

# Journal of Rehabilitation Research and Development

## Rehabilitation R & D Progress Reports 1986

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# XIII. Sensory Aids

## A. Blindness and Low Vision

### 1. General

#### An Auditory Data-Flow Indicator for the Blind

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Arthur Jampolsky, M.D.; J.A. Brabyn, Ph.D.; Deborah Gilden, Ph.D.

Rehabilitation Engineering Center, The Smith-Kettlewell Eye Research Foundation, San Francisco, CA 94115

Sponsor: *National Institute of Handicapped Research and The Smith-Kettlewell Eye Research Foundation*

**Purpose**—When a blind person is transmitting or receiving data over an RS-232 serial interface connected to a modem, printer, or other device, he often has difficulty in ascertaining whether the data flow is proceeding normally, and whether the transmission has ended. In response to inquiries from blind computer users regarding this problem, we have developed a simple auditory data-flow indicator, consisting of an appropriate audio transducer connected directly into a standard RS-232 interface cable, and driven from the data signals. The device indicates to the user when data transfer is in

progress, aiding him in knowing whether the interface to printers and other peripherals is working normally and when the computer is free to receive other input. The indicator device is especially useful with modem operations, for alerting the user when a long data transmission has finished.

**Results**—This device, after evaluation by the Kentucky Bureau for the Blind, is now being produced commercially under the name of “Tweedle-Dump.”

#### Auditory Breakout Box

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Arthur Jampolsky, M.D.; J.A. Brabyn, Ph.D.; Deborah Gilden, Ph.D.

Rehabilitation Engineering Center, The Smith-Kettlewell Eye Research Foundation, San Francisco, CA 94115

Sponsor: *National Institute of Handicapped Research and The Smith-Kettlewell Eye Research Foundation*

**Purpose**—Although standards theoretically exist for the interconnections between computers and peripherals, it is well known that individual usage varies considerably. Sighted individuals have access to breakout boxes which can be connected between the computer I/O port and a peripheral. Each input signal line can be connected, through the use of jumpers, to any output line, and the device indicates (through activation of LEDs) when the correct connections have been made. In order to provide the same capabilities to blind individuals,

we have developed an auditory version of the breakout box.

**Progress**—This version provides the same capabilities as a normal breakout box, allowing different connection combinations to be tried out conveniently, but utilizing a tonal sound-coding system to indicate whether any selected line is grounded, high, low, or open. In an improved version of the device, recently completed, the jumper connectors for the input and output lines are fabricated from banana plug sockets

at quarter-inch spacings, to facilitate easy tactile location of any desired input or output line.

**Preliminary Results**—The first prototype has

been successfully tested in practical use by several blind users, and means are now being sought for transfer of the device to commercial production.

## Pediatric Vision Screening

Arthur Jampolsky, M.D.; J.A. Brabyn, Ph.D.; Deborah Gilden, Ph.D.

Rehabilitation Engineering Center, The Smith-Kettlewell Eye Research Foundation, San Francisco, CA 94115

Sponsor: *National Institute of Handicapped Research and The Smith-Kettlewell Eye Research Foundation*

**Purpose**—Among infants and children, the major causes of visual impairment are strabismus and amblyopia, which affect approximately 3-5 percent of all infants. One million ophthalmologists visits per year are related to strabismus. In addition, it has been estimated that approximately 15,000 children in the U.S. are born with or develop cataracts in early infancy. Infantile cataracts differ from adult cataracts in that they produce a sensory deprivation during development, which leads to permanent sight loss if the cataracts are not removed very soon after they appear.

These conditions fortunately respond well to simple rehabilitative measures if detected early enough. However, conventional vision testing methods that require verbal responses are obviously unsuited to this population group. Thus, means of early detection of such conditions are urgently needed so that early intervention can prevent permanent handicaps. Clearly, maximum human benefit as well as cost-effectiveness in rehabilitation would be realized if methods could be found to detect and reverse blinding conditions as soon after birth as possible.

**Progress**—A simple photographic mass screening technique for several common ocular anomalies that can seriously affect vision has been under engineering development. The concept of this device derives from that underlying the retinoscopes and ophthalmoscopes commonly used by clinicians to diagnose diseases and anomalies of the eye; a camera system has been developed which mimics the action of these instruments. The system does not require the skill involved in using a retinoscope or ophthal-

moscope, and it produces a permanent, readily interpreted record of the state of both of the eyes. As such, it should be suitable for mass screening of ocular anomalies by non-eye care specialists.

The technique is easily applied in even the youngest infants, and requires only a small amount of training for the operator. We envision that this system, which is made of standard photographic equipment, could be placed in pediatricians' offices and in hospital nurseries for use by hospital staff in screening infants at well-baby clinics. Children with abnormal photorefractions would then be referred to the appropriate eye care specialists.

The camera system consists of a 35-mm camera with a 500-mm mirror telephoto lens. An electronic flash is placed immediately adjacent to the margin of the lens which forms the entrance pupil of the camera's optical system. Light from the flash is refracted by the lens of the eye, once upon entering the eye and again upon leaving the eye after being reflected from the fundus. The refractive state of the eye, as well as the presence of media opacities such as cataracts, affect the image returned from the eye that is recorded on film.

For example, the presence of a bright band at the top of the pupil in an infant with a significantly different refraction between the two eyes indicates that the eye is hypermetropic or farsighted, and the size of the band indicates the magnitude of the error. A band is not visible if there is no refractive error in that eye. We are developing a geometrical optics model of the camera and eye which can accurately predict the size of the bright band as a function of the magnitude of the refractive error and the

size of the eye and pupil being photographed.  
The technique will be validated in several

clinicians' offices before larger scale screening studies are undertaken.

## Assessment of the Spatial and Temporal Characteristics of Vision as a Function of Age

Edward J. Rinalducci

Veterans Administration Medical Center, Decatur, GA 30033

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The main objective of the research reported here was to examine changes that occur in the spatial and temporal properties of the human visual system as a function of the aging process. It was proposed that data of a preliminary nature be gathered on spatial contrast sensitivity and visual persistence for a group of young adult observers (18-29), middle-aged (30-49), and older observers (50-75).

Due to delays caused by funding and equipment purchases, it was decided that much useful normative information could be gained by employing the following tests with the age groups of interest: 1) the Vistech Contrast test; 2) the Keystone Optical Tester; 3) the Ishihara Color Vision Test; 4) the Tritan plate (F2) test developed by the Naval Medical Submarine Research Laboratory-New London; and 5) the Munsell-Fransworth 100-hue test.

The Vistech Vision Contrast Test was used to obtain a rapid assessment of spatial contrast sensitivity for each subject. The results could then be compared to a measure of Snellen acuity obtained with the Keystone Optical Tester. The contrast sensitivity test and the Snellen acuity test were chosen so as to give an assessment of spatial vision together with visual resolution.

The color vision tests were chosen (especially the Munsell-Farnsworth 100-hue test) so as to examine changes in color discrimination with age, particularly in the short-wavelength end of the visible spectrum. A standard color

screening test (Ishihara) was included in order to identify those observers with red-green color deficiencies and the F2 test was used to identify those individuals who may be tritanopic or tritanomalous. Data for the young adult observers have been collected (about twenty in all) and analyzed. Few significant departures from normal functioning were obtained with the young adult group. Differences are expected for the older observer population.

The middle-aged and older groups of observers will be run in the next few weeks. It is anticipated that at least 20 subjects will be run for the older observer group. The middle-aged observer group will be chosen largely from the faculty of Georgia Tech.

Visual persistence will be measured by flickering a grating of a given spatial frequency (e.g., 1, 3, and 12 Hz) at a rate which is just fast enough to be seen as fused (i.e., until a critical fusion level is obtained). This technique should allow rapid and relatively easy collection of data using older observers. A test for visual persistence should be useful for determining spatio-temporal changes in the visual system with age, and as a test of the persistence theory which predicts longer lasting effects of a stimulus in the older as compared to younger nervous systems.

Based on the analysis of the data from the above test, recommendations could then be made with regard to adequate vision under normal and adverse conditions.

## The Effects of Preview Distance on Blind Mobility

Rebecca Hollyfield, Ph.D.

Veterans Administration Medical Center, Hines, IL 60141

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The objective of this research project was to establish boundaries for the effective preview distance for blind pedestrians. Using an ultrasonic ranging device, we did this by systematically varying the preview distance for a group of experienced, blindfolded travelers walking over a predetermined course six times.

**Progress**—The first time the group walked over the route, we used no preview device and placed no movable obstacles on the route. This trial familiarized the traveler with the route and gave baseline data on walking speed, step length, cadence, etc. In the remaining trials, we

placed movable obstacles randomly along the route, and each subject had the preview device along.

For the test, we used a modified version of a Polaroid ultrasonic ranging device, setting it to a predetermined preview distance for each subject in each trial. This distance varied from one to ten feet. Half of the subjects had increments of even distances (2,4,6,8, and 10 feet) and half had odd distances (1,3,5,7 and 9 feet); also half of the subjects had ascending preview distances over their five trials and half had descending distances.

## The Elderly Blind Client: Factors Associated with Employment Outcome

J.M. Giesen, Ph.D. and K. Ford, M.S.

