

Journal of Rehabilitation Research and Development

Rehabilitation R & D Progress Reports 1984

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XIII. Sensory Aids

A. Blindness and Low Vision

1. General

Demonstration of a Low Vision Aid Clinic as an Employment Enhancement Technique

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Research Problem Addressed—The purpose of this study is to determine whether providing a low vision aid (LVA) to a partially blind person who is employed in a protected work setting will enhance that person's employment as measured by productivity and self-satisfaction.

Methodology—A single subject research design is being employed to examine the use of LVAs by 50 subjects randomly selected from the partially blind workforce of the Mississippi Industries for the Blind (MIB). These subjects were serially screened for LVA prescription by (i) complete medical and extraocular examination, and (ii) Goldman field examination. Following LVA prescription as required for maximum efficiency in his/her work environment, specific training was provided to encourage use of the LVA on the job.

Progress to Date—Forty-eight randomly selected subjects were seen in the LVA clinic. Of the 48, 18 (mean age=38.72; S.D.=9.45) were prescribed LVAs (≥ 4 +add). Fifteen (mean age=32.07; S.D.=10.94) were prescribed optical aids (OA) (≤ 4 +add), and 15 (mean age=42.06; S.D.=9.48) received no aid because visual functioning could not be improved through the use of an aid. Analyses of payroll data, absentee rate, responses on the Minnesota Satisfaction (MSS) questionnaire, and other interview data

are being collected 30 days, 6 months, and 12 months after receipt of the prescription. Preliminary analyses show that the LVA and OA groups have responded favorably to the aids. The LVA and OA groups questioned said they could work better with the aids and had little or no trouble using them. Eighty percent stated their aids neither decreased mistakes nor increased income, while 20 percent said their aids increased income and helped them make fewer mistakes.

Industrial Services Program Model for Sheltered Workshops for Legally Blind Workers

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Research Problem Addressed—Does the Industrial Services Program model (ISP) enhance the employability of blind or partially blind persons? This research project addresses two questions:

1. Does the ISP increase the productivity of blind workers who are newly employed in a protected industry?

2. Does an adapted ISP increase the productivity of blind workers who are newly employed in a competitive industry?

Methodology—A multiple time series design has been used to investigate the efficiency of a specific ISP on the performance of 12 of 45 blind subjects. The experimental group was 12 persons hired by Mississippi Industries for the Blind (MIB) who had received preemployment training using the adapted ISP. The control group consisted of the last 45 employees hired by MIB prior to the initiation of in-plant ISP training. MIB, an affiliate of the National Industries for the Blind, has a work force of approximately 300 employees, 200 of whom are blind.

Progress to Date—Twelve experimental subjects of the planned 33, who had not previously been employees of MIB, have been hired since February 1981. All have completed ISP training. Attendance data, the MSQ, and the MSS have been collected 7, 21, 60, and 90 days following the completion of ISP training. Eight of these subjects remained employed at MIB for

the full 90-day period; four terminated prior to completion.

FY 1985 Activities—An interim progress report will be published. During the upcoming year, ISP projects will be initiated in competitive industries in the state of Mississippi. Research will focus upon the performance of blind and partially blind research subjects in preemployment training classes■

Assessment of Current Career Development Intervention Services and the Needs of Blind and Severely Visually Impaired Individuals

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Research Problem Addressed—The purposes of this project are (i) to assess current career development services for blind, partially blind, and severely visually impaired persons, and (ii) to assess the career development service needs of these persons.

Methodology—The research design used will determine the extent to which current career development intervention strategy services meet the career development needs identified by: blind students, their teachers, and parents; rehabilitation agency administrators and counselors; and adult consumers and parents of consumers randomly selected from special populations.

Progress to Date—Questionnaires were sent to persons in the following groups: students, parents, and teachers in grades K, 3, 6, 9, and 12; agencies; counselors; adult consumers; and, parent consumers.

FY 1985 Activities—Research efforts during the upcoming year will be focused upon data analysis. Career development needs will be identified■

Functional Outcome for Blind/Severely Visually Impaired Clients of State Rehabilitation Agencies

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Research Problem Addressed—The purpose of this study is to identify factors that predict the functional outcome of services provided to blind clients of selected state rehabilitation agencies. The research question to be answered is: To what extent can the functional outcome of blind individuals closed "26" or "28" by state rehabilitation agencies be predicted by a) services received, b) client characteristics, c) county economic conditions, and d) proximity to rehabilitation services?

Methodology—Multiple discriminate analysis is being used to assess functional outcomes and related characteristics of 619 blind and partially blind persons whose cases were closed "26" or "28" by rehabilitation agencies in Florida, Kansas, Mississippi, and Ohio. Subjects were selected at intervals in proportionate numbers according to rehabilitation case closures, from the four state agency populations in FY 1978, 1979, and 1980.

Stepwise multiple discriminate analysis is being used to develop a multiple discriminate function to predict the work status outcome criterion variable. This process allows the computation of the best possible combination of predictive variables associated with the functional outcome group. Other analyses will be made as deemed appropriate.

Results to Date—The data are undergoing analyses. Regression equations, discriminate function analyses, and other statistics have been computed.

FY 1985 Activities—Analysis of data collected for this project will be completed during the coming year. A technical report will be available from the Rehabilitation Research and Training Center in Blindness and Low Vision■

Illumination Level and Color Contrast Studies

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Research Problem Addressed—The purpose of this project is to determine whether manipulating the illumination level and altering color contrasts significantly increase productivity and comfort of partially blind production workers. This project addresses three questions:

1. To what extent does increasing or decreasing illumination affect the performance of partially blind production workers on a task performed visually?

2. To what extent does varying color contrast affect the performance of partially blind production workers on a task performed visually?

3. To what extent does optimizing illumination of work site and color contrast of work site materials increase the productivity and comfort of partially blind production workers?

Methodology—Fourteen subjects, half of whom use powerful low vision aids prescribed in RRTC/BLV project R-1 (Demonstration of a Low Vision Aid Clinic as an Employment Enhancement Technique) were tested with respect to various illumination levels and color contrast conditions to determine the specific levels of the variables that maximized their productivity and comfort. The job site of each subject was then modified in accordance with optimum illumination and color needs.

The design was an A-B-A-C-A-D-A single subject withdrawal design, with A representing non-treatment phases, and B, C, and D representing light-only, color-only and color-plus-light modification phases, respectively. Before and after each modification (or treatment) phase, the modifications were withdrawn, resulting in non-treatment phases alternating with treatment phases. The dependent measures were productivity rates and comfort ratings.

Progress to Date—At the test site an optimum level of lighting and color contrast was identified for each subject. Results of visual testing indicated that, for some individuals, specific lighting conditions and color contrasts were related to better performance. There were considerable individual differences in terms of what constituted optimum conditions for

each subject and to what degree optimum conditions facilitated visual performance.

Production rates before and during the treatment sequence were highly variable; some exhibited higher production rates related to one or more of the modifications, while others did not. Of those who did, better performance was related to the light modification and not to color.

Subsequent to collection of productivity data, subjects were asked to respond to comfort questionnaires. The majority of subjects responded favorably with respect to all modifications.

FY 1985 Activities—Analysis of data collected during this project has been completed. A technical report of findings will be available from the Rehabilitation Research and Training Center in Blindness and Low Vision.

Development of Electromechanical Vocational Assessment Technology for Finger Dexterity and Hand/Foot Coordination

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Research Problem—The purpose of this study is to determine the reliability and validity of four preemployment evaluation and training electromechanical work task units (EVAT). The question to be answered is: Are each of the six electromechanical work task units reliable and valid preemployment assessment technologies for blind or partially blind production employees?

Methodology—A test-retest over time design was used on 30 subjects drawn from the following rehabilitation facilities and sheltered workshops: Mississippi Industries for the Blind, Jackson, Mississippi; Addie McBryde Rehabilitation Center, Jackson, Mississippi; Royal Maid Association for the Blind, Hazlehurst, Mississippi; Regional Rehabilitation Center, Tupelo, Mississippi; Royal Maid Association for the Blind, Tupelo, Mississippi; and, Louisiana Association for the Blind, Shreveport, Louisiana.

Background data were collected on all subjects tested. Data included date of birth, medical and psychological information, work history, and level of

education. Additional information included relevant vocational evaluation and assessment scores: Valpar, WRAT, IQ, and the Pennsylvania Bi-Manual Dexterity Work Sample. For individuals who were employed at the time of testing, job analysis and supervisor ratings were obtained.

Reliability levels indicating test accuracy over time are being established by computation of coefficients of stability obtained through test-retest procedures. Product-moment correlation is the primary method used. A standard error of measurement also is being determined.

Data collection procedures have been arranged to minimize practice effects on test-retest reliability; the length of interval between testing periods, and the lack of intervening training activities, tend to reduce the impact of practice on the reliability measure. Preliminary results indicate that the reliability of the Five Finger Dexterity Work Task Unit is quite high. This appears to hold true even when the retest interval is varied.

Progress to Date—At this time all testing has been completed. Efforts are being made to determine the accuracy of the background data collected from personnel folders and facility client files. These efforts have resulted in the addition of some medical information and vocational assessment scores.

FY 1985 Activities—Data analysis on this project will be completed during this year. A technical report of findings will be available from the Rehabilitation Research and Training Center in Blindness and Low Vision. ■

Vocational Assessment of Blind, Partially Blind, and Severely Visually Impaired Persons: Adaptation of the Vocational Education Readiness Test

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Research Problem Addressed—In connection with training programs in the fields of auto mechanics, electrical wiring, and industrial sewing, the research question to be answered can be stated as follows: Are each of the adapted Vocational Education Readiness Tests (VERTs) reliable and valid indicators of a blind or

partially sighted person's aptitude for success in a specific training program?

Methodology—Each VERT test was screened to determine the elements requiring vision. The training samples were then constructed at the field work site. Project personnel have been and are receiving training and consultation in use of the training samples and recording of project data. The training sample data being collected at the field test site serve as the basis for revisions to the training samples or training sample procedures.

A test-retest over time design is being used. The tests are being administered to present trainees and employees at the Royal Maid Association for the Blind and the Regional Rehabilitation Center, both in Tupelo, Mississippi. Participants have been selected randomly from a group of volunteers in each location. There have been 15 individuals tested and retested on each work task. Sighted standards and norms have been developed for blind and legally blind individuals. Baseline data have been collected for all training samples.

Reliability levels will be established by computation of coefficients of stability obtained through test-retest procedures. Retests will be conducted within a 90-day period. No additional training on the work sample will be conducted. Practice effects will potentially impact any performance-based assessment technique, but here the length of the interval between testing periods and the absence of training activities reduce the impact of practice on the coefficient of stability.

