auditory display to the existing tactile display of the Optacon. This creates both an auditory and tactile display, which may allow easier learning of the Optacon and improved reading speeds. The evaluation is in progress.

### AmBiChron 102

An AmBiChron Model 102 pitch-correcting device for use with variable speed tape recorders was evaluated at the center. The pitch-correcting quality of the device is good, and it has other advantages in that it is portable and works on 110-V power, in addition to its internal batteries.

### Spatial Contrast Sensitivity

One of many mobility problems facing the low vision traveler is that of distinguishing "figure from ground." This conception is, however, closely analogous to detecting grating patterns of varying frequency and contrast. To test the analogy, a cooperative project with Drs. Ian Bailey and Jim Meron of the School of Optometry, University of California, Berkeley, was begun. The project had two phases. First, each subject was tested using projected sine wave gratings of varying frequency and contrast. Second, each subject's mobility performance on three different routes was assessed. The three routes included an indoor controlled environment, an outdoor mobility route, and an indoor route. Preliminary data analysis indicates significant differences in spatial contrast sensitivity compared to normals — and the degree of impairment appears to be related to performance on mobility tests. If the final data analysis confirms these results, spatial contrast sensitivity testing may become a useful tool in low vision examinations for prescribing filters, low vision aids, and in training.

### Parameters in the Use of CCTV's

Previous work at the WBRC has related reading performance to a

number of factors related to the use of CCTV's. Among these are contrast, working distance, linear and effective magnification. While no single expression of these variables completely accounts for all performance variance, it appears that reading speed is directly related to the number of characters (e.g. letters) that can be displayed across one line of print on the CCTV monitor. Current portable CCTV's derive their portability primarily by reducing the size of the monitor. The unfortunate result is a reduction in reading speed with the portable CCTV (compared to full-size systems). A cooperative project with Mr. Roger Macdonald of Smith-Kettlewell Institute of Visual Sciences has been undertaken with the long-term goal of developing a portable CCTV system which allows user performance to match that obtained with large table models. The initial steps of the project have been to measure user performance as it is affected by variations in contrast, magnification, and length of line of print. This data will be used to evaluate different monitor displays, including liquid crystal displays (LCD's), light emitting diode displays (LED's), and cathode ray tubes.

### IT&T Nightscope Evaluation

Late in 1978, three IT&T Clinical Pocketscopes were delivered to the WBRC for preliminary testing and to be used in the development of an evaluation protocol. The protocol includes measures of visual acuity under photopic and scotopic illumination, photopic and scotopic mobility performance independent of the aid, and scotopic mobility performance with the aid. Results of initial testing of the aid indicate wide variability in subject performance with the aid. In part, the variability may be due to the size of visual field of the subject—if the subject's visual field exceeds a minimum visual angle, mobility performance may be impaired by the device, but for angles below this value, performance may be improved.

The protocol is currently being written in final form to be sent to EBRC and CBRC for additional testing.

### Electronic Travel Aids

During the current reporting period, two Orientation and Mobility staff members obtained electronic travel aid instructor-training at Western Michigan University.

## Clinical and Acoustic Parameters of Hearing Aid Effectiveness

**Biocommunications Laboratory**
**University of Maryland**
**College Park, Maryland 20742**

**Washington, D.C. VA Medical Center**
**Washington, D.C. 20422**

**G. Donald Causey, Ph. D., Jerry L. Punch, Ph. D., and Howard C. Schweitzer, Ph. D.**

### The Performance of Aids with AGC

Previously collected data, on the operation of automatic gain control (AGC) hearing aids during the simultaneous processing of noise and "signal", were used to prepare a tutorial manuscript on the operational characteristics of AGC aids. This paper has been accepted for publication in the Journal of the American Audio Society.

### The Relation of Measurements on KEMAR to Behavioral Performance

This is an updating of the investigation to obtain functional gain measures on sensorineurally-impaired subjects and relate those measures to hearing-aid insertion gain. Functional gain is defined as the difference between aided pure tone sound field thresholds and unaided pure tone sound field thresholds. Insertion gain is the sound pressure at the coupler microphone with the hearing aid in place on KEMAR, less the pressure which would exist at the coupler microphone with no hearing aid in place.