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

Sponsor: National Institute of Handicapped Research and Mississippi State University

**Purpose**—The American population is growing older, and blindness is much more prevalent among the elderly. The purpose of this study was to assist vocational rehabilitation agencies serving elderly blind and visually impaired persons in program planning and allocation of agency resources targeted specifically to increase successful employment closures of elderly blind persons.

**Progress**—A review of literature and empirical research were the means. This study identified factors that were associated with four client employment outcomes: competitive employment, sheltered workshop employment, homemaker closures, and unemployed closures. The categories of factors used to predict employment outcome of elderly blind clients included rehabilitation process, personal, financial, environmental, occupational, and counselor-related variables. This study utilized the 188 elderly (age 56 and over) blind cases from the MSU

RRTC Employment Database formed in previous research projects as indicated by the following summary.

Extensive data were abstracted directly from case records of 619 legally blind and totally blind clients, chosen by systematic quota sampling, closed as successful (status 26) or unsuccessful (status 28) by rehabilitation agencies in Florida, Kansas, Mississippi, and Ohio. In addition to data from the R-300 form, data were also obtained from case files on disabilities, use of aids, occupational history, expenditures, etc., forming the MSU RRTC Employment Database of over 270 variables.

This study used stepwise multiple discriminant analysis to identify which variables were best able to discriminate among the employment outcome groups for the sample of elderly blind clients.

**Results**—Using the 21 predictor variables identified by the discriminant analysis, a 77 percent

correct classification of employment outcome group was obtained, representing a 71 percent improvement over the chance correct classification rate. Fifty-seven percent of the significant discriminating variables for the elderly blind sample were rehabilitation process variables: expenditure for personal or vocational adjustment training, expenditure for "other" atypical services, whether restoration services were provided, total expenditure for rehabilitation facilities, expenditure for hospital and convalescence, expenditure for diagnostic evaluation, whether maintenance was provided, whether diagnostic services were received, expenditure for trade school training, skill level of the IWRP occupational goal, and total for "other" unclassified expenditures.

Biographical and disability-related variables accounted for 29 percent of the discrimi-

nating variables: whether nonoptical aids were used; age at onset of blindness, whether the client had a Spanish surname, total number of disabilities, sex, and expenditure for travel and transportation. There were two discriminating variables in the financial/disincentive category which were: 1) whether the primary source of support at referral was from personal and private sources; and 2) time on public assistance at referral. Proximity to the vocational rehabilitation counselor was the only environmental variable that discriminated the employment groups. No occupational or counselor-related variables were among the set of significant discriminating variables.

A technical report is available at a nominal fee from the Rehabilitation Research and Training Center on Blindness and Low Vision, P.O. Drawer 5365, Mississippi State, MS 39762.

## Factors Influencing Employment Outcomes of Legally Blind Rehabilitation Clients Who Have Hearing Impairments

B.J. Maxson, M.Ed.; J. Martin Giesen, Ph.D.; William Graves, Ed.D.; Kevin Ford, M.S.

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

Sponsor: *National Institute of Handicapped Research; Helen Keller National Center, Mississippi State University*

**Purpose**—The purpose of this study is to identify factors that influence the employment outcomes of legally blind clients who also have hearing impairments and are served by state rehabilitation agencies for the blind.

**Progress**—Multiple discriminant analysis was used to assess employment outcomes and related characteristics of 44 legally blind individuals who were closed in status "26" or "28" by rehabilitation agencies in Florida, Kansas, Mississippi and Ohio in FY 1978, 1979, and 1980. Employment outcomes were defined as competitive, sheltered, homemaker and unemployed. Variables were categorized as those related to 1) disability and biological data; 2) geographical data; 3) vocational process data; and 4) financial data.

**Results**—It was found that there were seven significant variables related to the employment

outcome of this sample. They were: 1) age at referral; 2) primary support at referral; 3) total services expenditure; 4) received maintenance; 5) months in status 00-02; 6) proximity to nearest sheltered employment; and 7) visual efficiency loss. There was no significant difference in the employment outcomes between this group and a larger sample of 575 legally blind clients who were not hearing impaired. Using a stepwise multiple discriminant analysis, there is a 98 percent successful classification rate for predicting the employment outcome of these hearing impaired clients based on 20 variables and an alpha of .10.

A technical report and executive summary are available through the Rehabilitation Research and Training Center. In June 1986, a Research Utilization Seminar held in Atlanta, Georgia included the reports of this study. Also, presentations are planned at the Association for the Education and Rehabilitation of the

Blind and Visually Impaired National Conference, the Helen Keller National Center Affili-

ate Conference, and other RRTC-sponsored workshops.

### **Prevocational Skill Acquisition of Multiply Handicapped Blind Youth Using Adapted Electromechanical Assessment Devices**

**B.J. Maxson, M.Ed. and Mark Haucke, M.S.**

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

*Sponsor: National Institute of Handicapped Research; Helen Keller National Center, Mississippi State University*

**Purpose**—This project is based on the need for prevocational training and vocational evaluation readiness activities for deaf-blind and multiply handicapped blind youth. Electromechanical Vocational Assessment Technology was developed by the National Industries for the Blind based on work success skills identified as important for jobs within their shops. The equipment was further adapted and used 1) to develop meaningful prevocational and work success skills training activities; 2) as a vocational evaluation readiness activity; and 3) as a field study for empirical research on learning and transferable prevocational skills.

**Progress**—Activities were developed to provide teachers, vocational evaluators, and prevocational specialists with a tool to measure the acquisition of work success skills. The prevocational activities also function as effective vocational evaluation readiness exercises, to provide multiply handicapped youth with experiences similar to those encountered in a vocational

evaluation setting. The study provided recommendations for more effective use of the electromechanical work task units as prevocational learning aids.

**Results**—A training manual and videotape were developed for practitioners and researchers to correctly implement each work task unit and evaluate subject performance. The results indicate that subjects who successfully completed the work task units exhibited many of the necessary work success skills needed for placement in real work settings. The field study highlighted some guidelines for users of the work task units. A printed manual and supplemental videotape are available through the Rehabilitation Research and Training Center on Blindness and Low Vision. In June 1986, the results of the project were reported in Atlanta, Georgia at the Deaf-Blind Research Utilization Seminar. Presentations are planned at other RRTC sponsored workshops.

### **Low Vision Performance as a Function of Environmental and Stimulus Characteristics**

**S. Marmion, Ph.D.**

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

*Sponsor: National Institute of Handicapped Research; Mississippi State University*

**Purpose**—The purpose of the study was to investigate the effects of several stimulus characteristics (such as illumination, contrast, size, target speed, and presentation mode) on the performance of vision impaired subjects, across various tasks related to many kinds of real world visual functioning.

Research questions included: 1) What is the relative strength of various stimulus characteristic effects? 2) To what extent do such characteristics interact with one another? 3) Are such stimulus effects and interactions consistent across differing visual tasks? 4) Are stimulus effects consistent for low vision subjects with

stimulated visual losses?

**Progress**—Three visual-performance tasks measuring aspects of visual functioning, such as visual search, pattern identification, and visuomotor control, were developed and administered to 1) 48 sighted subjects wearing special lenses to stimulate significant visual loss; and 2) 43 low vision clients. Tasks and variables were as follows:

1) A Landolt-C Search Task, which relates to tasks involving visual scanning (such as reading), was performed under three levels of illumination, three levels of contrast, and three target sizes;

2) A Rotary Pursuit Task, which relates to tasks involving visual tracking, was performed at two different speeds and with three levels of contrast between target and background; and

3) A Pattern Identification Task, which relates to tasks involving visual inspection, required subjects to a) identify a target letter; and b) indicate its orientation in space. Two presentation modes were employed: moving-target and stationary-target. Three contrast ratios, two background/foreground conditions, three stimulus sizes, and three levels of illumination were compared.

**Results**—Performance of the two groups significantly differed on all tasks, with the Simulated-Loss group performing better than the Low-Vision group. A number of interactions between stimulus variables and the group variable were obtained across tasks, which indicated that virtually all stimulus variables exerted a more potent effect on the Simulated-Loss group than on the Low-Vision group. An explanation for this finding may lie in the greater performance variability exhibited by the Low-Vision subjects. This was not unexpected, due to the greater heterogeneity of subjects in this group on such variables as age and vision characteristics of impairment.

Across tasks, the size variable had the most consistent and potent effect on both groups. Interactions between size and the other stimulus variables indicated that stimulus size becomes more critical to performance under more difficult levels of other variables (i.e., lower illumination, contrast, etc.). All stimulus variables significantly affected performance either singly or in combination with other variables on every task, especially for the Simulated-Loss group.

The project has been completed and a technical report is now available from the Rehabilitation Research and Training Center on Blindness and Low Vision.

## Electromechanical Vocational Assessment Technology for the Evaluation of Industrial Work Abilities of Blind and Visually Impaired Persons

M. Bagley, M.S.; W.H. Graves, Ed.D.; S.D. Machalow, Ph.D.

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

*Sponsor: National Institute of Handicapped Research; Mississippi State University*

**Purpose**—The purpose of this study is to determine the reliability and validity of six electromechanical work task units designed for use as preemployment evaluation tools. The question to be answered is: Are each of the six electromechanical work task units reliable and valid preemployment assessment technologies for evaluation of blind or visually impaired production employees?