Validity will be determined in two ways. Concurrent validity will be established by (i) correlating training task scores with the subjects' scores on other vocational evaluation systems for which similar tasks are available, and (ii) by comparing the job analysis of the job on which the training sample was designed with the resulting training sample. Other data to be gathered on the client data form will include visual disability and information on secondary disabilities.

Progress to Date—Reliability and validity data are being collected for adapted VERT. Fifteen subjects have been tested and retested on adapted auto mechanics and adapted electrical wiring. Criterion tests (VALPAR 2) for validity, as well as additional work task adaptations, are in process.

FY 1985 Activities—This research design will be employed to establish the reliability and validity of the industry sewing and quantity food tests. The auto mechanics test will be field tested in various sites throughout the country. ■

Training Opportunities Profile for Visually Impaired Persons: (TOP-VIP)

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Research Problem Addressed—The intent of this project is to develop a series of assessment materials that can be used in vocational evaluation centers to assess the capabilities of blind persons to enter training in one of the five following job clusters: (i) computer programming; (ii) counseling/social work; (iii) management; (iv) sales; and, (v) allied health.

Methodology—Technical and professional job clusters were identified which met the conditions of (i) a high number of employed or in-training blind persons, and (ii) forecasts indicating that employment possibilities are expected to continue for the foreseeable future.

The information concerning the tasks involved in each of these job clusters and information concerning the characteristics of persons employed to perform these tasks is being collected. Information concerning the job task and manpower requirements is being obtained from literature and interviews with sighted and blind workers, as well as from trainers of blind and sighted persons in the respective job areas.

This information will be used in constructing assessment materials for each job cluster. The assessment materials will be criterion referenced for use in career decision making by blind persons.

Results to Date—Work Samples and Visually Impaired Persons: A State-of-the-Art Review and Resource Manual will be published in 1984.■

Prevocational Work Ability and Success Acquisition Training of Deaf-Blind and Other Multiply Visually Handicapped Individuals

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Research Problem Addressed—This project is based upon preliminary findings of RRTC/BLV research project R-6, Development of Electromechanical Vocational Assessment Technology (EVAT) for Finger Dexterity and Hand/Foot Coordination. Those EVAT units found to be reliable assessment technologies of finger dexterity and hand/foot coordination will be adapted to determine whether they may be used as prevocational work-ability and success-acquisition training technologies.

Methodology—A single subject research design will be employed to assess the utility of 3 EVAT task units. Fifteen deaf-blind or otherwise multiply handicapped blind children between ages of 14 and 22 years will be the subjects in this study located in Jackson, Mississippi.

The project will be conducted in three phases. During the first phase, the EVAT task units will be modified for use by the subject population and a pilot study with the adapted equipment will be undertaken. Training manuals also will be developed. A brief case history of each of the subjects will be collected during this phase as well. The second phase will consist of assessment of each subject's prevocational skills. During the third phase, each subject will be trained in the use of the EVAT task units. On subsequent trials, data will be collected on work proficiency, work rate, work quality, work perseverance level, work repertoire, and work endurance.

Progress to Date—Work has begun to modify the selected EVAT task units.

FY 1985 Activities—The adapted EVAT work task units will be field tested at the Mississippi School for the Blind in Jackson, Mississippi. The reliability and validity of the adapted work task units will be investigated.■

Assessment of Eye-Hand Coordination and Manual Dexterity Under Different Illumination Levels and Contrast Conditions

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Research Problem Addressed—This project is an extension of the strategies and techniques developed in RRTC/BLV project R-5, Illumination Level and Color Contrast Studies, to increase knowledge about the effects of visual environment modifications on various types of performance that are basic to many work abilities. Answers to three questions will be sought:

1. To what extent do environmental modifications such as changes in illumination level, contrast, size, and presentation speed affect performance of low vision subjects on tasks involving perceptual and psychomotor skills?
2. How do these environmental characteristics interact to affect performance, and are the effects and interactions consistent across tasks requiring different combinations of skills?
3. How much variation exists among low vision individuals with respect to such effects, and can relationships to subject characteristics be identified?

Methodology—The tasks on which dependent measures are to be obtained tap basic perceptual and psychomotor skill abilities that underlie much visual functioning. This is important because, unlike the familiar job tasks of R-5, these tasks will be novel to the subject and thus require a continuous use of vision. Moreover, the testing for optimal stimulus characteristics will be done on multiple tasks, each requiring a different combination of perceptual and psychomotor skills, allowing for greater generalization of on-the-job skills and an investigation of the consistency of stimulus effects in a variety of tasks.

The number and type of independent variables or stimulus characteristics have been increased, resulting in the following improvements:

1. Contrast will be studied in terms of one of its major components: luminance contrast. The present study will focus on luminance contrast.
2. For each task employed, the two primary independent variables to be manipulated are illumination and luminance contrast. In addition, each will

include one or more of the following task characteristics as independent variables: size, speed of presentation, or target speed.

Data collection on each subject can be completed in about two hours instead of the months required in the project on illumination level and color contrast. This allows for better control of motivational variables and the elimination of history effects.

The subjects to be included in this study will be 60 people who are legally blind in the state of Mississippi. To help insure representativeness, subjects will be selected with the cooperation of Mississippi Vocational Rehabilitation for the Blind.

The task-dependent variables of the three tests are: (i) subject's time-on-target record in tracking a paced target path with a stylus; (ii) the number of correctly identified stimuli in a prescribed orientation during a timed task; and, (iii) the subject's ability to accurately identify stimulus patterns and orientations within timed intervals.

Selected Career Development Factors and Outcome of Vocational Rehabilitation Services Provided Middle-Aged and Older Blind Persons

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Research Problem Addressed—This study is an intensive investigation of one of the subpopulations identified in RRTC/BLV project R-4, Functional Outcome for Blind/Severely Visually Impaired Children of State Rehabilitation Agencies. Answers to the following two research questions will be sought:

1. Do middle-aged and older blind clients of rehabilitation agencies differ from younger clients of the agency providing services to them, as well as from one another, with respect to (a) disabilities (primary, secondary, tertiary), (b) proximity to a rehabilitation counselor, (c) services received, (d) funds expended, (e) vocational skill levels, and (f) functional outcome? If yes, to what extent with respect to each?
2. Do functional outcomes of blind middle-aged and older persons closed "26" or "28" by state rehabilitation agencies differ from each other with respect to (a) services provided, (b) client characteristics, and (c) county economic conditions? If so, what factors predict "26" as opposed to "28" closures?

Methodology—A multivariate discriminant analysis will be used to assess functional outcomes and related characteristics of middle-aged and older people from the data base of 619 blind persons whose cases were closed "26" or "28" by state rehabilitation agencies in FY 1978, 1979, and 1980 in Florida, Kansas, Mississippi, and Ohio. Middle-aged subjects will be defined as those persons who were 40 to 54 years old at referral. Older subjects will be defined as those persons who were 55 years old or older at referral. Younger subjects will be defined as those who were 39 years old or younger at referral.

Subjects were selected at intervals according to rehabilitation totals from the four state agency populations in FY 1978, 1979, and 1980. The data base has been built from individual case files abstracted for project R-4. The same statistical analytic procedure will be employed in R-10 as was used in Functional Outcomes for Blind/Severely Visually Impaired Clients of State Rehabilitation Agencies.

FY 1985 Activities—Analysis of data on this project will be completed this year. A technical report of findings will be available from the Rehabilitation Research and Training Center on Blindness and Low Vision.

Predicting the Visual Abilities of Partially Sighted Persons

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The objective of this project is to define a set of measures of visual function that can be used to predict how well partially sighted persons can perform visually guided tasks. The tasks range in complexity from simple discrimination of letters, shapes, and faces to everyday activities. If successful, this project will provide clinicians with new diagnostic tools for assessing visual function in partially sighted persons. The research plan involves:

1. Assessing visual function in a group of partially sighted persons and an age-matched group of normally sighted persons;
2. Measuring performance on visual tasks involving letter discrimination and face discrimination;
3. Quantifying each person's ability to perform everyday tasks, such as travel, shopping, personal hygiene, work, and recreation; and,

4. Determining the relationship between performance of these tasks and measures of visual function.

Visual function will be assessed using both standard optometric techniques and threshold contrast sensitivity. All measures of visual function will be reduced to parametric form for subsequent statistical analyses.

Performance on everyday tasks will be measured with a survey instrument designed specifically for visually impaired persons. The survey instrument already has been validated for this population.

At this stage, we have started gathering data on contrast sensitivity in age-matched normally sighted persons. Our next step will be to gather contrast sensitivity data for a large population of visually impaired veterans.

A Study of the Effectiveness of a Blind Rehabilitation Program

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Purpose—This study assesses the degree of effectiveness of the Blind Rehabilitation Center in bringing about positive changes in the lives of blind patients, and develop means of predicting individual success in rehabilitation training. In order to measure the degree to which the Blind Rehabilitation Center effects changes in patients' life states, the dimensions of life state were defined during a series of pilot studies preparatory to the currently ongoing study. The scales derived from the pilot studies are used to assess the patients' life state prior to rehabilitation and again after treatment. This permits us to measure the amount of change in patients' lives that is due to rehabilitation treatment.

We use a method of scale development that permits an unusual degree of validity and reliability, and so increases precision in specifying the amount of a given skill or characteristic possessed by the individual patient. Our measuring instruments, or scales, can be used in the evaluation of any blind rehabilitation program, and so perhaps aid in improving the quality of treatment and the efficiency of service allocation in all such programs.

Progress—Since the inception of the study, we have developed a general model for the rehabilitation

process in the Blind Rehabilitation Center. We also have developed a set of measures which, taken together, give us a definition of life state. First, there is an attitude toward blindness inventory that measures the attitudes of the patient toward the disability, and of the significant other toward the disability. Second, there is a mood scale that measures the psychological resources of the patients to note the level of anxiety, depression, or other psychological impairment to learning. Finally, there is an activity and mobility inventory that assesses the level of skill in activities of daily living and travel independence. In the course of validating the activities inventory, desire to improve in the activities was measured in already rehabilitated veterans, constituting a measure of unfulfilled needs of these veterans. Each measuring instrument has been validated on a sample of at least 100 patients. In addition, a large number of rating scale analysis programs have been developed for use on computers.

New patients are interviewed before they reach the Blind Rehabilitation Center to assess their life state prior to rehabilitation. When they return home from the Blind Rehabilitation Center they are measured again, and a change score is derived to note the effect the blind rehabilitation program has had on their life state. The measure is repeated 6 months later.