The subjects were 33 patients of the Audiology and Speech Pathology Service, VA Medical Center, Washington, D.C., with sensorineural hearing losses in the moderate to moderately-severe category. The Grason-Stadler Audiometer Model 1702 was used for the measures of functional gain. Bruel & Kjaer and associated test equipment was used for insertion gain measures on KEMAR. The insertion gains of two moderate power over-the-ear hearing aids were measured on KEMAR in the anechoic chamber. Volume control positions were full-on for these measurements. Aided and unaided threshold measurements using interrupted pure-tone stimuli were then obtained with the opposite ear occluded. Volume control positions were identical for both procedures. Fully occluding earmolds were used on the manikin and the subjects. The mean difference in decibels between insertion gain and mean functional gain, as a function of frequency, is shown in Table 1. Mean differences were small (2 dB or less) for most of the frequencies examined.

Because of the increased use of insertion gain and functional gain, research in this area is continuing.

TABLE 1.—*Mean and standard deviation of differences between insertion gain and functional gain.*

| | 500 | 750 | 1000 | 1500 | 2000 | 3000 | 4000 |
|---|---|---|---|---|---|---|---|
| MEAN | 3.8 | 2.2 | 1.7 | 1.4 | 1.2 | 1.6 | 6.6 |
| S.D. | 3.5 | 4.5 | 4.0 | 5.0 | 5.0 | 6.8 | 6.8 |

## Hearing Aid Quality Judgments

Our previous work in the area of quality judgments of hearing-aid-processed speech, performed under contract with the Veterans Administration, has led us to the following conclusions:

1. The intrasubject test-retest reliability of paired-comparison preference judgments of the quality of speech reproduced by hearing aids is satisfactorily high;
2. Hearing aid preferences assigned for male speech, female speech, and music stimuli are highly associated;
3. Similar hearing aid rankings are assigned to hearing-aid-processed conditions by normal-hearing listeners and listeners with sensorineural hearing loss; and
4. There is an overall lack of interaction between hearing aids and listeners, as evidenced in both a normal-hearing group and in a group of hearing-impaired listeners having high-frequency sensorineural loss.

More recent work in this area has concentrated on the question of what perceptual factors underlie judgments of the quality of hearing-aid-processed speech. Although it appears reasonable to assume that listeners evaluate their aided success in real-life situations on the basis of subjective impressions of the quality of amplified speech, little is known about the bases for a listener's judgment that speech is of low or high quality. Therefore, it is desirable to have information relating quality judgments of hearing-aid-processed speech to electroacoustic characteristics of the instruments.

The strategy being used to study this question is to apply multidimensional analytical techniques, including INDSCAL (Carroll and Chang, 1970), to similarity ratings and preferences obtained using a paired-comparison paradigm in which connected discourse was recorded through 20 different hearing aids. This resulted in a total of 190 paired comparisons, which were replicated for purposes of test-

ing reliability. Recording was accomplished by using the acoustic manikin KEMAR (Burkhard and Sachs, 1975), located in an anechoic chamber, in conjunction with two Zwislocki couplers (Zwislocki, 1970, 1971). Three groups of subjects, normal listeners, listeners with high-frequency sensorineural loss, and listeners with flat sensorineural loss, are being investigated; each group comprises 10 subjects. Data collection is complete on these groups, but we are continuing to analyze the results and to draw clinically relevant conclusions from them. A preliminary group analysis was reported for the normal listeners and the listeners with high-frequency hearing loss in the Spring 1979 Bulletin. Analyses performed thus far indicate that these listener groups exhibit reasonably high reliability in their ratings and preferences. In all groups, low-cutoff frequency (LCO) has been identified as the perceptual dimension on which similarity ratings and preferences are most strongly based.

Because INDSCAL provides a measure only of the dimensions shared in common by subjects in a sample population, further multidimensional analyses are underway to identify the perceptual bases underlying the quality judgments of individual listeners. Results thus far indicate that normal-hearing individuals do indeed differ in their use of specific perceptual dimensions to evaluate speech quality — although low-cutoff frequency remains the most salient dimension for any given listener.