**Progress**—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 sub-

jects 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 Samples scores. For individuals who were employed at the time of testing, job analysis and supervisor ratings were obtained.

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

Data collection procedures were arranged to minimize practice effects on test-retest reli-

ability; the length of interval between testing periods, and the lack of intervening training activities, tended to reduce the impact of practice on the reliability measure.

**Results**— This project has been completed and a technical report was published in August 1985. Design problems necessitated early termination of data collection on two units. Good reliability results were obtained for all of the work task units. Data analyses indicate some degree of validity for the remaining four work task units. Due to the limited number of subjects, the data necessary for the validity study were difficult to obtain; therefore, conclusions regarding the validity of these reports are considered to be tentative.

### Modification and Adaptation of the Vocational Education Readiness Test for Blind/Severely Visually Impaired Individuals

L. McBroom, M.A. and S. Chen, Ph.D.

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

*Sponsor: National Institute of Handicapped Research; Mississippi State University*

**Purpose**—In recent years vocational evaluation has been recognized as an effective procedure for determining the vocational strengths and needs of handicapped persons. The purpose of this project is to determine whether each of the Vocational Education Readiness Tests (VERT) adapted for blind and visually impaired persons is an appropriate assessment tool for determining the aptitude of these persons to enter vocational education programs in Auto Mechanics, Basic Wiring, Quantity Foods, and Industrial Sewing.

**Progress**—Subjects were randomly selected from the blind clients and work force of the Regional Rehabilitation Center in Tupelo, Mississippi, the Arkansas Enterprise for the Blind, and the Mississippi Industry for the Blind to serve as the sample of this project. They included 44 subjects for automechanics, 32 subjects for industrial sewing, and 35 subjects for basic wiring. Twenty cases from the Addie McBryde

Center for the Blind, Jackson, Mississippi, will be selected for an evaluation of the Quantity Foods VERT.

The demographic and visual information on these subjects was collected. Test-retest reliability of the VERT assessment tools is being established. Validity has also been assessed in the data collection process. Descriptions of the norm groups will be provided along with percentile charts used by vocational evaluators.

The motor skills tests and most of the cognitive skills tests in the automechanics work sample were found to have significant test-retest reliability and concurrent validity with VALPAR. The reading test was found to be unreliable, and the vocational terminology tests did not correlate with WRAT scores.

Data for industrial sewing and basic wiring are being analyzed. The data collection for Quantity foods was completed in October 1986. A technical report may be obtained from the Rehabilitation Research and Training Center.

## Development and Validation of a Work Environment Visual Demands (WEVD) Protocol

W. H. Graves, Ed. D.; B. J. Maxson, M.S.; H. Takacs, Ph.D.; J. Adkisson, M.S.; G Smith, M.S.  
Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

*Sponsor: National Institute of Handicapped Research; Mississippi State University*

**Purpose**—The purpose of the study is to develop a procedure to be used in analysis of the visual demands of a job held by or desired by a visually impaired person. The information may be used by eyecare professionals in prescription of low vision aids which will facilitate performance of job tasks or in modification of visual tasks required in the job setting.

**Progress**—Forty randomly selected, employed, legally blind individuals will be assigned to experimental and control groups. After assignment, the researcher will analyze jobs based on the Work Environment Visual Demands Protocol. Protocol information will be entered into a computer, generating a one-page report for analysis by the low vision clinic team prior to, and for use in conjunction with, a low vision examination for the experimental group. The computer report will be withheld for the control group until all subjects have been seen by the clinic one time, at which juncture the low vision team will review the information and schedule a follow-up appointment if necessary.

Information will be collected on length of examinations, reported comfort levels, frequency of visits to clinic, number of aids prescribed, and physician's notations. Multivariate analysis of variance will be used to analyze data.

A Work Environment Visual Demands Protocol has been developed. Forty randomly selected legally blind individuals who are gainfully employed have been evaluated at their work site utilizing the protocol; computer reports have been generated for the Low Vision Clinic which has seen all study participants for the initial evaluation and prescription. Software has been completed for the IBMPC.

**Future Plans**—Study participants in the control group will be seen with WEVD Protocol information provided to the Low Vision Clinic. Follow-up will be done on all participants. Apple IIe software will be completed. All manuals will be completed. Training will be provided for selected personnel in state agencies and private nonprofit agencies serving blind persons.

## The Effects of Sensory Aids on the Employability and Career Development of Visually Impaired Persons

S. Marmion, Ph.D.; L. McBroom, M.S.; S. Machalow, Ph.D.  
Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

*Sponsor: National Institute of Handicapped Research; Mississippi State University*

**Purpose**—The purpose of the study is to determine the effects of the use of sensory aid technology on the employability and career development of blind and visually impaired persons. "Sensory aids" refers to any specially adapted electronic or mechanical device used by a visually impaired person to replace sensory information lost through the effects of visual impairment. The output of these devices is usually in

a tactile, auditory, or enhanced visual mode. Answers to the following research questions are sought:

- 1) How is technology being used to enhance the career development of blind and visually impaired persons?
- 2) What technology is being used?
- 3) What resources are being used to support the provision of sensory aids to rehabilita-

tion clients?

4) What factors are related to the provision of sensory aids to rehabilitation clients?

**Progress**—A survey instrument was developed that was designed to be filled out by rehabilitation counselors of the visually impaired. It asked for information concerning their educational training, caseload, and agency factors involved in provision of sensory aids to clients. It asked for further detailed information on two randomly selected clients who had received a sensory aid in the past year, including their background characteristics (visual impairment,

employment history, etc.), sensory aid usage and/or training, and the perceived impact of sensory aid usage on their employability and career development. A total of 385 surveys were sent to both public and private rehabilitation agencies for the blind, to be filled out by randomly selected counselors. Eighty-nine completed surveys were received from 32 states. Thirteen percent were received from private agencies; 87 percent from public agencies. The data from the surveys are undergoing analyses. A technical report is available from the Rehabilitation Research and Training Center on Blindness and Low Vision at a nominal fee.

### **Perceptions of Teachers, Rehabilitation Counselors, and Rehabilitation Administrators of the Career Development Needs of Blind and Visually Impaired Students and Adults**

W.H. Graves, Ed.D.; S. Lyon, M.S.; S. Marmion, Ph.D.; K. Boyet, M.S.

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

**Sponsor:** *National Institute of Handicapped Research; Mississippi State University*

**Purpose**—The project was designed to determine the perceptions of kindergarten teachers; teachers of grades 3, 6, 9, and 12; rehabilitation counselors; and rehabilitation administrators of the career development needs of their clientele who are blind or visually impaired. Their perceptions of their own access to the services they need to meet the career development needs of their clientele were also sought.

**Progress**—A survey of teachers, rehabilitation counselors, and rehabilitation administrators serving clientele who are blind or visually impaired was conducted. From the surveys, factors were derived which identified the perceptions of these providers of the career development needs and career services needs of their clients who are blind or visually impaired. Factors were also derived which were used to identify the perceptions of the services the providers needed to meet the career development needs of their clients.

**Results**—Providers of educational and rehabilitative services to blind and visually impaired

students and adults do not perceive that the career development needs of these students and adults are being met. Additionally, these providers do not perceive that their circumstances permit them to meet the career development needs of this group of people, either in types of services or in the frequency of provision of services. The findings suggest that educational and rehabilitation services providers recognize the importance of career development service in enhancing the quality of life of people with visual disabilities. The results also suggest that schools and rehabilitation agencies need to examine exemplary career development programs for sighted people, and plan career development programs for their visually impaired clientele on the basis of those exemplary programs. The findings further suggest that the providers will need to adapt the exemplary programs to meet the special needs of their clientele which are caused by the intrinsic and extrinsic factors of blindness and visual impairment.

Copies of the technical report and an executive summary may be obtained from the Rehabilitation Research and Training Center.

## Career Development Needs of Blind and Visually Impaired Students and Adults

W.H. Graves, Ed.D.; S. Lyon, M.S.; S. Marmion, Ph.D.; K. Boyet, M.S.

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

Sponsor: *National Institute of Handicapped Research; Mississippi State University*

**Purpose**—The project addresses the need for research which describes the career development of blind and visually impaired persons, and information on which to base a career-development approach for the delivery of educational and rehabilitative services. The purpose of the study was 1) to identify the career development needs of blind and visually impaired persons across age groups; and 2) to determine which career development needs were perceived as being met by rehabilitative agencies.

**Progress**—A survey of blind and visually impaired students (grades 3, 6, 9, and 12), teachers (grades K, 3, 6, 9, and 12), parents of blind and visually impaired students, and blind and visually impaired adults was conducted. Two hundred and five students, 127 parents of visually impaired children, and 143 adults answered questionnaires assessing their perceptions of their career development needs and their career services needs; factors were derived which identified the factorial structures of the career development and career services needs of the groups in the sample.

**Results**—The results indicate that blind and visually impaired students and adults as well as the parents of the blind and visually impaired students do not perceive that their career development needs are being met. Find-

ings of equal importance indicate that the career development process of blind and visually impaired students and adults parallels that of the sighted population. The differences between the two groups that were identified relate to the career service needs of the blind and visually impaired students and adults. The career service needs identified are those services needed to cope with intrinsic and extrinsic factors associated with visual impairments.