To date, 290 patients have been interviewed prior to rehabilitation; 187 patients have been assessed for changes upon completion of training, and 174 have been remeasured after 6 months at home in order to estimate the degree to which immediate changes are retained. In a progress report prepared for the John Malamazian Blind Rehabilitation Center, it was indicated that positive changes in life state were effected immediately after rehabilitation. Interviewing of patients and processing of already collected data are being continued. ■

[See also **IV. Spinal Cord Injury, G. Wheelchairs Including Seating and Controls, Images Project**]

2. Mobility Aids

The Effects of Preview Distance on the Mobility of the Blind Pedestrian

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The optimal distance at which blind pedestrians should receive information regarding their upcoming environment is an important variable for the design of mobility aids. Previous research in this area has not provided a definitive distance or range of distances for the necessary foreknowledge, or preview of the environment.

It is hypothesized that a decline in performance indicates an insufficient amount of preview for the blind pedestrian. Insufficient preview does not allow sufficient time to respond appropriately to upcoming environmental features and also disrupts the pedestrian's processing of other, more global orientation and mobility information, such as route knowledge. Thus, this project assesses a range of these preview distances from 1 to 10 feet to determine at what distances both the overall mobility and a set of specific gait-related parameters of mobility deteriorate.

Preview distance is controlled in the study through the use of a modified Polaroid ultrasonic transceiver which ascertains that an obstacle is at some distance from the pedestrian and causes an audible signal to be produced. Data have been collected and are presently being evaluated.

This study should yield insight into optimal preview distances. Then, future mobility aids can be designed to be more informative and compatible with the user and less disruptive of the basic psychological processes that underlie mobility. ■

Measuring the Mobility of Blind Travelers

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To perform a valid evaluation of a training program in blind mobility, the means for measuring the effect

of that program on the blind traveler must be available. Previously, two quite different approaches have been taken in assessing the blind person's mobility performance: (i) measuring, either qualitatively or quantitatively, the travel skills of the blind person or, (ii) ascertaining the amount and type of travel in which the blind person is reported to have been engaged. Earlier attempts at measuring both of these have been less than optimal. Moreover, the two types of measures have never been compared in relation to each other. It is now possible to determine the effect of travel skills training on the travel behavior of the trained blind traveler. Recent improvements in both of these types of measures make it feasible to do such a comparison.

This study measures the travel skills and travel behavior of two groups of veterans from the VA Central Blind Rehabilitation Center: a low vision group and a blind group. Each group's travel skills, as measured by the interankle distance measuring system (IAMS), and travel behavior, as measured by the Travel Inventory, will be determined at four times: twice before training, once at the end of the training period, and once 6 months after training. The relationship between travel skills and behavior will be determined for each of these four measurement points. Comparisons between the IAMS and the Nottingham group categories of mobility skills will be made. It is hypothesized that the level of travel behavior at the third and fourth measurement points will not be fully explicable in terms of the level of acquired travel skill. Factors unrelated to travel skills, such as spatial abilities and psychological stress, will result in lower travel activity than would have been anticipated from the level of travel skill. Data are being collected at the present time on this study. ■

The VA Guide Dog Harness

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Purpose—This is a student design project. The purpose is to design and test new guide dog equipment with more appropriate choice of materials technology. The goal is to develop a harness and leash that have better wear, require less care, have superior esthetics, and have lower production cost.

Progress—Prototypes have been completed for field testing and evaluation. The leather has been replaced by nylon strapping because it is lightweight, more comfortable, requires little care, and is believed to have a longer lifetime. All buckles have been replaced with Scotch-Mate, a product similar to Velcro, because it is infinitely adjustable and perceived to be more comfortable for the dog. The initial harness handles were made from both acrylic and polycarbonate rod. The simplicity, practicality, and esthetics of the new harness and harness handle were rated highly by persons using guide dogs. The new handle excelled as a communication link between the dog and the disabled person. However, preliminary handles have not been as durable as necessary. We are continuing to search for a rod that proves satisfactory to our needs. Possibilities being considered are Lexan, Nylon, and Delrin.

Future Plans—Plans are formulated for the cooperative testing of the VA Guide Dog Harness. Several guide dog schools have expressed a desire to assist in field evaluation. A potential manufacturer has been located and production will follow successful testing. ■

SONA/SONA-ECS

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Purpose—The SONA/SONA-ECS is a digital radio transmitter-receiver system that has applications for visually impaired persons as an orientation aid and to manually impaired persons as a Decentralization Environmental Control System, ECS.

Progress—Both the SONA and the SONA-ECS have proven to be highly reliable and to function well technically. SONA-ECS has had approximately 4,000 hours of field testing to date, both in a work environment and in a veteran's home. It also is being used to operate a door/wheelchair lift control and interior lights in a van.

Both systems are now being redesigned to simplify the hardware involved by replacing the discrete digital ICs and DIP switches with a single chip microprocessor and a few support devices. This will enhance the system's capabilities, as many modifications and improvements can be implemented through soft-

ware..A broader range of output devices, including input to a computer, can be easily interfaced to the system. The digital coding of the radio signal can also be expanded so that transmitters for different uses or disabilities will send a different generic use code in addition to the device code.

The SONA, Sonic Orientation and Navigational Aid, for the visually impaired traveler is now ready for field testing at the Atlanta Veterans Administration Medical Center. Thirty-five units have been installed and initial testing is beginning to determine some design criteria for improvements in both technical and human factor areas. The use of microprocessor technology in the system will greatly facilitate the implementation of these improvements. One such improvement involves the proposed use of synthetic speech units for those applications where the Musical Language output is inappropriate.

Future Plans—The Atlanta Veterans Administration Medical Center intends to continue development and evaluation of this system in both of its aspects.

This research will center in two main areas: (i) to enhance the performance and capabilities of both systems through the application of microprocessor technology and (ii) to evaluate the SONA as an aid to the visually impaired traveler.

The final result of this research is intended to be the development of products that are low cost and easily manufactured.

The Expansion of a Computerized Information System to Assist Researchers and Practitioners in Developing and Evaluating Theories and Aids to Improve Mobility for Individuals with Low Vision

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Sponsor: National Institute of Handicapped Research

Background—In a previous NIHR grant, a low vision data base was implemented. This data base supported all other grant related research activities, especially in exploring the effects of psychosocial factors on the rehabilitation of low vision persons. A subset of 471 patients were administered a psychosocial inventory. This inventory was developed by the project staff and analyzed by factor analysis, as well as

analyzed for suggestive relationships between inventory scores and the demographic, clinical, and functional data items.

Four objective data collection forms reflecting interdisciplinary information needs were prepared for this project. To assure the usefulness of these forms, most local service delivery staff aided in their development. This process of consensus-making resulted in implementation delays and required some retrospective data collection.

Current Progress—Research efforts seek to refine the data base and integrate it with information concerning mobility performance to assist in the development and evaluation of theories and aids.

This existing data base served as the core of the information system developed in this project. All of the original forms were substantially revised, as were the data management and analysis programs. New programs allowing input of information specific to orientation and mobility performance of clients involved with other research projects were written in a way to allow integration with the existing core of over 900 items.

Input manuals containing detailed instructions on the content and coding of the data base items have been prepared. Search and analysis routines have been written and manuals explaining their use in laymen terms are being prepared. These search and analysis routines have been used to provide staff with information needed for presentations, or for finding subpopulations of patients to serve as subjects in specific research projects.

An intelligent report generator has been programmed, which prints English language reports on clients based on information contained in the data base. Data on 420 new patients have been coded at this point, and information on a total of 600 is anticipated to be included in the data base at the end of the grant period.

Another goal of this project is the analysis of the information included in the data base to prioritize data related to adjustment to independent mobility. In addition, a concern in the development of the data base has been for its ultimate use by other rehabilitation facilities. Involvement of clinical staff in the design, attention to pragmatic aspects of implementation of the system, and the design of easy-to-use forms and manuals, we believe, will lead to acceptance of the system, or some subset of the system, by other agencies. Long term goals include using this information as the basis for exploration of knowledge needed for development of computer-based, expert consultation systems.

Orientation and Mobility of Low Vision Pedestrians

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Sponsor: National Institute of Handicapped Research

The project addresses theory development issues in the orientation and mobility of low vision pedestrians through two different research studies. Project 2a, Studies of the Spatial Orientation of Low Vision Pedestrians deals with orientation by examining the knowledge of self-to-object and object-to-object distance and direction relationships within a known environment. Project 2b, Studies of the Low Vision Pedestrian's Visual Environment and Mobility, involves the examination of the effect of travel hazards on the travel ability of people with varying types of vision loss under different levels of illumination.

Project 2a uses data collected from 20 subjects in each of four different groups. The groups are defined by the amount and type of remaining vision (20/70 to 2/200, 20/200 to 20/800, central field loss, and peripheral field loss). Four measurement procedures are used to assess knowledge of a known area. The procedures include straightline triadic distance judgments, functional triadic distance judgments, pointing, and verbal descriptions of routes. The triadic distance judgments require the subject to indicate the longest and shortest relative distances between three different landmarks. The study is designed to investigate differences among the groups across the different types of distance and direction measures through the use of analysis of variance. Multidimensional scaling analyses will be used to portray maps derived from the distance judgments. Finally, multiple regression techniques will be used to intercorrelate different subject variables with the measures of spatial learning and orientation.

Project 2b seeks to identify common hazards to travel, analyze the effects that the types of low vision and illumination levels have on the ability to detect and negotiate the hazards, and identify the visual information used by low vision persons to detect and negotiate the hazards. The hazards will be identified by low vision individuals and orientation and mobility instructors through survey methods. The effects of type of low vision and illumination will be assessed by behavioral measures while the subject is walking a route during which the hazards will be presented. The behavioral measures will include speed of walking and a secondary task procedure. In addition, perform-

ance on the behavioral measures will be correlated with tests of visual functioning, including extensive field and acuity measures and tests of contrast sensitivity.

The Effects of Low Vision Aids and Traditional Versus Nontraditional Methods on the Independent Mobility Performance and Stress Levels of Low Vision Individuals

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Sponsor: National Institute of Handicapped Research

Increased levels of stress (as measured by heart rate) have been documented in visually impaired individuals when compared to sighted counterparts in independent mobility situations. In this research project both traditional and nontraditional mobility training procedures are hypothesized to reduce stress levels of low vision pedestrians using low vision optical aids.