Some of the secondary dimensions include index of response irregularity (IRI), equivalent input noise level (Ln), high-cutoff frequency, and transient decay. These cues differ, and vary in number, from subject to subject. The fact that LCO is the strongest dimension for all listeners is probably sufficient to explain the lack of a substantial hearing-aid/listener interaction, noted in our earlier work in the area of quality judgments (Punch, 1978). The implication is that listeners will utilize this characteristic predominantly as the basis for their judgments of aided speech quality.

INDSCAL and individual subject analyses are continuing at the time of this writing, and results will be reported as available.

### Hearing Aid Quality Judgments: A Confirmatory Study

A followup experiment was designed in which low-cutoff frequency (LCO) was parametrically controlled via a binaural "master hearing aid," and hearing-impaired listeners were asked to make paired-comparison preference judgments of the quality of recorded speech as processed by this instrument. The results were expected not only to provide support for our earlier findings, which, as described above, were obtained by a posteriori methods, but also to determine the

effect of relative differences in LCO magnitude on evaluative judgments of aided speech quality.

A single 20-sec passage of connected discourse, spoken by a male talker with "General American" dialect, was used as the stimulus material. The master hearing aid (MHA) consisted of a two-channel hearing evaluator constructed by Starkey Labs, Inc. For a given channel of this apparatus, the acoustic signal is picked up at ear level by a hearing aid microphone mounted in a conventional behind-the-ear case. The electrical signal is led to self-contained hearing aid amplifier circuitry whose adjustments provide wide ranges of gain, maximum output, high-cutoff frequency, and low-cutoff frequency. The amplified signal is routed to a hearing aid receiver, also housed in the behind-the-ear case. The binaural cases were mounted on KEMAR, and the outputs of the respective channels were recorded on two tracks of high-quality magnetic tape in paired-comparison format.

With all other settings of the MHA held constant, LCO was varied in seven discrete steps ranging from 300 to 700 Hz. Symmetry of the two channels of the MHA and of KEMAR was measured and found to be acceptable for the study. Stimuli were recorded at an input VU meter reading corresponding to the level of speech-spectrum noise yielded at the respective LCO settings. This precedure ensured that subject responses would not be based simply on relative intensity differences of the two channels. Each LCO setting (1-7, from highest to lowest LCO) was paired with every other setting, for a total of 21 paired comparisons. For purposes of determining reliability and any effects of practice on listener performance, three additional sets of all paired conditions were recorded. Order of settings and channels was randomized throughout each of the four experimental trials.

The recordings of the passage of MHA-processed speech were presented to 12 listeners with gradually sloping sensorineural hearing loss, who were asked to listen alternately to the two channels of the recordings and to state a channel preference (A or B), based on sound quality, following each paired condition. Signals during this experimental procedure were transduced by a wide-response hearing aid receiver, adjusted for minor response irregularities and attached to custom-fitted standard earmolds.

The data reveal a strong trend toward preference for higher-numbered settings over lower-numbered settings, indicating preference for speech having lower LCO's, or greater low-frequency emphasis. Listeners were highly sensitive to small differences in LCO, in that they indicated strong preferences even for settings representing only slightly lower low-cutoff frequencies. Therefore, we conclude

that individuals with gradually sloping sensorineural hearing loss are likely to base their judgments of the quality of hearing-aid-processed speech largely on the degree of low-frequency energy contained in the signal. This observation appears to hold true regardless of the actual values of LCO or the relative magnitude of paired LCO differences used in this study. These results were highly reliable, as evidenced by a mean agreement of 88% between responses during a given trial and any of the other three trials.

These findings, in conjunction with those reported in the preceding section, raise a provocative clinical question. Since LCO appears to be a dominant psychological dimension in listeners' judgments of aided-speech quality, and enhanced low-frequency energy is generally believed to reduce speech intelligibility through upward spread of masking, what is the relationship between quality judgments and speech intelligibility under identical aided conditions? It is conceivable that electroacoustic conditions producing optimal speech "quality" concomitantly degrade speech understanding. Experimentation is underway to study this relationship, and results will be presented in a subsequent report.

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# Digital Spectrum Shaping and Contraction of Speech Applied to Audiological Instrumentation

Department of Electrical Engineering
Illinois Institute of Technology
Chicago, Illinois 60616
Daniel Graupe, Ph. D.