The findings suggest that schools and rehabilitation agencies need to examine their career development programs to determine ways in which the programs can be modified to better meet the needs of their students and clients. The findings also suggest that schools and rehabilitation agencies can examine exemplary career development programs for sighted persons and use those programs as a basis for planning career development programs for blind and visually impaired adults and students. The career service needs of blind and visually impaired students and adults can be met within the service delivery context of career development programs which have been shown to be effective in meeting the individual needs of their clientele.

A technical report and an executive summary may be obtained at a nominal fee from the Rehabilitation Research and Training Center on Blindness and Low Vision.

## Predicting Work Status Outcomes of Blind/Severely Visually Impaired Clients of Rehabilitation Agencies

J.M. Giesen, Ph.D.; W.H. Graves, Ed.D.; S. Schmitt, Ed.D.; A.M. Lamb, M.Ed.; D. Cook, M.S.; C. Capps, M.S.; K. Boyet, M.S.

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

Sponsor: *National Institute of Handicapped Research; Mississippi State University*

**Purpose**—The purpose of this study was to assist vocational rehabilitation agencies serving

blind and visually impaired persons in program planning and allocation of agency resources to

increase successful employment closures and reduce the underemployment of blind persons. The study's means are literature review and empirical research. This study sought to identify factors that were associated with four client employment outcomes: competitive employment, sheltered workshop employment, homemaker closures, and nonworking closures. The categories of factors used to predict client employment outcome included rehabilitation process, personal, financial, environmental, occupational, and counselor-related variables.

**Progress**—Extensive data were abstracted directly from case records of 619 legally blind and totally blind clients, chosen by systematic quota sampling, that were closed as successful (status 26) or unsuccessful (status 28) by rehabilitation agencies in Florida, Kansas, Mississippi, and Ohio. In addition to data from the R-300 form, data were also obtained from case files on disabilities, use of aids, occupational history, expenditures, etc., forming the MSU RRTC Employment Database of over 270 variables.

In this study, stepwise multiple discriminant analysis was used to identify which variables were best able to discriminate among the work status outcome groups.

**Results**—Using the predictor variables identified by the discriminant analysis, a 68 percent correct classification of work status outcome group was obtained. This was a 270 percent increase over the chance correct classification rate. The 10 best predictors of work status category at closure were age at referral, the skill level (total vocational quotient) of the last IWRP occupational goal, sex, years disabled prior to referral, number of disabilities in addition to blindness, highest grade completed, on the job training, proximity to counselor, wage category at referral, and whether the client received institutional training. Compared to the other three outcome groups, the competitively employed group had more years of education, had higher weekly earnings at referral, had a higher skill level on the first IWRP goal, received vocational school services more often, had more expenditures for prostheses, and received fewer medications and treatments. A technical report with recommendations for policy and practice issues may be obtained at a nominal fee from the Rehabilitation Research and Training Center on Blindness and Low Vision, P. O. Drawer 5365, Mississippi State, MS 39762.

## Blind Clients Closed as Homemakers: Employment Outcome Antecedents \_\_\_\_\_

J.M. Giesen, Ph.D. and K. Ford, M.S.

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

**Sponsor:** *National Institute of Handicapped Research; Mississippi State University*

**Purpose**—The present study was to assist vocational rehabilitation agencies to better serve blind and visually impaired persons in program planning and allocation of agency resources to increase successful employment closures of blind persons by providing an extensive analysis of the homemaker case closure. This study was intended to review relevant literature and provide empirical information on the antecedents of the homemaker case closure, so that client characteristics and rehabilitation process

patterns which lead to homemaker closures can be identified early and appropriate service patterns can be established. Thus, this study seeks to identify the characteristics of clients closed as unsuccessful and to identify factors that differentiate this outcome from other outcome groups. The four client employment outcomes were competitive employment, sheltered workshop employment, homemaker closures, and unemployed closures. The categories of factors used to predict employment outcome of blind

clients included rehabilitation process and personal, financial, environmental, occupational, and counselor-related variables.

This study utilized the 619 blind cases from the MSU RRTC Employment Database. This database was formed in previous research as indicated by the following summary. Extensive data were abstracted directly from case records of 619 legally blind and totally blind clients, chosen by systematic quota sampling, closed as successful (status 26) or unsuccessful (status 28) by rehabilitation agencies in Florida, Kansas, Mississippi, and Ohio. In addition to data from the R-300 form, data were also obtained from case files on disabilities, use of aids, occupational history, expenditures, etc., forming the MSU RRTC Employment Database of over 270 client variables.

This study used stepwise multiple discriminant analysis to identify which variables best discriminate between the homemaker closure group and each of the other three successful employment groups in three separate analyses.

**Preliminary Results**—Data analysis is in progress and is expected to indicate which vari-

ables will discriminate between the homemaker group and each of the other outcome groups, along with classification accuracy of each of the discriminant functions, and profiles on the differences between the homemaker group and each of the other outcome groups.

The data analysis completed thus far indicates that the discriminant function for the homemaker and unsuccessful groups classified clients significantly better than chance at an overall rate of 78.5 percent. Compared to the unsuccessful group, the homemaker clients were more likely to be female, had a lower skill level of their IWRP occupational goal, were referred when over 16 years of age, were more likely to have received restoration services, lived farther from their VR counselor, were in training for a shorter time, were more likely to receive noninstitutional training, were more likely to be currently married, were less likely to have been referred by an educational institution, received a lesser amount of public assistance at referral, and were less likely to receive maintenance services.

A technical report with recommendations for policy and practice issues is in preparation.

## **Training Opportunities Profile for Visually Impaired Persons: (TOP-VIP)** \_\_\_\_\_

**J.M. Peterson, Ph.D.**

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

*Sponsor: National Institute of Handicapped Research; Mississippi State University*

**Purpose**—The purpose 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 for training in one of the five following job clusters: 1) computer programming; 2) counseling/social work; 3) management; 4) sales; and 5) allied health.

**Progress**—Technical and professional job clusters were identified which met the conditions of 1) a high number of employed or in-training blind persons; and 2) 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.

The information will be used in constructing assessment materials for each job cluster based upon a model of assessment exercise development adapted from business and industry. A national survey of individuals involved in training of such personnel will set criterion-ref-

erenced standards for skill levels.

**Preliminary Results**—We have published a monograph entitled: *Work Samples and Visually Impaired Persons: A State-of-the-Art Review and Resource Manual* and have developed participant and assessor manuals for all five career areas and a draft Technical Manual. As-

essment materials are now being field-tested in Rehabilitation Centers for the Blind in Mississippi, Virginia, and Oklahoma. Results of the usefulness of materials are positive to date. Finally, a national survey of trainers in all five career clusters has been conducted. Publication of all materials related to this project was completed September 30, 1986.

## The Unsuccessfully Closed Blind Client: Employment Outcome Antecedents \_\_\_\_\_

**J.M. Giesen, Ph.D.;**

Rehabilitation Research and Training Center on Blindness and Low Vision, Mississippi State University, Mississippi State, MS 39762

**Sponsor: National Institute of Handicapped Research; Mississippi State University**

**Purpose**—The present study was made to assist vocational rehabilitation agencies in program planning and allocation of agency resources in order to increase successful employment closures of blind persons, through an extensive analysis of the status of 28 unsuccessful closures. This study was intended to review relevant literature and provide empirical information on the antecedents of the unsuccessful case closure, so that client characteristics and rehabilitation process patterns which lead to unsuccessful closures can be identified early and averted. Thus, this study seeks to identify the characteristics of clients closed as unsuccessful and to identify factors that differentiate this outcome from other outcome groups. (The four client employment outcomes were competitive employment, sheltered workshop employment, homemaker closures, and unemployed closures.) The categories of factors used to predict employment outcome of blind clients included rehabilitation process, personal, financial, environmental, occupational, and counselor-related variables.

**Progress**—This study utilized the 619 blind cases from the MSU RRTC Employment Database. This database was formed in previous research as indicated by the following summary. Extensive data were abstracted directly from case records of 619 legally blind and totally blind clients (chosen by systematic quota sampling) who had been closed as successful (status

26) or unsuccessful (status 28) by rehabilitation agencies in Florida, Kansas, Mississippi, and Ohio. Finally, in addition to data from the R-300 form, data were also obtained from case files on disabilities of clients, use of aids, occupational history, expenditures, etc., forming the MSU RRTC Employment Database of over 270 variables.

This study used stepwise multiple discriminant analysis to identify which variables were best able to discriminate between the unsuccessful closure group and each of the other three successful employment groups in three separate analyses.

**Results**—The discriminant analysis between the competitive and unsuccessful groups showed a correct classification of 66.4 percent which was significantly better than chance. Compared to the competitive group, the unsuccessful clients lived closer to their VR counselor, had a lower skill level of their IWRP occupational goal. They were less likely to use optical aids, had lower expenditures for surgery and other physical restoration procedures, and had been out of work over three times longer. They were more likely to have a severe secondary disability, were more likely to be supported by transfer payments at referral, were less likely to have received noninstitutional training, were more likely to have received SSDI during service, were disabled for a shorter period prior to referral, and had more disabil-

ities in addition to blindness.