Four different treatment groups are compared. Group A receives prescription of low vision optical aid, maximum of 30 hours of orientation and mobility instruction (traditional training procedure) and 10 hours of deep relaxation techniques (nontraditional training procedure) to reduce stress levels and improve mobility performance. Group B receives prescription of low vision aid and 30 hours maximum of orientation and mobility instruction. Group C receives prescription of low vision aid and 10 hours of deep relaxation training. Group D receives prescription of low vision aid only. All four groups receive minimal 1-hour training in the use of the low vision aid. Low vision aids used are handheld telescopes, frame mounted telescopes, or a field enhancement system (30▲ fresnel lenses). Both Single-Subject and Between Group Differences designs are being used to analyze data.

The following information is being collected and analyzed for baseline information, pre-comparison, and post-comparison.

Psychosocial/attitudinal responses:

1. Beliefs About Blindness Scale
2. Type A Personality Test
3. Cognitive-Somatic Anxiety Scale
4. Feinbloom Psychosocial Inventory
5. Spielburger Self-Analysis Questionnaire

6. Low Vision Mobility Attitude Survey
7. Reports from personal journal kept by each subject during participation in the research project.

Mobility:

1. Orientation and Mobility Critical Events
2. Checklist—performed on a predetermined, structured 10 block route that each subject walks—observed by an orientation and mobility specialist.
3. Orientation and Mobility Stress Inventory

Physiological Stress Measure:

Heart rate is recorded by portable heart rate monitor and tape recorder and analyzed on computer for heart rate and variance of heart rate.

It is hypothesized that subjects in group A who receive a combination of orientation and mobility instruction and deep relaxation training will improve mobility skills, reduce physiologically measured stress, reduce self-perceived stress in mobility situations, enhance self image, attain healthier attitudes toward visual impairment, and increase mobility performance. Conversely, the opposite is hypothesized for group D (receiving neither mobility instruction nor relaxation training).

In addition to exploring these hypotheses, another purpose of this project is to explore a multitude of correlations such as: acuity and stress levels; acuity and mobility performance; field of view and stress levels; comparison of varying levels of acuity with mobility function; acuity and attitudes; length of time since onset of vision impairment and attitude toward vision impairment; and, percentage and degree of Type A personalities with vision impairment compared with rest of general population.

Preliminary results are available only for a small number of subjects reported in Single-Subject design. No between group analyses are possible yet.

The project is ongoing until March 1985. Results will be published and available from National Rehabilitation Information Center in Washington, D.C.■

Illumination and Low Vision Mobility

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In the low vision population, the most commonly reported functional problems relate to glare and photophobia. When a person has an impaired visual system, any reduction of visual acuity can have a profound effect on both the perceived and actual ability to travel safely.

This project was designed to explore the effects that sunlenses have on the mobility performance of low vision persons. Subjects are randomly placed in either a control or treatment group. Each group is required to walk a 10 block route in a residential and small business environment. The treatment group wears sunglasses; the control group does not.

Data are collected on heart rate (through a heart monitor connected to a tape recorder), illumination levels, visual acuity with and without the sunglasses, mobility performance, and environmental characteristics such as crowd density, temperature, and traffic density. It is hypothesized that group differences will be present on these measures, with the treatment group having a lower heart rate, better visual acuity with sunglasses, and better mobility performance. Basic descriptive statistics, t-tests, and exploratory data analyses will be used to test the hypotheses.■

Superfold Cane Development Program

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Sponsor: American Foundation for the Blind
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Cane Design I—Our first design consisted of placing a compression spring in each section of the cane, thus permitting sections to be replaced by removing a retaining screw from individual sections. The compression spring replaced the elastic cord, eliminating the failure mode of the elastic cord breakage. Also, the compression spring could not be overstressed, thus extending the life of the cane.

However, it was determined that the cost of the cane would be approximately twice that of existing

canes; the weight would be increased and balance point shifted toward the tip; and, the spring inside the cane section made noise when it touched the aluminum tubing sections. For these reasons, Cane Design I was rejected.

Cane Design II—Our second attempt to remove the elastic cord failure mode was the use of a constant force spring contained in the handle. Attached to the spring was a plastic non-elastic cord which had excellent wear characteristics and over 1,000 pounds of strength. The cord material was of special fibers manufactured by Dupont plastic and coated with a Teflon surface with excellent wear characteristics.

A number of these canes were produced for evaluation by the Jewish Guild for the Blind. Their evaluation was negative primarily for one reason. In order to take the cane apart, it was necessary to separate the cane from the tip end since the spring was in the handle. This design then also was rejected.

Cane Design III:

1. **Elastic Cord**—The previous approaches seemed to indicate that even with the failure mode associated with the elastic cord, this was still the best method of holding the cane together. In some of the existing canes the handles had to be removed to replace the elastic cord, and with age, the handle tended to adhere to the aluminum tubing, making it difficult to remove. We solved this problem by placing the elastic external to the handle on the upper end, and external to the tubing on the lower end. The cord was held in place by simply tying a knot in the upper and lower ends. Thus the handle would not have to be removed, and the tension on the cord could be changed by simply tying the knot at the tip end at a different location.

In order to increase the strength and reduce the weight of the cane, we contacted Alcoa to find materials which were substantially stronger than those used in existing canes. The tubing was primarily of the type utilized in aircraft in strong aluminum alloys developed for the aircraft industry. Of the two recommended types, we selected one which had over twice the tensile strength of ordinary cane tubing. The cost was approximately 50 percent less than the price of the strongest material available but was still over twice the cost of conventional tubing.

2. **Cane Joint**—Many existing canes are built with a tapered joint. Because the joint is aluminum against aluminum, there is excessive wear and a tendency to

stick. Tapered joints also tend to freeze, making it difficult to remove cane sections. The integrity of the joint was also related to the tension of the elastic cord; positive pressure was required to maintain it, and this further increased the difficulty in removing sections of the cane.

A prime consideration therefore was to reinforce the joint. We first designed an insert made of plastic. Nylon, which is used in gears and has superior wear characteristics, was our first material. The entire joint was made of nylon. Tests performed in AFB Labs indicated that (i) the nylon was not strong enough and caused the cane to break at the joint, and (ii) nylon absorbs moisture and expands, which caused the joint to become tight when exposed to high humidity.

To solve these problems, we changed the plastic material to Delrin, which does not absorb moisture, and placed a stainless steel insert within the Delrin. This stainless steel was stronger than the aluminum material and tests on the cane showed that the joint would not fail—the aluminum tubing would fail before the joint. Since the major reason for failure of canes was the joint, this should result in better cane performance and increase the life of the cane.

The cane joint was made with a straight entry point instead of a taper. In order to make the insertion easier, the section near the tip of the joint was made smaller at the tip and larger at the base, enlarging the overall size of the insert slightly. The aluminum tubing was larger at the entry point, and smaller (approximately 1") inside the material. This permitted the joint to be assembled to within the last eighth of an inch in a free condition requiring no pressure, with the joint being held tightly during the last eighth of an inch of motion. Since there was no taper, the joint did not tend to vibrate loose with use, thus creating less tension on the elastic cord.

The completed Cane Design III has an elastic cord down the center, a nylon tip fabricated of stainless steel inserts around Delrin plastic, and high strength aluminum tubing.

Evaluation—Tests performed by the Carleton Laboratory at Columbia University in September 1983 showed no significant change in the canes after 10,000 insertions. In addition, the cane strength was superior when compared with other canes. The new cane was tested for over one year and 1,000 canes were produced. A close watch was made on their performance. We found that tips were too loose on some canes and a fracture occurred in the aluminum. This problem was due to quality control in manufacture, related to oversized inserts and tips.

We had recommended tightening the joint in the last eighth of an inch in each section, by tapping the cane on the ground, forcing the joints together and making the cane rigid. The completed cane would then feel like a single aluminum section with no perceptible wobble in the joints. Occasionally, however, the joint would not go into the aluminum tubing and when the cane was tapped to tighten the joint, the hard stainless tubing would cut or nick the aluminum, which would eventually score the plastic insert and reduce cane life. This was a design flaw which had not shown up in our initial field tests.

This problem was solved by placing a plastic insert around the end of the stainless, beveled at a 45 degree angle, with a hole to center the elastic cord. The insert guided the sections together, reducing noise since the elastic was centered, and reducing the possibility of the cord touching the aluminum. This eliminated the failure mode since the stainless steel could not touch the aluminum even if the joint was not centered.

This change was made in the last 600 canes sold. Fifty canes were delivered to the Veterans Administration for evaluation in April 1984.

3. Reading Aids

Development of a Graphic Braille Display

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Sponsor: Veterans Administration Rehabilitation
Research and Development Service

Problem—Computers are rapidly becoming prerequisites for educational and vocational opportunities. There are numerous public and private groups actively seeking means of making computers accessible to the visually impaired. The most common means of access are synthetic voice outputs, single-line refreshable braille displays, and large print displays. None of these provide access to graphic information (e.g., bar graphs, pie charts, histograms, etc.). Thus, there is a pressing need to make such graphic information accessible to the visually impaired.

A means of presenting such information would have numerous other applications (for example, in presenting trigonometric and geometric mathematics, geographic maps, flow charts, organizational charts and diagrams of instruments, buildings, and equipment). These applications are relevant to all visually impaired individuals regardless of age or occupation.

Significance—The four blind rehabilitation centers of the Veterans Administration routinely provide training on a variety of computer-related devices. Most of this training is directly related to the veteran's vocational or educational objectives. Current training is often restricted to programming or word processing tasks because of the lack of a suitable means of presenting graphic and/or tabular materials. The development of a tactile graphic display would significantly improve the ability of these centers to provide comprehensive training in the use of adapted computer aids.

The development of such a display would also be directly applicable to many non-veterans who have severe visual impairments. Current estimates indicate that over 60,000 veterans and over 1.5 million non-veterans are blind.

Background—Since 1981 the Western Blind Rehabilitation Center (VAMC, Palo Alto) has been providing training in the use of adapted computer aids. More recently the center has entered into a cooperative program with the Sensory Aids Foundation of Palo Alto to offer an expanded training program to visually impaired veterans and non-veterans and to rehabilitation professionals who need such knowledge to work effectively with their own clients. The center also has some 7 years experience in research and evaluation of computer aids for the visually impaired. Much of this work has been a cooperative endeavor between the Western Blind Rehabilitation Center and the Rehabilitation Research and Development Center.

The American Foundation for the Blind has recently designed a graphic braille display which is thought to be suitable for providing graphic and alphanumeric information. The current project will allow continued development of that display, the development of needed software, and evaluations of the display in both laboratory and field-testing conditions.