Biocommunications Laboratory
University of Maryland
College Park, Maryland 20740

VA Hospital
Washington, D.C. 20422

G. Donald Causey, Ph. D.

During the first half of 1979, from January 1, 1979 to June 30, 1979, work on the present project has been concentrated mainly on (*i*) frequency-contraction programs for use in the spectrum fitting test device and in hearing aids for persons with hearing at a very narrow frequency range (this part of the project evolved from general work on accurate fitting of spectra to hearing-impaired persons and its testing) and (*ii*) construction of a digital deterministic spectrum-fit testing system and a distortion testing system.

In particular, (*i*) above, was concerned with using the earlier design for optimal staircase fitting of spectra for implementation in a small desk-size (eventually the size of a pocket calculator) audiometer, using microprocessor hardware. Here, control of frequency range and step width is provided, as is the coding and the generation of signals at controlled amplitudes and frequency ranges, and a combination of any or all of the above, to facilitate a single keyboard-operated mapping of audiograms. Mixing of noise with signal is also to be provided by a controlled band-limited pseudo-random noise generator. For this design, several parts of the hardware have already been tested, such as the staircase filter and the noise generator.

Concerning (*ii*), work on spectrum and distortion testing systems consisted of testing a digital microprocessor-based control system for the harmonic and subharmonic distortion generator, which had been designed and constructed earlier under the same project. This distortion generator is capable of generating harmonic distortions of incoming speech or other acoustic signals at controllable amplitudes and at controllable ranges of the frequency spectrum, the control and the mixing with the original speech signal being effected from a digital keyboard. The distortion generator similarly provides for generat-

ing sub-harmonics of speech and of other incoming audio signals, again at controlled amplitudes and frequency ranges, and of mixing these with the original speech signal or with any other audio signal for audiological test purposes.

As a result of the work on fitting spectra of deterministic digital filters (spectrum shapers) for audiometers used in testing of hearing impairments, it has been decided to attempt digitally to condense the information in speech, which mostly (up to 95 percent) lies in the frequency range from 200 Hz to 3000 Hz, to narrower ranges of ⅓ of the previous range or less, to accommodate persons whose hearing lies only in the range of up to 1000 Hz or even less. The idea was to use the on-line spectrum contraction system to extend the spectrum-fitting and audiometer to testing of intelligibility and of the degree of spectrum contraction needed for certain hearing impaired patients, though extensions to spectrum contracting hearing aids are obvious. Here, use has been made of previous results by the investigators on mixing of harmonics in music, to design a spectrum-contraction system to contract the information within a frequency spectrum of a 0-to-3000 Hz range to a 0-to-1000 Hz range. Computer simulated tests have demonstrated that no observable information loss occurs in a contraction of up to 1:3 — as can be proved by reexpanding the information back to the original 0-to-3000-Hz range.

Contraction beyond the 1:3 ratio is, however, more difficult. Here it is necessary to use properties of spectrum synthesis and pitch detection. Analysis shows that in this manner contraction of up to a 1:6 ratio should be feasible with very little information or intelligibility loss. (This would imply considerable training of the user to learn a "new language"—but for a person with a hearing range of up to only 500 Hz there seem to be no other alternatives.) For this purpose, hardware and software, based on the spectrum shapes as above to filter a train of zero crossing data as obtained from speech, have been designed. The speech segment corresponding to zero-crossing data at above a frequency threshold of about 1000 Hz is considered as unvoiced speech, whereas the segment of speech corresponding to zero-crossing data below that threshold is considered as voiced speech, as long as the speech energy in the former is mostly above the threshold frequency — and in the latter the energy is below that threshold.

It is obvious that such a testing device is to become an important part of this audiogram shaping and testing program — to be able to evaluate degree of spectrum contraction needed, to be useful to patients with hearing in only narrow frequency bands, and to evaluate the resultant intelligibility achieved for these patients. No such device

in any form is yet available anywhere else, although such a testing device is a prerequisite to fitting of a spectrum-contraction hearing aid. There is little doubt that such hearing aids are needed for persons with narrowband hearing.