The discriminant function for the sheltered and unsuccessful groups classified clients significantly better than chance at an overall rate of 83.9 percent. Compared to the sheltered group, the unsuccessful clients were more than two times older at onset of blindness, had much lower expenditure for personal or vocational adjustment training, were more likely to be white than nonwhite, and had an education level almost three grades higher than the sheltered group clients.

The discriminant function for the homemaker and unsuccessful groups classified clients significantly better than chance at an overall rate of 78.5 percent. Compared with the

homemaker group, the unsuccessful clients were more likely to be male, had a higher skill level of their IWRP occupational goal, were referred when over 16 years of age, were less likely to have received restoration services, were in closer proximity to their VR counselor, were in training for a longer time, were less likely to receive noninstitutional training, were less likely to be currently married, were more likely to have been referred by an educational institution, received a greater amount of public assistance at referral, and were more likely to receive maintenance services.

A technical report with recommendations for policy and practice issues is in preparation.

## Research into the Development of a Nonisomorphic Codification System for Electrocutaneous Sight Substitution

Stewart Ferguson, Ph.D.; and Sherry Ferguson, Ph.D.

University of Windsor and University of Ottawa, 1965 Fairglens Mews, Blackburn Hamlet, Ottawa K1B 5A5, Canada

Sponsor: N.S.E.R.C. and the National Research Council of Canada

**Purpose**—The purpose of our work has been to establish the feasibility of a sequential nonisomorphic coding system as an alternative to the isomorphic analogue coding system used by previous researchers in vision substitution work. (The theoretical base for our approach is described in an article by these authors published in the *Journal of Visual Impairment and Blindness*, January 1986.)

**Progress**—In the initial period of work, the technical staff at N.R.C. designed and built to our specification an electrocutaneous impulse generator, sequential encoder, nonisomorphic transducer, and fixed test pattern modules.

The initial work involved investigating the possibility of a more flexible codification system afforded by the use of a biphasic impulse generator. Many of the shortcomings of the single-phase approach, which were in large part responsible for a shift from the electrocutaneous approach to the vibrotactile approach, seemed likely to be avoided by the biphasic approach, and this proved to be the case.

Our next task was to investigate the possi-

bility of decoding linear relationships through a nonisomorphic transducer pad. Because of the possibility of a more compact transducer afforded by a nonisomorphic approach, the pad was first designed to be worn on the forearm. However, tests confirmed that the abdomen offered a much more sensitive transfer point, as had been found by previous workers.

A series of tests was run to check on the learnability of linear relationships using nonisomorphic transfer. These tests involved repeated recycling of 100 points of location along a line. To speed up the learning time, the sentence was displayed on a line of LEDs. After several hours of training, the subject was able to locate with some accuracy the position along the line indicated by a single point signal. The next series of tests involved the encoding of repeated patterns of interruptions along the line, using fixed pattern modules. Although some level of success was achieved in these test, the subject had difficulty in sustaining the ability to distinguish a set pattern. This we attributed to the masking which took place as a consequence of the physiological accommodation in-

duced by the fixed repetitive input.

**Future Plans**—At present, we are developing a hand held photoelectric pickup device, in order to introduce a higher level of dynamic input and will use this to explore light patterns in a

way more approximating the natural system. Work on a prototype of the photo-sensor is being carried out at the National Research Council of Canada Medical Engineering section, where we have been granted guest worker privileges.

## Microcomputer Magnification for Low-Vision Users

Lawrence H. Boyd, Ph.D.

Berkeley System Design, 1708 Shattuck Avenue, Berkeley, CA 94709

Sponsor: *National Eye Institute*

**Purpose**—The objective of this project is to develop an aid for partially sighted people that enhances access to mainstream computer technology through the software magnification of computer displays.

InLarge evolved through two generations of prototyping. The first generation was implemented on the Apple Macintosh as a desk accessory which could be called up anytime during the use of major applications. This prototype produced a magnifying glass like window on the screen containing a pixel-magnified view of the area around the cursor. While this prototype demonstrated the feasibility of the software-based approach and its advantages over other approaches, subsequent evaluation with low vision subjects revealed a considerable number of shortcomings. These included flickering effects from rapid movements of the pointing device, the inability to magnify the cursor or pull down menus, unintended concealment of portions of the application display and of the magnified area by application windows, inability to position the magnifying glass through the keyboard, the loss of context and place when scanning text, and difficulty in moving from application to application.

**Progress**—To remedy these shortcomings, a completely different approach to integrating inLarge was implemented. In effect, the second generation inLarge instructs the operating system to create and maintain a duplicate image of the real display, and to selectively superimpose user selected parts of that image on the real display. This approach to integration

proved to be an extremely effective solution to the problems of the desk accessory approach. Complete independence from other system software with unrestricted control of the appearance of the screen made possible new solutions to the problems of context and loss of place, including a tracking option, and a feature which keeps the position of the cursor in the magnified view consistent with its position on the real screen.

**Preliminary Results**—Product development was accompanied by basic research into design questions involving screen magnification and human performance. An immediate question for software development was whether the grainy appearance of magnified letters required some kind of cosmetic programming. Results from a controlled experiment assisted by Professor Ian Bailey, School of Optometry, University of California, Berkeley suggested that letter graininess due to magnification does tend to increase scanning time and reading errors. However, the magnitude of these effects does not warrant immediate attention.

**Future Plans**—InLarge is currently being readied for field testing and distribution to users. This includes the development of appropriate documentation and an easy to use "configuration screen" for tailoring user options to individual needs. The major tasks of subsequent research and development are to extend availability to other machines and operating systems, to supplement magnification with audible cues for very low vision users and to develop specialized

support materials, in the form of large print manuals and audio cassettes which meet the

special needs of low vision users in diverse settings and requirements.

## Sensorimotor Aspects of Visual Rehabilitation Using Head-Mounted Magnification Devices

Joseph L. Demer, M.D., Ph.D.; Franklin I. Porter, M.S., O.D.; Herman A. Jenkins, M.D.; Jefim Goldberg, Ph.D.  
Cullen Eye Institute and the Clayton Foundation for Research Neurotology Laboratory, Baylor College of Medicine, Houston, TX 77030

Sponsor: *National Eye Institute and the Clayton Foundation for Research*

**Purpose**—Potentially a great majority of severely visually impaired persons could benefit from spectacle magnification aids such as telescopes or microscopes. But many low vision patients cannot tolerate spectacle magnifiers or use them functionally. We hypothesize that this may be due to inadequate ocular motor stabilization reflexes. Retinal images must not be perturbed by ubiquitous head movements, because retinal image slip of more than a few degrees per second degrades visual acuity. Retinal image stability is normally achieved by the vestibulo-ocular reflex (VOR) in conjunction with visual tracking mechanisms.

The VOR uses head velocity information sensed by the inner ear to reflexively move the eyes to eliminate retinal slip. VOR gain (eye velocity/head velocity) is normally equal to 1.0 during vision, and is about 0.7-0.9 in alert subjects in darkness. The increase in VOR gain produced by vision is the result of visual-vestibular interaction (VVI). When spectacles are worn, the VOR gain required for eliminating retinal image slip must equal the magnification factor of the spectacles. Visual acuity suffers when VOR gain is not appropriate to spectacle magnification. Fortunately, animal experiments have shown that VOR gain, as measured in darkness, undergoes gradual plastic adaptation to ultimately compensate for 2X spectacle magnification. Similar adaptation also occurs in humans, although blurred vision and motion sickness may often occur until adequate adaptation develop.

We hypothesize that inadequate VOR gain plasticity and inadequate visual-vestibular interaction (VVI) are major factors in failure of low vision patients to functionally benefit from

spectacle magnification aids. These factors have been clinically overlooked. We have assembled a team of eye care specialists, vision scientists, biomedical engineers, orientation and mobility specialists, and rehabilitation professionals. We are employing computer assisted electro-oculography during active and passive head movements to accomplish the following:

- 1) Measure VOR gain plasticity and VVI with telescopic spectacles (2X, 4X, 6X, and 8X) in normal and low vision subjects;
- 2) Study subjects' dynamic visual acuity (DVA) which is the acuity achieved during head movement and contrast sensitivity function, while wearing telescopic spectacles;
- 3) Determine clinical magnification efficiency (actual/predicted acuity) of telescopic spectacles;
- 4) Retrospectively determine if plasticity, VVI, DVA, magnification efficiency, and contrast sensitivity are different in low vision patients who ultimately succeed versus those who fail in daily use of head-mounted magnifying aids; and
- 5) Construct and validate a predictive function of success in long-term functional use of head-mounted magnification devices.

**Future Plans**—Preliminary studies indicate that VOR gain plasticity, VVI, and DVA can be clinically measured in normal and low vision subjects. We are currently testing normal subjects to optimize the testing protocol and accumulate a database for fully sighted persons. Studies of telescopic spectacle magnification efficiency are ongoing. A retrospective study of low vision subjects was begun in late 1986.