Approach—The research will combine hardware and software development with concurrent evaluation so that the design process can immediately benefit from information obtained in the evaluation process. It will be facilitated by the initial construction of three

prototype displays. This will allow two displays to be used for field and laboratory testing and one prototype to be used for hardware refinement. The three units can be rotated (from the American Foundation for the Blind to the Western Blind Rehabilitation Center) so that advances in hardware are immediately incorporated into the evaluation without the loss of time typically encountered when prototypes malfunction or are returned for modification. Software development will focus on Apple II+ and IIe computers and on CP/M-based systems. These encompass the most widely used computers.

Status—The project received merit review approval in December 1983 and is currently awaiting the availability of funds (anticipated in October 1984.)■

The Positive Braille Writer

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Sponsor: Royal Commonwealth Society for the Blind

Blind people read and write by using braille, which represents letters through the presentation of various combinations of raised dots.

For the first 100 years after its invention, braille was produced manually by placing paper on a frame and pressing down through the paper with a stylus. This meant that to produce correct characters reading from left to right, the stylus had to be used to impress the characters in reverse from right to left. Thus blind children and newly blinded adults had their difficulties compounded by having to learn to write backwards as well as learning to read.

The great interest in blindness which came about as a result of Second World War casualties led to the invention of a mechanical braille writer that created characters in the correct form from left to right. This meant that the reading and writing process was simplified with the added bonus that the operator could read what had just been written, rather than having to turn the paper over, because the pins that produced the dots embossed upwards from the rear of the paper.

Mechanical braille writers cost in the region of \$350, and although they are widely used in the industrialized countries, they are prohibitively expensive for developing countries. Perhaps 5 percent of blind children in developing countries have access to

any kind of formal education and one of the major factors retarding the growth of the education for blind children has been the cost of equipment. Until recently the choice was between a very difficult and primitive form of braille writing and a very expensive machine.

This problem has now been solved through Dr. Rudi Sampimon's simple invention. He took a totally fresh look at the problem of braille and instead of the pointed stylus making an impression on the paper, which had to be reversed for reading purposes, he produced a hollow stylus matching a raised pin in the writing frame. When this hollow stylus is employed, on paper over the raised pin, braille can be produced from left to right in the same way that it is produced by mechanical braille writers, but at no greater expense than the traditional stylus and frame. Dr. Sampimon's invention means that, for the first time, first-rate equipment for writing braille and doing simple calculations will be available at a very low cost—and this has tremendous implications for the future of the education of blind children in developing countries.

The Royal Commonwealth Society for the Blind welcomes this invention with enthusiasm, and hopes that it will soon be possible to mass-produce the new form of positive braille writing equipment for particular use in developing countries.■

A Large Print Word Processor for the Visually Impaired Person

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Sponsor: Veterans Administration Rehabilitation Research and Development Service

Purpose—The Large Print Word Processor is a generic equivalent of cassette-braille machines for large print users. The system features a large print display and typewriter keyboard with microcassette storage of information.

Progress—Construction of prototype test units is still proceeding. There are currently two units in working order. This system is based upon the Typecorder, a battery powered portable Sony word processor. The Typecorder has been modified to accept an intelligent interface and a large print display suitable for use by visually impaired persons. The new system is designed as an electronic add-on and is plug compatible with the Sony LCD display. The Typecorder interfaces with a new display, the Deca 245A. It is a vacuum tube

fluorescent display with a standard ASCII character display set. To connect the Typewriter with the Deca display, an interface circuit had to be built. This interface allowed the Typewriter to handshake with the Deca display; it had to transform the Typewriter's cursor instructions into instructions recognized by the Deca display. These two functions are handled by the Intel 8741 peripheral controller. A third function of the interface is to provide electrical isolation between the CMOS circuitry of the Typewriter and the TTL circuitry of the Deca. This electrical buffering is handled by Motorola MC14503 buffers.

The completed prototypes now offer an alternative display with 40 characters of 0.2 inch height. The display is of high resolution and considerable brightness. Preliminary tests indicate it to be of great value to the population that needs it at a reasonable cost, especially when compared to the alternatives. The problems remaining include the provision of reading material on the Sony microcassette format and the legal repercussion of such an attempt.

Future Plans—Work will continue in locating a suitable manufacturer for this product. Initial contacts have been made with potentially interested manufacturers, and the research team is working closely with these to evolve a production-ready prototype.

Musical Language and Large Print Considerations in Human Factors Engineering

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Sponsor: Veterans Administration Rehabilitation
Research and Development Service

Purpose—To determine the optimal, most cost-effective methods of interfacing the visually impaired person to computer display/digital information recovery and entry systems.

Progress—A preliminary study has been conducted that consisted of analytical interviews with a visually impaired computer user. The recommendations which resulted from these interviews were published in a paper entitled Human Factors Considerations in the Development of a Large Print Display for the Visually Impaired Computer User, published in the proceedings of the Second Annual Conference on Rehabilitation Engineering, June 1984, Ottawa, Canada. In addition, some recommendations of the inter-

views have been implemented on an Apple computer and are being tested by several visually impaired computer users. It also was suggested that the musical language be combined with the large print displays as a means of providing bimodal display recognition. This is now being implemented and will soon be tested by several visually impaired users. The musical language referred to here was the result of a graduate feasibility study, the results of which have been discussed in previous reports.

Future Plans—Future plans are to continue the implementation of the recommendations of the above-mentioned study and further testing of these implementations by computer users under a variety of work and home situations. Finally, the results of these implementations and tests will be used as guidelines in the development of a Video Emulator Monitor and Display for the visually impaired computer/word processor user. VMED is a universal device that will act as an interface between any computer and the visually impaired person.

Development of a Hand-Guided Reading Aid for the Visually Impaired

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Sponsor: Veterans Administration Rehabilitation
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Need—For both professional and personal reasons, visually disabled people often need direct access to inkprint—that is, without requiring the intervention of a sighted person either as a reader or braille translator. Devices such as the Optacon and the stereotoner, which attempt to meet these needs by converting letter shapes into identifiable tonal patterns or into non-braille tactile displays, require, in practice, considerable skills and training on the part of the user. Speech-output readers (e.g., the Kurzweil Reading Machine) can serve a large population, but current models are both expensive and non-portable. The need, therefore, is for a convenient, affordable, and portable reading aid.

Background—In the mid-70's, Telesensory Systems, Inc. undertook to make a hand-guided, speech-output reading device by attaching an optical character recognition module to their existing Optacon camera. Seven of these talking Optacons, officially designated

the Hand Scan 1, were distributed to various centers for evaluation. The resultant conclusions suggested that while the time was ripe for a device of this sort, and while the Hand Scan 1 provides a clear proof of concept, the existing units were too costly, bulky, and operationally demanding. This VA-funded work stems from a proposal to develop a device removing the Hand Scan 1 shortcomings found during evaluation.

Approach—A hand-guided reading aid is being designed, and three prototypes are to be constructed. The devices have been designed to be versatile, portable, less expensive than functionally comparable devices, and easy to use. This reading aid will capture inkprint images via a small, hand-guided camera capable of reading printed materials over a wide range of type sizes and styles. The device will use adaptive signal processing techniques to select appropriate thresholds and magnification levels during operation, and additionally will provide the user with feedback to assist in the task of line tracking while allowing tolerance for error in hand tracking.

The design will replace complicated mechanics and optics with signal processing techniques. To make the aid versatile in use, it has been designed to interface to a variety of output devices, including speech synthesizers, low-vision magnified letter displays, Optacon, stereotoners, and commercial personal computers. These options should allow users to configure personalized systems in accordance with their own needs, abilities, preferences, and pocket-books.

Status—Hardware items for all major components in the project development stage have been acquired, including input optics, sensor CCD and RAM chips, central microprocessors on their printed circuit boards with memory chips, card cages with power supplies, printed circuit boards to serve input and output interfacing, an Optacon with light box, a stereotoner, various quality speech synthesizers, and a compiler and cross compiler to allow software development to proceed in a high-level language on the center's VAX computer. These components are currently configured into an operational development system, enabling software generation and testing to proceed for the final device. A laboratory system for capturing images using an Optic RAM behind camera optics has been developed and is being debugged. It is planned that in the reading aid prototype, the Optic RAM will receive images which have been reduced in size by a demagnifying fiber optic element and focused on the proper plane by a Selfoc self-focusing fiber optic unit.

Software development is being carried out by project personnel, with the collaboration of students and EE professors from Stanford and Cornell Universities. Packages to effect auto-correlations, adaptive thresholding, character separation, and preliminary optical character recognition are under development. Output interface work is at an advanced stage. The interface board to the Optacon has been completed and interfaced to the 68000 microprocessor, allowing that output device to run under our device's microprocessor control. A stereotoner that attaches to the Optacon is operational as well.

Work in progress focuses on completing the design and building a prototype image input device, developing the software to incorporate into the image pre-processor (to handle adaptively thresholding, magnification, textual line finding, and character finding), and the optical character recognition module.

Reading Aids for the Blind

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The first project was the development of a novel system for the production of high quality embossed maps. One part of the evaluation concentrated on the problems of distinguishing different embossed symbols; this involved over 50,000 tests and 250 blind people. The other part of the evaluation was informally testing maps of the insides of buildings, shopping centers, and neighborhoods.

A computer-based system was developed for the production of a wide range of short documents in contracted braille. The system was evaluated by transcribing two million words of text into contracted braille. This system has been adopted by the Royal National Institute for the Blind. A further development was a microprocessor-based transcription system for the local production of braille. The Braille and Ink-print Text-processing System (BITS) is used by National Deaf-Blind Helpers' League, Lloyds Bank, and Warwickshire Association for the Blind.

The Braille and Speech Information System (BASIS) permits a blind person to write in contracted braille and obtain high quality print copies. The system incorporates word-processing facilities and also permits a sighted typist to input text for translation to

contracted braille, which is then recorded on a paperless braille device.

Deaf-blind people are severely restricted in their access to information such as the news and weather forecast. A system has been developed to permit information from the British Telecom Prestel viewdata system to be automatically produced in braille.

Lack of privacy is one of the most serious deprivations caused by blindness, therefore the availability of bank statements in braille can be important to some blind individuals. In order to be useful, bank statements must be current and errors can not be tolerated. These conditions are met by the automatic transcription of statements from digital data provided by the banks. Lloyds and Midland banks use this system on a regular basis.

For a blind person working in a scientific or technical area, keeping up to date with his subject raises special problems. A pilot scheme involved obtaining computer tapes of abstracts from INSPEC and Psychological Abstracts each month. The blind users specified their interests in terms of the indexing system used by the abstracting service. A computer program automatically selected the abstracts of specific interest to each blind person, translated them into contracted braille and output on an on-line embosser.