Once voiced/unvoiced discrimination is accomplished, it is intended to separate the voiced and the unvoiced speech, and contract the spectrum of each separately. In order to obtain a simple device of that kind, it is necessary first to condense the unvoiced speech, which lies mainly in the high frequencies and therefore causes most of the problem to the above hearing impaired. Since unvoiced speech differs from voiced speech by being not only at higher frequency but also of a more stochastic nature, different contraction rates for voiced and for unvoiced speech will be tested for intelligibility and for coding. It is hoped that this will be a first step in developing a frequency-contraction device for testing patients as above, and then in providing frequency contraction aids which may or may not follow the same contraction approach.

## Development of an Advanced, Optical Character Recognition Speech-Output Accessory to the Optacon Reading Aid for Blind People

**Telesensory Systems, Inc.**
**3408 Hillview Avenue**
**Palo Alto, California 94304**
**Gabriel F. Groner, Ph. D., and Robert E. Savoie, Ph. D.**

Telesensory Systems, Inc., develops a family of devices intended to meet the print reading needs of blind people. One of these devices, the Optacon, was introduced in 1971. There are now over 5,500 deployed throughout the world. Two additional devices are under development; one is a synthetic voice accessory for the Optacon that recognizes printed characters and speaks when the reader scans print by hand. The other is a speech-output reading system that automatically scans the print. The research and development leading to the new devices is partially supported by an interagency contract from the Veterans Administration, the Bureau of Education for the Handicapped, and the Rehabilitation Services Administration; it is that work which is described here. Plans include accomplishing the following objectives over a 30-mo period:

1. Implement low-cost optical character recognition (OCR) techniques suitable for reliable operation with the electronic signals provided by the rear panel connector to the Optacon;
2. Implement low-cost text-to-speech techniques that provide high

intelligibility, naturalness, and low fatigue for extended listening periods (the first year of which is not supported by this contract); and

3. Implement means for automatically scanning a bound book under command of a blind user.

The objectives for the first year (starting September, 1978) are to build and evaluate a test unit, finalize the OCR and system architecture, and let contracts for special purpose integrated circuits.

The first year's objectives have been substantially accomplished. The first test unit comprised an Optacon, microcomputers, a PDP–11/34 minicomputer and a Votrax phonemic synthesis device. The importance of simple, easy-to-use controls, and the advantages and difficulties of hand tracking, were shown by human factors studies. Once Telesensory's text-to-speech system was operating in real time on a second PDP–11/34 minicomputer, that system was used in place of the Votrax device. Evaluation of this improved test unit emphasized the importance of natural sounding, easily understood, synthetic speech. A third test unit, with the PDP–11 minicomputers replaced by LSI–11 microcomputers, is now operational. This equipment is used solely for evaluation whereas the PDP–11's were used for both development and evaluation. Also, because it is closer to the eventual reading machines, evaluations will be more useful.

The OCR and system architectures have been finalized. A modular, microcomputer-based architecture was chosen to take advantage of the power and low cost of microcomputer technology. Separate modules perform the OCR, text-to-speech conversion, optional automatic scanning, and control functions. Modularity makes it practical to upgrade the functional components, as new technologies are developed and as improved or less expensive hardware becomes available. It also allows the system to be reconfigured to meet other needs; e.g., the controller and text-to-speech modules can be used, with a computer terminal, to provide a talking terminal for blind programmers. This approach avoids the necessity for developing special purpose integrated circuits other than those already being developed to implement a model of the vocal tract.

The OCR module interprets camera images to identify the characters they represent. It is designed to read correctly many common print fonts at moderate speed. This module has two components; one selects and enhances camera images, the other generates topological features from the images and makes character decisions. The text-to-speech module uses an electronic simulation of the human vocal tract to speak the words received from the OCR module. It is a cost-effective implementation of the comprehensive text-to-speech conversion techniques developed at the Massachusetts Institute of Tech-

nology. The scanner module, to be used only in the automated system, will automatically locate and scan print. All of these modules and the user controls attach to the controller which supervises all system functions. The controller also reformats text so that abbreviations, dates, times, and dollar amounts are spoken intelligibly.

The project staff conducted a technical briefing and held a meeting of the Advisory Committee on February 22, 1979. Vernon Nickel, M.D., Director of the VA Rehabilitative Engineering R & D Service, Franklyn Coombs, the project officer, Howard Freiberger of the VA Prosthetics Center, and representatives of other sponsoring agencies attended in addition to advisors.