## Trisensor Rearing with Infant Macaques

David H. Warren, Ph.D.; Edward R. Strelow, Ph.D.; B.J. Sonnier, Ph.D.; Austin H. Riesen, Ph.D.  
Department of Psychology, University of California, Riverside, CA 92521

Sponsor: *National Eye Institute*

**Purpose**—We hypothesize that infant monkeys (*macaca arctoides*), reared from birth without vision but fitted with a sensory substitution device, will acquire functional spatial behavior. The device is an experimental version (Trisensor) of the commercially available Sonicguide™, a sonar-based device which codes distance as pitch, direction as Interaural Device (IAD), and surface quality as timbre. The subject is raised alone in a cage with a cloth mother surrogate and various items of environmental enrichment. Various behavioral tests are made during the rearing period, including motor and locomotor activity, and responsiveness to natural sound cues and to looming stimuli. At three months of age, the animal is sacrificed and the brain is prepared for neuroanatomical analysis of visual, auditory, and motor cortical areas.

This experimental condition is compared with three control conditions: normal colony rearing with vision, cage rearing without vision or Trisensor, and cage rearing without vision

but with a Trisensor delivering signals which are uncorrelated with the animal's activities.

**Preliminary Results**—Neuroanatomical evidence is not yet available. Behavioral evidence from experimental animals suggests good acquisition of spatial behaviors and normal responsiveness to auditory cues.

**Future Plans**—The purpose of the research is twofold. First, it is desirable to explore the potential usefulness of sensory substitution devices for blind human neonates, but such work is ethically unacceptable at this time, absent knowledge about any adverse effects that might occur such as interference with the development of selective auditory attention. The animal model is a necessary precursor to such work with human neonates. Second, valuable information will be gained about the neuroanatomical consequences of rearing with such an altered sensory environment.

## Sensory Aids and Spatial Training of Blind Children

David H. Warren, Ph.D.; and Edward R. Strelow, Ph.D.  
Department of Psychology, University of California, Riverside, CA 92521

Sponsor: *March of Dimes Birth Defects Foundation*

**Purpose**—We hypothesize 1) that blind children have allocentric spatial concepts of their familiar surroundings (such as their homes) but egocentric concepts of novel settings; 2) that the initially egocentric concepts of novel settings can become allocentric concepts with appropriate experience; and 3) that sensory aids (in this case a modification of the commercially available Sonicguide™) offer a means of enhancing the effectiveness of such experience.

**Progress**—In the first experiment, 5-to-12-year-olds are tested in their own living rooms. Procedures requiring localization of objects from var-

ious station points allow determination of whether the spatial concept used was allocentric, egocentric, or neither. The same test is used in a similar but unfamiliar environment. The subject also constructs models of the objects localized in these settings.

In the second experiment, the same subjects are exposed to novel arrays of objects in a schoolyard setting. In this phase, a test trial follows each training exposure, so that the egocentricity/allocentricity of the spatial concept can be examined as it develops with experience. This procedure is followed under three conditions of auditory reference information: reduced

ambient auditory information (the subject wears ear occluders), normal ambient auditory information, and auditory reference signal (an audible beacon is mounted at a prominent place in the experimental space). One group performs these tasks while wearing the sensory aid; a second group wears the sensory aid during the training exposures but not during the test trials; a third group does not wear a sensory aid at all.

**Future Plans**—This project is just beginning, and no results are available at this time. Three important kinds of information will be sought. 1) What differences are there between the spatial concepts for familiar and novel settings? 2) What is the nature of the emerging concept of an initially novel setting as it changes (or so we hypothesize) from egocentric to allocentric? 3) Can a sensory aid play a facilitatory role in acquiring spatial concepts of novel settings?

## Rabbit ERG Responses to White-Noise Modulated Stimuli

Arthur Koblasz, Ph.D.

Georgia Institute of Technology, Atlanta, GA 30332

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—We are presently studying the electroretinogram (ERG) responses to simultaneous electrical and light stimuli. The refractory periods associated with each response will be indicated by Wiener Cross-kernels, which is a special transfer function estimated by using independent white-noise modulations of the combined stimuli. Our main objectives are as follows: 1) to identify the functional differences ERG responses to white-noise-modulated between electrical and light stimuli; and 2) to develop a white-noise electrical ERG protocol which will be safe for clinical testing of patients with opaque media.

**Progress**—Thus far we have designed and tested a circuit for controlling the electrical stimulus and for subtracting the stimulus artifact from the ERG response. We have also designed and constructed an apparatus for holding lenses and a small Xenon light source which will be projected into the eye at the same time that the electrical stimulus is applied. The ERG is measured by using a cup electrode, which is a small cup filled with an electrolytic tear solution and containing an annular shaped

Ag/AgCl electrode.

An IBM PC has been assembled and programmed to perform the necessary data acquisition and analyses. Since both the electrical and the light stimuli are white-noise (randomly modulated, it is difficult to quantify the accuracy and reliability of the hardware and software. We have conceived several protocols for testing the equipment and programs; e.g., the Wiener kernels were calculated when the response was set equal to the stimulus, with a variable delay. We have also tested the electrical stimuli on inanimate objects and found a small error in the current generator circuit, which was corrected. We are presently testing the apparatus and analytical procedures on bullfrogs.

**Future Plans**—We will next evaluate the proposed clinical test on a population of adult male rabbits. It is unlikely that we will be ready to apply the proposed protocol on humans during the present period of VA support. However, the equipment and analytical methods are being developed with the eventual human study in mind.

## The Correlation of Retinal Sources with the Electroretinogram

**Kent Davey; Art Koblasz; Bill Nation**

Georgia Institute of Technology, Atlanta, GA 30332 and Veterans Administration Medical Center, Decatur, GA 30033

**Sponsor:** VA Rehabilitation Research and Development Service

**Purpose**—The research objective is to realize a correlation of the clinical electroretinogram (ERG) with retinal source activity. Specifically, the question being addressed is, “Given a knowledge of surface potential distribution across the cornea, can one infer a commensurate retinal firing sequence, i.e., the spatial distribution of current sources responsible for the electrical potential gradients measurable noninvasively?” Mathematically, if one were given the sources, an exact inference of the fields could be made; the inverse problem, unfortunately, has no unique solution. The solution of that inverse problem is further complicated by the fact that rods are extremely sensitive compared with cones; this means that light directed at a certain spot on the retina (via a slit lamp with lens, or low-intensity laser) also excites numerous peripheral retinal cells due to scattering in the vitreous humor and the high sensitivity of rods to even low-intensity field scattering.

**Progress**—To obtain a firm grasp on the analytical side of this problem, two computer models have been built to predict the sensitivi-

ty of the corneal potential to various retinal excitation scenarios. The first model is a two-dimensional circuit model of the eye used to solve Laplace’s Equation, as various current sources (groups of retinal cells) are fired. The second model builds on the first, solving Laplace’s Equation, but accounting for three-dimensional effects by integral theory. Both models indicate that some degree of source localization can be inferred if the scattering is minimal and noise effects are small.

Given that these two problems (noise and scattering) are often quite serious in a typical clinical context, a third scenario has been investigated employing a series of measurements in time rather than a series of spatial measurements (across the cornea). The temporal measurements will be triggered by a set random ring stimuli, each ring corresponding to a separate ring on the retina. The autocorrelation of multiple ERG measurements with the input stimuli may yield an accurate picture of the retinal source impulse response. Experiments are being conducted on frogs to evaluate the viability of this thesis.

## Local Authority Social Rehabilitation Services to Visually Handicapped People

**Penelope Shore**

Royal National Institute for the Blind, 224 Great Portland Street, London W1N 6AA, England

**Sponsor:** None Listed

**Purpose**—This study provided a survey of the current Local Authority provision in England and Wales of social rehabilitation services for visually handicapped adults, together with an investigation of the needs and expectations of visually handicapped people in relation to social rehabilitation.

**Preliminary Results**—The survey of Social Services Department personnel and their clients in a stratified 17 percent sample of Local

Authorities revealed that age and location are the 2 primary factors affecting the delivery of rehabilitation services to newly blind people. The survey demonstrated that the availability of specialist assessment and rehabilitation services was likely to vary significantly not only from one Local Authority to another, but also within individual Local Authority areas. The majority of visually handicapped respondents to the survey (57 percent) had not been offered practical rehabilitation training, and over a

third of those interviewed claimed not to have been given any information about the services and benefits available to them.

Only a small minority (18 percent) had been offered any advice or counselling about their feelings towards loss of sight.

Particularly disturbing was the identification of very low levels of provision for people over the age of 65—less than a third of those in this age group were offered rehabilitative training, compared with 90 percent of the 20-49 year olds interviewed—evidence which suggests that discriminatory attitudes towards age attitudes result in discrimination against elderly visually handicapped people in respect of the rehabilitation services available to them.

The report points to unacceptable delays in the registration procedures which are, in the great majority of cases, the essential preliminaries to the initiation of rehabilitation services. It substantiates existing evidence of wide variation in the numbers and caliber of Social Services Department staff responsible for assessing the needs for visually handicapped people and providing rehabilitation services to them. Among the sample as a whole, there were considerable variations in specialist staffing levels.

Only 21 percent of the Local Authorities surveyed appeared to have reached an acceptable standard of rehabilitation service. Features that were common to these few authorities included clearly defined management structures, the coordinated provision of specialist field-work staff, and the provision of day-centre rehabilitation programs.

**Future Plans**—Elsewhere, the evidence presented in the report on Local Authorities' future plans suggests that, in areas where provision is already poor, the situation seems likely to deteriorate further. The report also highlights deficiencies in the management of specialist services to the visually handicapped. In many areas there were no clear policies for service delivery, no arrangements for the effective monitoring of rehabilitation services by Social Services senior management, and in many instances no clear line of managerial responsibility from the Director of Social Services to the social worker in the field. The report reveals that the lack of development must be attributed not simply to economic constraint alone, but also to the low priority accorded to the needs of visually handicapped people within Social Services Departments.