In the printing industry, compositors' tapes have been in use for many years. Error-free computer-compatible tapes are now available with the introduction of computer-based composing systems. The project involved an examination of the codes used by printers and development of programs to convert these tapes to the format required by the braille translation program.

The first series of experiments involved a compensatory tracking task with random input signals with five one-dimensional displays. The analysis of results included a comparison of the measured closed-loop frequency response with that obtained from a modified form of cross-over model. From these results it was possible to define two performance parameters for assessing display. The second series of experiments involved a comparison between audio error displays and a visual displays in terms of monitoring the change in operator's response to a step change in the frequency bandwidth of the input signal. ■

B. Deafness and Hearing Impairment

Development of a Cochlear Prosthesis for the Profoundly Deaf

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Sponsor: National Institutes of Health
(National Institute of Neurological and Communicative Disorders and Stroke)

This progress report combines results on three NIH contracts and one NIH grant, all directed at various facets of the development of a cochlear prosthesis for the profoundly deaf. The facets on which we report are, (i) development of cochlear stimulation arrays, (ii) development of transdermal electronics for stimulating the array, and (iii) developing speech processing strategies for proper electrical encoding of speech to yield speech discrimination in human subjects.

The work on electrode array development has focused on using thin film structures and photolithographic techniques to achieve electrically and mechanically stable stimulation arrays. Electrode arrays may be either of a rigid variety intended for insertion in the auditory nerve as it exits in the cochlea or a flexible variety to be inserted in the curved scala tympani chamber of the cochlear. For both types of electrodes, achieving arrays that preserve insulation integrity and adhesion between layers under protracted years of immersion in a biological environment is the principal difficulty. For the rigid electrode array we feel we have solved most of the problems using a sapphire substrate, tantalum conductors, and a multilayer thin film insulation of which Ta_2O_5 and Si_3N_4 are important members. For the flexible array we are working with a polyimide-platinum-polyimide sandwich for which we have solved many problems, but with which we still have significant adhesion problems; the stimulation pads tend to come loose from the polyimide substrate when soaked in saline and stimulated.

For driving the implanted array, we have developed several generations of implantable receiver-stimulators. For all these, both power and instruction are transmitted to a fully implantable device. We now have on test an eight-channel receiver-stimulator that uses an rf link to deliver power and a digital ultrasonic link to deliver data. The unit features all-custom integrated circuit chips, and is hermetically sealed in a cylindrical titanium package roughly the size of a

quarter. Our psychoacoustic tests with volunteer implant subjects have demonstrated that successful speech processing strategies probably require greater timing flexibility and current waveform control than this unit affords. We also find that the ultrasonic data link is the most failure-prone component of our system. We have developed to the breadboard stage a more advanced eight-channel system with both data and power carried over the rf link, and with greater timing and wave shape capabilities. This unit has not yet been packaged, but is being subject to bench tests.

Perhaps the most difficult of all the tasks facing development of a truly effective cochlear prosthesis is that of identifying and implementing a speech processing strategy that encodes speech into a pattern of electrical stimulation which the brain will interpret successfully as speech. Defining the appropriate speech processing strategy involves psychoacoustic and psychophysical tests with human volunteers to characterize the percepts elicited by electrical stimulation and the speech discrimination achieved by various candidate speech processing strategies. In the last year, such studies have been conducted intensively on two eight-channel implants and in a less intensive fashion on three single-channel human implants. We have established that we are able to achieve significant speech discrimination using multichannel stimulation on the multielectrode subjects; whereas for single-channel stimulation of the same subjects, we can improve their auditory communication skills somewhat, but not achieve significant speech discrimination. Portable speech processors embodying the most successful multichannel speech processing strategies are being designed. It is interesting to note that the speech processing strategies most successful for the two subjects are quite different.

Design and Evaluation of a Wearable Vibrotactile Aid for the Deaf

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Sponsor: National Institute of Handicapped Research

The purpose of this project is to develop a wearable tactile aid to represent the voice pitch (fundamental frequency) of speech sounds received by the aid. Such a pitch-indicating aid is intended for use primarily as an aid to lipreading, and also may be used for distinguishing environmental sounds that have distinctive fundamental frequencies.

The sound-spectrum above the fundamental, which distinguishes among the speech and environmental sounds, will not be represented. It has been well demonstrated that adding only the pitch sound to lipreading affords a large improvement. Thus, we believe that a tactile pitch aid has considerable potential. The project has designed methods of pitch extraction that are realizable with wearable microprocessor chips, has selected vibratory transducers that have suitable band width and power characteristics, and is now building a prototype of the aid.

Development of a Digital Hearing Aid and Fitting Procedure

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Sponsor: Veterans Administration Rehabilitation
Research and Development Service

The objective of this research is to develop a new hearing aid concept, and a companion computer-based hearing assessment and fitting procedure. The hearing aid uses digital signal processing methods

that allow auditory signal processing to be flexibly adjusted to fit the patient's hearing deficiency. The computer-based audiometer system controls the measurement of the patient's residual hearing, and uses the data to specify the hearing aid characteristics.

The digital hearing aid that is worn home by the patient at the completion of the clinical visit is, in effect, an integral part of the hearing evaluation and, therefore, the individual acoustic variability introduced by the size of the patient's ear, the ear hook, the connective tubing, and the ear insert are correctly accounted for in the fitting procedure. Since the hearing evaluation and fitting procedure is automated, the clinical visit is simplified and shortened with concomitant benefit to the patient and audiologist.

Project Goals—Specific tasks are: (i) to construct a breadboard simulator of the digital hearing aid from conventional components that operates in real time, (ii) to study the performance of the breadboard connected to an ear-level, hearing aid mockup containing the microphones and receivers, (iii) to develop a computer-based clinical test system and programs for controlling the aid during testing and for controlling the test protocol, (iv) to study the perception of noise, distortion, and annoying sounds with hearing-impaired listeners as related to the hearing aid, (v) to fabricate a small number of pocket-sized versions of the digital hearing aid, and (vi) to evaluate the pocket-sized versions under natural conditions of signal and noise in field tests.

Work related to the first three goals will be completed this first year and is described below.

The Digital Hearing Aid Simulator operates in real time and has been designed with the capacity for testing a wide range of signal parameters. The simulator is connected to an ear-level mockup containing the microphones and receivers of the aid. The simulator consists of six high-performance digital signal processors (DSP). These are low-cost integrated circuit chips manufactured by Texas Instruments. One DSP controls the system bus, the analog-to-digital converter subsystem, and the serial interface to the host computer. Four DSPs provide the multiband filtering and limiting of the signals; their output values are routed to the sixth processor, which sums and interpolates the samples and passes them directly to the digital to analog converter.

The computer-based clinical test system has been assembled, and the programs for this system are under development. One program will act like an automatic audiometer and will measure the patient's

auditory area (threshold, MCL, and UCL) and adjust the characteristics of the hearing aid according to a specific fitting rule. Another program will administer speech intelligibility tests under simulated conditions of speech, and noise for the purpose of testing the digital hearing aid. ■

Acoustic Feedback Suppression in Hearing Aids

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Research and Development Service

Background—Acoustic feedback is a problem to all hearing aid users and to all audiologists who fit hearing aids. In fact, it is one of the major limitations of fitting high-gain aids to those with severe hearing loss.

Hypothesis—The purpose of this project is to answer the following long-standing questions which have plagued engineers and audiologists:

1. What are the physical mechanisms that facilitate the squeal of acoustic feedback and which, if any, of these could be altered in predetermined ways to suppress feedback?
2. How does the presence of the feedback path from vent outlet back to the microphone affect the shape of the frequency response of an aid that is not undergoing feedback?
3. How effective are recently developed earmold designs for suppressing acoustic feedback?
4. Could any of the current schemes for suppressing acoustic feedback in public address systems be adapted to hearing aids?
5. Could a microprocessor-based, adaptive system be utilized in a feedback suppression scheme designed specifically for hearing aids?
6. Could a feedback-suppression circuit, microprocessor-based or otherwise, be designed to meet requirements such as size, maximum allowable current drain, etc. of a head-worn hearing aid?

Methodology and Preliminary Findings—A hearing aid's stability (i.e., a measure of the likelihood that it will squeal under a given set of conditions) may be judged by determining values of its open-loop transfer function GH. In particular, stability determinations are made by comparing values of GH with those known to cause feedback in other systems. Conse-

quently, preliminary work on this project has concentrated on methods for (i) determining GH of an in situ hearing aid and (ii) avoiding those values of GH that are known to cause feedback.

A mathematical replica of this portion of the GH transfer function lying between the vent outlet and the microphone has been developed. This replica is currently being incorporated into a mathematical model of an entire in situ hearing aid. Preliminary work indicates that the one-port rendition of this model is inadequate to explain signal flow in an in situ hearing aid. Investigators have replaced this with a more realistic two-port rendition.

Investigators also have designed and built two different microprocessor-based, adaptive feedback suppression systems. In both systems, low-level pseudo-random noise (PRN) is injected into the circuit just ahead of the amplifier. That portion of the original PRN that returns to the microphone via the feedback path is monitored at the microphone output. A microprocessor then utilizes these two signals—the original PRN and that returning via the vent—to compute the open-loop transfer function GH of the hearing aid. In one system, called the time delay/notch filter (TDNF) system, the microprocessor uses computed values of GH to automatically place high-Q notch filters at those frequencies where feedback is most likely to occur.

In the other system, called the active feedback cancellation (AFC) system, the microprocessor uses computed values of GH to create an estimator. The estimator causes the input informational signal (e.g., that containing information such as speech and not PRN) to react destructively with signals returning via the vent outlet, thereby canceling the effect of the feedback path.

Preliminary results indicate that 6 to 8 dB of additional stable gain can be achieved with either of these systems. ■

Investigation of Acoustic Reflex in Elderly Persons

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Research and Development Service

The report period covers termination of one project (above) and initiation of another.

A large-scale laboratory study was completed on the morphology of the acoustic reflex response. The

acoustic reflex, activated with tones and noise, was measured with an aural acoustic immittance instrument. The investigation utilized a new digital instrument, coupled with a quantitative approach to analysis and reduction of acoustic reflex data. Reduced data contained predictably large intersubject variance, but the analytical procedure was sensitive to small, intrasubject changes. Results revealed age-dependent trends in several measures related to amplitude of the acoustic reflex response. The relative success of the quantitative approach has implications for assessment of acoustic reflex in persons with hearing loss. The data have been presented at a recent professional meeting and are being prepared for publication.