## Development of a Visual Evaluation and Training Book: The Vet Book

Gregory L. Goodrich, Ph.D.; Olga Overbury, Ph.D.; Edwin Mehr, O.D.; Robert D. Quillman, M.A.  
Rehabilitation Research and Development Center, Veterans Administration Medical Center, Palo Alto, CA 94304  
Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The VET Book project seeks to develop a near-vision training manual for use in clinic or home training of persons with functional residual vision. Approximately 2 million individuals in the United States are classified as legally blind. Of these, approximately 80 percent are partially sighted. An additional 2-to-3 million people have vision that can only be corrected to 20/70 or worse. Included in these categories are approximately 265,000 veterans.

The rehabilitation needs of these partially sighted persons include prescription of low vision aids and training in the use of their residual vision. Services to assist these individ-

uals range from optometrists and ophthalmologists to comprehensive rehabilitation centers; however, most are able to offer only two or three appointments. These limited appointments do not provide an opportunity for vision training, which has been shown to be essential in maximizing the individual's ability to overcome a visual handicap. The VET Book project is developing training materials that can be prescribed in the low vision clinic and then used for home training.

Research conducted by the Western Blind Rehabilitation Center and others has shown that training reduces the rate of rejection of

low vision aids, improves near-visual capacity for reading, and improves an individual's ability to travel independently. Such training, though highly effective, has not been routinely available (except in the most comprehensive rehabilitation settings) because it has traditionally required intensive staff contributions of time—typically one-on-one training of 15 to 20 hours over a 3-or-4-week period. Since low vision services are not covered by health insurance plans or Medicare/Medicaid programs, the services have been too expensive for most low vision programs to implement. Comprehensive low vision services including training are largely limited to the Veterans Administration rehabilitation programs, and even in those programs, budget pressures make it desirable to reduce the time needed to complete a rehabilitation program.

The project will also develop training materials that will allow training to be conducted in low vision services that currently cannot afford such programs, and may reduce the cost of programs offering such training.

**Progress**—Pilot testing of the VET Book has begun at the Western Blind Rehabilitation Center and at the low-vision clinic at the Royal Victoria Hospital, McGill University, Montreal. Research to date has shown that visual perceptual capacity can be improved through the use of home training materials, and that the improvement is equal to (and perhaps better than) that obtained with clinic training.

The VET Book is designed to train either central or peripheral vision, depending upon the patient's visual needs. Four training sections are currently being developed. These are COPY/DRAW, TARGET MATCH, FIGURE-

GROUND, and READING. The first three sections are designed to train perceptual skills and sensory motor skills necessary for a variety of near tasks including scanning/searching text, viewing pictures, etc. The reading section, as the name implies, trains reading skills including the eccentric viewing skills necessary for individuals with central visual-field deficits.

**Preliminary Results**—Preliminary data indicate that the current VET Book materials are effective and differentiate between partially sighted individuals having the same visual acuity. The data indicate that the materials are effective in terms of individual perceptual function, rather than merely reflecting sensory capacity.

Testing of materials developed for the VET Book continues, and a proposal for funding of the project has been submitted.

**Future Plans**—Each training section will be divided into three levels of difficulty. The remaining sections of the VET Book will be a section of tests designed to assess an individual's training progress, a section describing visual pathologies which will contain useful information for the patient and his/her family, and normative data useful to the clinician in defining the individual's level of visual functioning.

The VET Book is intended to be contained in a three-ring binder so that the clinician can select only the appropriate materials for the patient and have these materials photocopied for the patient to take home. Thus the VET Book will not have to be purchased for each patient, and the only added training cost will be for photocopying.

## QUO VADIS: Voice-Output Questionnaire Administrator

Gregory L. Goodrich, Ph.D. and David L. Jaffe, M.S.

Rehabilitation Research and Development Center, Veterans Administration Medical Center, Palo Alto, CA 94304

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—There are recurring needs for clinical programs to accomplish the following: 1) provide follow-up services to veterans; 2) develop

quality-control procedures; 3) assess the impact of the clinical program on the veteran; and 4) survey the needs of veterans for various clinical

services.

Clinical programs in blind rehabilitation centers face unique problems in responding to these needs, because commonly used techniques such as printed questionnaires and surveys are not appropriate for a visually impaired population. Alternative techniques such as telephone interviews are very time-consuming, and are also vulnerable to human bias.

It is proposed that a telephone-accessible, computer-based, interactive speech synthesizer system can be developed to greatly reduce the cost of gathering needed information from visually impaired veterans, while increasing the amount and quality of data collected. The system, currently bearing the name "Quo Vadis," would also be capable of performing relevant data analysis and could be used to facilitate communication of the results to appropriate persons.

The proposed system calls for an IBM PCXT compatible computer with printer, a DECTalk speech synthesizer, and appropriate software. The DECTalk unit has been chosen because it is readily understood even by those who have no computer experience.

Prior to administration of a questionnaire, a staff member would telephone each veteran, explain the purpose of the call and the nature of the questionnaire, and explain that it would be administered by a computer. The interviewer would also tell the veteran to respond to each verbally presented question by pressing the appropriate key on his/her Touch Tone™ telephone keypad. The veteran would then be

given an opportunity to ask questions or to decline the automated questionnaire. If the veteran declined, the questionnaire could be administered by the interviewer.

It is estimated that the initial "human-to-human" telephone call will last 10 minutes and the computerized administration of the questionnaire would require an additional 20 to 25 minutes, so that the entire "interview" would be about 40 percent shorter than if entirely done by a staff member.

**Progress**—A voice-output "information kiosk" has been developed. It uses the telephone system and a centrally located microcomputer and DECTalk speech synthesizer to disseminate RR&D project summaries. In operation, when a user calls the computer, he or she is greeted by the artificial DECTalk voice. The user is then prompted to press buttons on his/her Touch-Tone keypad to choose the project information to be retrieved from the computer and "spoken."

**Future Plans**—The pending pilot study will be based upon the above work, and is expected to result in the creation, testing, and evaluation of special-purpose software for administering questionnaires, and to provide for its integration with commercial computer hardware. A goal of this project is to construct a complete system with which nontechnical staff personnel can easily create questionnaires, information dissemination systems, interviews and other interface systems.

## The Effectiveness of a Blind Rehabilitation Program

R. Lambert, Jr., M.D.; S. Becker, Ph.D.; B. Wright, Ph.D.; S. Courington, Ph.D., L. Ludlow, Ph.D., E.M. Schulz, M.S.; D. Burnet, B.A.

Veterans Administration Medical Center, Hines, IL 60141

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—To assess the effectiveness of the Blind Rehabilitation Center, it was necessary to develop instruments to measure quality of life or life state: i.e., attitudes toward self and blindness, independence in activities and travel, and psychological state. We validated scales to

measure these variables with data collected in a series of pilot tests. (The way in which these scales were to be used in the evaluation study and the way in which they fit into a general model of the rehabilitation process were described in a previous report.)

**Progress**— Our evaluation model required that we measure a patient's life state before he or she entered the rehabilitation program, shortly after completing the program, and again 6 to 9 months later. Since the report mentioned above, 245 patients have completed initial interviews, 190 patients have completed second interviews, and 143 patients have completed third interviews. We are continuing the data collection, focusing in three areas: 1) continued analysis of the measuring instruments' validity; 2) preparation of the program and data for future analysis; and 3) integration of the data into a larger database management system.

We have constructed all of our measuring and survey instruments; most have been thoroughly tested, analyzed, and reported in the literature. In the past year, we compared the method of scaling used in developing the measures with factor analytic techniques. We found that Rasch Scaling techniques gave stable, unidimensional scales, while factor analysis gave scales of indeterminate strength and fluctuated from group to group, and therefore was too unreliable for research purposes.

We revised the Attitude Toward Blindness

Scale to make it applicable to wheelchair-bound individuals. We then completed the analysis of the validity of the activity and travel measure. While we collected data primarily to validate the activity and travel measure, our additional analyses made it possible to develop a needs assessment of the rehabilitated blind veteran.

We also have constructed two information systems for the blind rehabilitation evaluation project. Through these systems a large amount of data is collected from each patient in multiple interviews, including a demographic file, a medical history and physical exam, an ophthalmologic exam, and five separate survey instruments, each of which is administered three times. The information system to manage the flow of work and data is an easily mastered, user-friendly system that can be adapted to many types of project management. The patient information resides in a database management system which is an industry standard DBMS with full security protection and privacy locks. It has the capacity to be used by many different programs and can easily be adapted to other research projects.

## Predicting the Visual Abilities of Partially Sighted Persons

John Trimble, Ph.D.

Veterans Administration Medical Center, Hines IL 60141

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—More than three-fourths of America's legally blind population may have useful residual vision. Many of these people could benefit from visual aids, but either they have not had them prescribed or they are not using the aids they have received. Accordingly, they must rely upon sighted people to help them perform many of the activities of daily living.

One explanation for this problem has been that the traditional tests of visual function used to prescribe low-vision aids do not tell us about an individual's ability to perform everyday tasks. This information is essential for prescribing aids that allow an individual to make the most of his or her remaining vision.