The new project is entitled Implementation of Digital Measurement of Aural Acoustic Immittance. The project involves continuing development, implementation, and evaluation of a digital acoustic-immittance instrument for improved quantitative measurement of aural acoustic immittance. The instrument is a computer peripheral with measurement capacities far exceeding those of existing acoustic-immittance instruments. The new system will allow efficient acquisition of large amounts of data in single test sessions, supporting rigorous clinical evaluations, alteration and tailoring of diagnostic routines, rapid assessment of new clinical measures, and exacting research applications. The system will be evaluated on a clinical population.

Work completed on the new project during the first few months includes modifications of the digital instrument's sample rate, pressure range, and monitor software. In addition, support software has been written for data reduction/measurement and for statistical analysis, and a paper on digital measurement of aural acoustic immittance has been prepared for publication. ■

A Psychophysical Model to Characterize Sensorineural Hearing Loss

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The purpose of this research program is to characterize the suprathreshold auditory function of an individual with sensorineural hearing loss (SNHL) by means of a theoretical model of pitch processing

(developed in our laboratory), and then to use that characterization to design a signal processing system to compensate for the hearing loss. If the results of the current research indicate that the model is useful in designing compensation systems—hearing aids—for SNHL subjects, the next major phase of the research will be the adaptation of these methods to the clinical setting.

The model was developed originally to explain aspects of pitch perception in subjects with normal hearing and then was shown to account for the results of a series of experiments on pitch perception in such subjects. Two factors suggest that the model may be useful in precisely defining the deficit in SNHL: (i) the close correspondence between the stages of the model and the functional parts of the peripheral auditory system thought to be damaged in SNHL, and (ii) our development of psychophysical methods to measure the parameters of these critical stages of the model in normal-hearing human subjects. If the model accurately represents peripheral auditory function, then the model with parameters measured on a subject with SNHL becomes a model of the hearing loss that can be used to define the properties of a hearing aid fitted precisely to that loss. The hearing aid should be such that for any sound input, the hearing aid plus the hearing-loss model produces the same output as the (unaided) normal-hearing model. To the extent that an individual's hearing-loss model corresponds to that individual's hearing loss, it thus defines the ideal hearing aid for that individual.

The hearing aid defined by the model (as described above) for each particular hearing-loss subject will be tested using speech stimuli modified to simulate the action of the aid by means of digital signal processing software. These simulated hearing aid outputs will then be generated with a digital-to-analog conversion system and presented to the subject through standard hearing aid receivers. The speech recognition performance of the SNHL subject with their aided stimuli then can be compared with these subjects' performance on unaided stimuli and with the performance of normal-hearing (control) subjects with unaided stimuli presented under exactly the same conditions.

At this time we have completed a series of psychophysical experiments, including those experiments needed to define the parameters of a hearing-loss model, on over 20 SNHL subjects. The results of these experiments support the following conclusion:

1. All of our subjects have sufficient frequency resolution remaining in one or both ears to receive

the frequency information critical in understanding speech.

2. The model parameters can be defined for such subjects throughout the necessary range of frequency and intensity.

3. The parameters thus defined are consistent with our current understanding of the nature of sensorineural hearing loss.

4. Binaural diplacusis is present in some SNHL subjects and a correction for binaural diplacusis may have to be incorporated into the hearing aid for binaural testing and use.

Current work includes the preparation of the digitally processed (aided) stimuli as well as the continued basic psychophysical testing of additional SNHL subjects. In the coming year, we will perform the first critical tests of the new hearing aid using the digitally processed speech stimuli. ■

An Electrotactile Aid for Treating Sensorineural Hearing Loss and Aphasia

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During the past 3 years we have conducted an investigation designed to test the efficacy of tactile representation of auditory stimuli for improving speech discrimination in patients with severe sensorineural hearing loss and auditory comprehension in patients suffering aphasia.

Study patients wore a tactile belt on the abdomen that converted frequency, intensity, and temporal auditory information into tactile patterns that can be perceived on the skin. Stimuli were environmental sounds and words generated by a computer analog system. These were presented in three modes—auditory, tactile, and auditory-tactile combined—in a modified random assignment of treatments design. Baseline, pretreatment, and performance were determined and followed by 20 treatment sessions and a withdrawal phase post-treatment. Hearing and language criterion measures were administered pre-treatment and post-treatment.

Our results were mixed. Mean performance for a group of normal subjects was 28 percent correct in identifying environmental sounds and 61 percent in identifying words in the tactile mode after 10 hours of training. Sensorineural patient performance on environmental sound identification, after 20 1-hour train-

ing sessions, showed a mean improvement of 10 percent in the auditory mode, 17 percent in the tactile mode, and 15 percent in the auditory-tactile combined mode. On the word identification task, sensorineural patients displayed a mean improvement, following 20 treatment sessions, of 7 percent in the auditory mode, 17 percent in the tactile mode, and 15 percent in the auditory-tactile combined mode. Aphasic patients, in the environmental sound task, displayed a mean improvement post-treatment of 8 percent in the auditory mode, 14 percent in the tactile mode, and 7 percent in the auditory tactile combined mode. On the word recognition task, post-treatment mean improvement in the aphasic group was 5 percent in the auditory mode, 0 percent in the tactile mode, and 3 percent in the auditory-tactile combined mode. Variability in improvement among patients in both groups was rampant.

Comparison of pre-treatment and post-treatment performance on the general hearing and language measures displayed similar variability among patients in both groups. On the Minimal Auditory Capabilities Battery, sensorineural patients showed a mean pre-treatment to post-treatment improvement on seven subtests with a range of five to nine subtests. On the Porch Index of Communicative Ability, aphasic patients showed a mean pre-treatment to post-treatment improvement of six percentile units with a range of zero to nine percentile units.

Our results indicate some promise, certainly not proof, that tactile representation of auditory stimuli may improve auditory discrimination in some sensorineural patients and auditory comprehension in some aphasic patients. Variability in performance among patients suggests tactile instruments may not be ready for tests in clinical treatment trials. More basic explorations on the psychophysical aspects of tactile representation of auditory stimuli and comparisons among the available tactile aids should precede clinical tests of the efficacy of these instruments to assist those with impaired auditory systems. ■

Changes in Frequency Organization of the Cochlea During Aging

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Research Hypothesis—We recently showed a development change in the frequency organization of the

cochlea. Our data indicated that the site of maximum stimulation of the basilar membrane shifts toward the apex during development. The purpose of the proposed studies is twofold: (i) to determine the functional correlates of this basal to apical shift during early development, and (ii) to determine if similar changes in frequency organization occur in the aged cochlea. We propose to use the avian auditory system as a model system to demonstrate these changes in frequency organization. Our past experiments have shown the utility of this model system for studying auditory ontogeny; the proposed experiments would extend this utility into aging and senescence.

Development changes in basilar membrane size, mass and/or stiffness could cause the shifts in frequency organization we have seen. Such changes in basilar membrane dimensions and elasticity have been reported in the aged cochlea. Therefore, our major hypothesis is that in old age, as in early development, changes in frequency organization are occurring.

Methodology—The first group of experiments are designed to investigate further the functional correlates of a changing place code for frequency during ontogeny. We will accomplish this by examining eighth nerve compound action potential (AP) threshold after acoustic overstimulation in chicks exposed to an intense pure tone stimulation at various ages. Preliminary results in a similar experiment indicated that the frequency of maximum threshold shift was higher in older animals even though the stimulation frequency was the same (and the location of hair cell loss was the same) as in younger animals at the same age. Confounding these results were the facts that anatomical results were taken from separate animals and survival time after stimulation was longer for older animals. The proposed experiment is designed to eliminate these confounding variables.

The second group of experiments deals with aging and auditory processing in the Japanese Quail. After the normal effects (anatomic and functional) of aging have been determined, we will proceed to study possible frequency organization changes as a function of aging. Pure tone acoustic overstimulation has been used to define frequency organization of mammalian cochlea. We have shown previously that it can be used with similar specificity for frequency organization of avians. In the proposed experiments, pure tone acoustic overstimulation is used to create discrete, localized regions of sensory cell loss and AP threshold shift. The localization of sensory cell loss is used to define frequency organization in the cochlea

during aging. AP thresholds are measured to determine corresponding functional changes during aging.

Goals—The proposed experiments should provide insight as to whether the observed change in position of hair cell loss after acoustic trauma in early development differentially affects the ability to hear throughout the frequency spectrum. This is of major importance in our attempts to understand how hearing develops. Further, it has broad implications for the effects of genetic or traumatic hearing loss in early life. In addition, if these same alterations in frequency/place coding can be determined in the senescent ear, we will have defined one mechanism responsible for presbycusis. The increasing age of the veteran population, accompanied by increased loss of hearing, makes it imperative to discover as much as possible about the causes of hearing loss as a function of aging. If we see changes in a fundamental auditory process such as place coding, it will have far reaching implications for the prevention and/or rehabilitation of hearing loss in old age. ■

Effects of Auditory Cues in Computer-Assisted Instruction in Lipreading

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Research and Development Service

The purpose of this project is to increase the effectiveness of lipreading instruction for postlingually hearing-impaired adults. Computer-assisted instruction (CAI) is being examined as a way of providing systematic supplementary drill and practice in lipreading.

Among the goals described in previous reports are the following: (i) assembling instrumentation for computer-assisted instruction (CAI), (ii) development of drill and practice sentences and programming these sentences for CAI in lipreading, (iii) preparation of 12 1-hour lipreading lessons, (iv) surveying the literature on lipreading for a state-of-the-art document on this topic, and (v) examining the effect of auditory redundancy versus linguistic redundancy in CAI in lipreading on the development of lipreading skill.

This report on the past year's progress involves primarily a change in instrumentation and in the programming language used for the supplementary

drill and practice sentences which are to be used in conjunction with face-to-face lipreading instruction to be given to postlingually hearing-impaired adults.

The instrumentation we chose for the project included the DAVID Instructional System, developed at the National Technical Institute for the Deaf (NTID) and subsequently assembled and distributed by Von-Tech, Inc., Rochester, New York. It should be pointed out that the original DAVID System designed and used at NTID incorporated a 1/2-inch videocassette player. Because 3/4-inch video cassettes are the standard size in the VA, we were required by VACO to purchase a 3/4-inch videocassette player with our DAVID System. It may be that the difference in cassette size led to some problems.

Two primary technical problems caused the DAVID System to be ineffective for the purposes of our project. First, in repeated accessing of specific video frames for the lipreading student, the mechanical process of stop-rewind-stop-replay caused tape slippage which made precise accessing of desired video frames impossible. Second, the time required for the stop-rewind-stop-play sequence was inordinately long, and for the purposes of our project, completely unsatisfactory. As a result, we explored the possible application of a laser videodisc interactive system. The purchase of such a system was approved by the VA Rehabilitation Research and Development Service, and it was ordered and received in the fall of 1983.

The distinct advantage of the laser videodisc interactive system lies in the immediate and precise accessing of any one of 54,000 video frames on the videodisc. This system has been found to alleviate totally the mechanical problems encountered with the previous videotape instructional system. The laser videodisc interactive system consists of the following Sony components: (i) LDP-1000 optical videodisc player, (ii) PVM-12700 color video monitor, (iii) SMC-70 microcomputer, (iv) SMI-7012 dual 3.5-inch micro floppy disc drives, (v) SMI-7073 RGB superimpose module, (vi) SMI-7031 RS-232C interface module, and (vii) cable connectors and other accessories. For controlling sound level in the auditory redundancy condition, a Coulbourn Instruments power supply (S15-05) and programmable attenuator (S85-08) and other accessories are in the system. The auditory signal is routed from the video monitor to the programmable attenuator and then to the external input of the Grason-Stadler 1701 audiometer and finally to TDH-39 earphones in the audiometric test chamber. For programming and editing purposes and for printout of students' responses during computer-assisted instruction in lipreading, an Integral Data

Systems Prism 80 printer is also in the system.

The 12 lists of 25 sentences each of drill and practice sentences have been programmed in Sony BASIC for presentation by CAI in conditions of auditory redundancy and linguistic redundancy.

The future objectives of this project include: (i) the application of the new laser videodisc interactive system for computer-assisted instruction in lipreading, (ii) administering 12 lipreading lessons to postlingually hearing-impaired adults and providing them supplementary drill and practice with CAI in lipreading, (iii) developing new stimulus materials on videodisc and programming these materials for CAI in lipreading, and (iv) applying these materials and procedures to hearing-impaired adults for an evaluation of their effectiveness. ■

The Modulation Transfer Function as a Predictor of Speech Intelligibility

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The present study applies modulation transfer functions (MTFs) to the prediction of speech recognition. The study assesses the effects of filtering, masking noise, and hearing impairment on both the MTF and speech recognition. The study calibrates the MTF with English speech materials, assesses the effects of hearing impairment, and determines the effect of hearing aids on modulation transfer. Moreover, this study explores the determination of individual MTFs using psychophysical (behavioral) procedures. All previous uses of the MTF as a tool to predict or assess speech-recognition performance have been acoustical in nature and applied only to average performance.

In one experiment, the psychophysical MTF was explored. Ten normal hearing subjects listened to tone pulses embedded in modulated noise, as in our previous report. No background noise was added to the test stimuli for the MTFs; they match the MTFs predicted for a first-order lowpass filter.

The listeners also produced MTFs and speech-recognition scores in two conditions employing background noise (broadband or highpass). A numerical index derived from the MTF, called the speech trans-

mission index (STI) showed a high correlation with the speech scores. The STI will require adjustment for English speech materials. The psychophysical MTF, however, appears promising.

In another phase of the study, 16 normal-hearing young adults have participated in three speech-recognition experiments with results compared to the acoustical STI. In Experiment I of this phase, the subjects made written responses to three tests: the Speech Intelligibility in Noise Test (SPIN); the Nonsense Syllable Test (NST); and the Northwestern University Auditory Test ≤ 6 (NU-6). Each speech test occurred in one of four signal-to-noise ratios (SNRs): quiet; +6 dB, 0 dB and -6 dB. The masking noise for every speech test was the speech babble taken from the SPIN test tapes.

A plot of speech scores versus the calculated STIs of the speech tests from this experiment were marked by L for the low-predictability scores (PL) of the SPIN test, N for the NST, and 6 for the NU-6.

Experiment II of this phase involved only the NU-6 test. The NU-6 lists were presented in quiet and in noise (SNR = +6 dB), with and without filtering (rej. rate = 48 dB/octave). The filter functions were 707 Hz, lowpass; 1414 Hz, lowpass; 1414 Hz, highpass; and 2828 Hz, highpass.

A high linear correlation ($r=0.90$) between the NU-6 scores and the STI was observed in quiet. In noise, the correlation between the scores and the STI was 0.92.

Finally, the last experiment of this phase added reverberation and babble to the NU-6 and NST tests. To calculate the STIs, we used formula for reverberation and added noise.

The results described in this report will be used to recalibrate the STI for each of the speech tests. Then the effects of hearing aids and hearing impairment will be measured for modulation transfer and speech recognition. Speech recognition measures obtained will be compared to those predicted by the acoustical and psychophysical MTFs. ■

Speech Processors for Auditory Prostheses

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Abstract—The purpose of this project is to design and evaluate speech processors for multichannel auditory prostheses. Ideally, the processors will extract (or preserve) from conversational speech those parameters that are essential for intelligibility, and will then appropriately encode the parameters for electrical stimulation of the auditory nerve on a sector-by-sector basis.

Major tasks in our project include the following: (i) identify and contrast the most promising approaches to the design of speech processors for multichannel auditory prostheses, (ii) build a computer-based simulator that is capable of rapid and practical emulation of all these approaches in software, (iii) design and fabricate a hardware interface that will provide a communication link between the computer and implanted electrodes, and (iv) evaluate promising strategies for speech processing in tests with single subjects so that meaningful comparisons of performance can be made.

At present, tasks ii and iii are essentially completed and work on tasks i and iv is in progress. The tests of task iv are being conducted in collaboration with investigators at the University of California at San Francisco (UCSF). Our colleagues at UCSF are also actively involved in the work of tasks i, ii, and iii. Finally, arrangements have been made to conduct parallel tests at the Duke University Medical Center using procedures identical to those used in the tests at UCSF. We expect to evaluate speech-processing strategies in at least two patients at UCSF and one patient at Duke by the end of this calendar year. The results of these evaluations will be used to identify the best strategies for the patients tested and to guide the design of further experiments for the second year of this project. ■

Improvement of Speech Perception for the Hearing Impaired by Enhancement of the Acoustic Features in Speech

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For persons with normal hearing, the perception of speech is a rapid and automatic process. The listener is generally unaware of the physical features in the speech signal by which speech sounds are differentiated. These physical or acoustical features of importance for normal speech perception have been fairly well identified through studies in speech science. It has been found, for example, that individual consonants generally have various acoustic features or cues that could be used for their perception. Some of these cues are primarily temporal in nature, others are spectral, and some are characterized by the presence versus absence of particular kinds of energy in the speech signal.

For hearing-impaired listeners, less is known about the acoustic cues that are used for speech perception. However, recent work has revealed that reduced discrimination for speech acoustic cues may be the basis of deficient speech perception for the deafened. It has been shown that some persons with severe deafness have fairly good discrimination for certain acoustic cues in speech, while others have only limited discrimination for most acoustic speech cues.

Recent work has revealed that particular adjustments to certain acoustic cues resulted in degraded speech perception for hearing impaired listeners with good hearing for speech. Logically, the opposite should occur; if these adjustments to acoustic cues could be reversed and exaggerated, improved speech perception should result. In the laboratory, adjustments to acoustic cues in natural speech have been accomplished by computer analysis and processing. Using these techniques, speech acoustic cues might be enhanced to facilitate speech perception for deafened listeners. This strategy of acoustic cue enhancement could be used in future hearing aids that would employ microprocessing to modify speech patterns. While future hearing aids would amplify speech as do conventional aids, such aids could be adjusted according to a wearer's needs, emphasizing critical acoustic cues that are imperceptible in their natural state for that particular user. Such aids would

have to include pattern recognition circuits that could pick out speech cues and selectively enhance them.

In this research, perception for certain consonants with enhanced cues is studied for deafened listeners. Two experiments are conducted, one focusing on enhancement of only spectral cues and the other focusing on enhancement of both spectral and temporal cues. In each experiment, numerous utterances of selected words that differ in their final consonants are used to evaluate various enhancement values for individual deafened listeners. The utterances are used in selecting the optimum enhancement values for each listener and for training the listeners to perceive consonants with enhanced cues. The optimum enhancements are then processed into utterances of another talker to assess each listener's generalizations for enhanced-cue-use relative to the speech of an unfamiliar talker. ■

Evaluation of a Physiological Glottal Sensor for Speech Training of the Deaf

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Persons who are born deaf experience great difficulty in learning to produce intelligible speech. Our research shows that abnormalities in speech breathing and phonatory control are often particularly troublesome for the deaf speaker. Speech teachers must rely primarily on tactile and kinesthetic information in order to correct phonatory/respiratory deficits. However, the inaccessibility and rapidity of movements of the laryngeal structures and the subtleties of phonatory/respiratory coordination, make reliance on such information relatively ineffective for habilitation of speech in most deaf individuals.

Recent technological developments, including development of specialized transducers, and advancements in high-speed, real time computing techniques, now make feasible the development of a phonatory/respiratory modification system for use in teaching speech to deaf individuals. However, efficient and effective use of such technology can be best achieved with well developed instructional programming. The present project therefore focuses on two general areas: the development of a comprehensive computer-based voice monitoring system that will enable

deaf speakers to obtain feedback concerning their own phonatory/respiratory behavior; and, the development and assessment of rehabilitative techniques and programs utilizing this computer-based system. ■

C. Speech Impairment

Tongue Initiated Speech Prosthesis for the Laryngectomy Patient

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Sponsor: Veterans Administration Rehabilitation
Research and Development Service

The initial phase of this investigation has been concerned with conducting a thorough and in-depth search of the appropriate engineering and medical literature. While several areas are still under examination, it is apparent that this topic has not received a great deal of attention in the past. The major obstacle to success in producing a suitable prosthesis for this purpose has been the inability to securely anchor a device that is capable of producing adequate power to modulate the air stream generated during speech.

Based on the available literature, recent developments in microelectronics, and the progress being made in the general area of speech recognition and synthesis, this investigator believes it will be possible to produce a device that can provide the desired solution. To accomplish this task, the patient will be required to use the oral cavity as a resonator so as to supplement the output of the prosthesis. This technique should allow the output power of the prosthesis to be held to a minimum, thereby diminishing the impact on surrounding tissue.

Future activity on this project will include selection of the equipment required for speech analysis, evaluation of various available electronic components for use in the prosthesis, and the feasibility of incorporating state-of-the-art speech synthesis technology into the design of the prosthesis. It is expected that these activities will culminate in the delineation of a basic device that can be used both to demonstrate feasibility of the technique and to secure funding for development and testing. ■