**Progress**—The goal of our study is to apply new measures of visual function to give us an understanding of the visual environment of partially sighted persons. The measure we are concentrating on is called the "contrast sensitivity function" or CSF, which gives us an indication of how well people see details of different sizes. We are measuring the contrast sensitivity function of partially sighted persons and then using these functions to process images by computer.

Theoretically, the images processed by computer will show us how the environment appears to partially sighted persons. If this is true, then we will perform additional studies in an effort to determine which aspect of the con-

trast sensitivity function is most closely correlated with the person's ability to perform certain tasks. In the first stages of the study, we will examine simple tasks such as recognizing letters, shapes, and faces. Later, we will study more complex tasks such as those encountered

in daily living. If our study is successful, we will gain a better understanding of the implications of severe visual impairment, and we will also develop techniques that may be useful in reducing the handicaps associated with it.

## Computer Vision for the Blind

**B.K.P. Horn and E.J. Weldon, Jr.**

Department of Electrical Engineering, University of Hawaii at Manoa, Honolulu, HI 96822

*Sponsor: VA Rehabilitation Research and Development Service*

**Purpose**—Our work has concentrated on low-level vision problems. Specifically, we have addressed the problem of how a monocular observer moving in a fixed environment can determine its motion and the depth of the world points in its field of view. This problem is important for a blind-assist prosthesis; its solution will simplify the mid- and high-level computational tasks which must be performed by such a device.

**Progress**—We have developed robust methods for recovering the motion of an observer in a static environment in the case of pure rotation, pure translation and arbitrary motion when the rotation is known. Some of these methods are based on the minimization of the difference between the observed time derivative of brightness and that predicted from the spatial brightness gradient, given the estimated motion. We

minimize the square of the integral of this difference taken over the image region of interest. Other methods exploit the fact that surfaces have to be in front of the observer in order to be seen.

We do not establish point correspondences, nor do we estimate the optical flow. We do not use higher derivatives of the image brightness, and we do not assume an analytic form for the surface.

We show that the field of view should be large to accurately recover the components of motion in the direction towards the image region. We also demonstrate the importance of points where the time derivative of brightness is small and discuss difficulties resulting from very large depth ranges. We emphasize the need for adequate filtering of the image data before sampling to avoid aliasing, both in the spatial and temporal dimensions.

## Pilot Studies in the Area of Sensory Substitution

**Jacqueline Wertsch, M.D.; Paul Bach-y-Rita, M.D.; Clement J. Zablocki**

Veterans Administration Medical Center Rehabilitation Medicine Service, 5000 West National Avenue, Milwaukee, WI 53295

*Sponsor—VA Rehabilitation Research and Development Service*

**Purpose**—Following the loss of vision, rehabilitation engineering approaches have been shown to be effective in providing substitute sensory information. An example of this is the ability of the congenitally blind person to perceive visual information picked up by a TV camera and provided in a tactile form onto his back. The purpose of these pilot studies was to explore the

feasibility of expanding this sensory substitution concept and technology to disabilities involving tactile deficits.

**Progress**—The disabilities involving tactile deficits which were explored were in four main groupings: 1) the insensate diabetic foot; 2) the blind diabetic with sensory deficits in the hands

due to peripheral neuropathy; 3) the spinal cord injured individual with risk of developing pressure sores because of inadequate sensation; and 4) the insensate hand in the peripheral nerve injured individual and in the spinal cord injured individual.

A Program Planning Conference was held in Milwaukee, Wisconsin to evaluate these concepts. The physiology of the sensory system and the pathophysiology of the individual disabilities were discussed in detail by participants representing multiple disciplines in such fields as rehabilitation medicine, engineering, computer systems analysis.

Based on advice from the program planning conference, the initial work focused on the insensate hand and foot. Commercially avail-

able pressure transducers were evaluated and a suitable transducer was identified and tested. For the insensate foot pilot work a method of encapsulating the transducers into the insoles by using silicone rubber was tested. Signal analysis and signal display systems were formulated. An electrotactile display system became commercially available and was found to be appropriate for use as an initial display system.

**Future Plans**—The initial work suggests that sensory substitution is a viable technological development for disabilities involving tactile deficits. Further investigation will focus on development of a sensory substitution system for the insensate foot.

## 2. Mobility Aids

### Measuring the Mobility of Blind Travelers

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Rebecca Hollyfield, Ph.D.

Veterans Administration Medical Center, Hines, IL 60141

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—One must be able to measure the effect of a blind mobility training program on the blind traveler to adequately evaluate its effectiveness. Two different approaches have been used previously to measure the blind traveler's mobility: a measurement of the travel skills of the traveler, and a determination of the person's amount and type of travel. Recent improvements in these measures now make it feasible to study programmatic effectiveness. One of these improvements is the use of a portable, ultrasonically-based, gait-measuring system. This system measures the traveler's step length, time, and cadence while walking. The other improvement involves the use of a more-psychometrically-valid questionnaire for assessing the travel behavior of the blind person.

Our study measures the travel skills and travel behavior of two groups of veterans: low-

vision travelers and blind travelers. We are measuring the travel skills with the inter-ankle-distance measuring system and the travel behavior with the Travel Inventory.

**Progress**—We are measuring the skills and behavior on four occasions; twice prior to training and twice after.

**Future Plans**—Once we have gathered the measurement data, we will assess the relationship between these two sets of measures and across the four measurement points. We hypothesize that the level of travel behavior at the fourth measurement will not be fully explainable in terms of the acquired travel skills, because there are other factors in addition to travel skill that affect actual travel behavior.

## Clinical Application Study of Training Techniques and Devices for the Blind

William R. De l'Aune, Ph.D., and Duane Geruschat, Ph.D.

Eastern Blind Rehabilitation Center, Veterans Administration Medical Center, West Haven CT 06516

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—At the present time there is no universally accepted evaluation procedure in the performance of orientation and mobility (O&M) by the blind and partially sighted. This has serious implications in terms of program and device evaluation as well as for documentation of patient progress. To address some of these concerns, the National Institute of Handicapped Research (NIHR) has supported the development of an O&M evaluation protocol at the Pennsylvania College of Optometry (PCO) R&D Center. The investigators in this project, through cooperative efforts between the Veterans Administration's Eastern Blind Rehabilitation Center (EBRC) and PCO, have been actively involved with the development and refinement of this protocol.

**Progress**—While the population studied at PCO is large and potentially representative of the visually impaired population of the United States, there are basic differences related to gender, visual history and secondary conditions between this population and that served by the VA. The current project seeks to adapt and extend the O&M evaluatory protocol to accommodate these perceived differences, to integrate and increase the number of subjects' scores contained in a cumulative O&M research database and to establish the reliability and validity of the measures when used with the veteran population.

All initially stated objectives of this project have been completed within the proposed timelines. A total of 36 subjects have been tested with 19 being seen for both pre-testing and post-testing. All clients of the blind center have been accounted for with only those who were physically incapable of completing the mobility routes being exempted. The entire mobility staff has participated in the development of the test routes and in the data collection.

**Results**—Inter-observer reliability was found to be satisfactory. The validity of the protocol was demonstrated by two methods. In the first, the assumption of skill improvement after the completion of the residential training program was verified by a significant increase in the pre-post test scores of the subjects ( $t(18) = -3.29$ ,  $p < .001$ ). In the second, the entire O&M staff was required to independently rank the veterans in terms of mobility performance. The mean staff ranking was correlated with the test scores of the clients for an  $r(17) = .627$ ,  $p < .001$ . This high degree of agreement with clinical judgment demonstrates the utility of the measure for objective client performance assessment and documents the efficacy of using clinical staff to quantify functional performance.

Since most of the veterans had some remaining vision, the mobility test route did not present a consistent challenge to their travel abilities. It was possible for a subject to walk a number of blocks before experiencing mobility problems. It appears that the mobility problems tended to cluster around high demand situations such as street crossings and high pedestrian and obstacle volume. In all other situations, the subjects performed with a high rate of travel efficiency and safety. Due to the time involved to walk the route and the physical limitations of the primarily elderly and sedentary subjects, it was not possible to extend the route to generate higher performance scores.

**Future Plans**—Because of ceiling and floor effects of the present methodology, additional research is being undertaken to develop more highly refined measures of O&M performance, emphasizing metrics concerned with the mental effort involved with travel situations. Secondary task methodologies will be utilized to obtain data concerning mental effort associated with O&M tasks of varying difficulty levels, before, during, and after training.

## SONA-ECS

Gary W. Kelly; David A. Ross; Richard M. Bass; Theresa M. Ackerman; Jeffrey L. Smith

Atlanta Veterans Administration Medical Center, Rehabilitation Research and Development Unit, Atlanta, GA 30033

Sponsor: VA Core Funding

**Purpose**—The SONA-ECS (Sonic Orientation and Navigational Aid - Environmental Control System) is a digital, radiofrequency transmitter-receiver system that has applications for persons with manual impairments as a decentralized environmental control system.

**Progress**—SONA-ECS has proved to be highly reliable and to function well technically. SONA-ECS has had approximately 8000 hours of field testing to date, both in a work environment and in a veteran's home. It is also being used to operate a van lift system where it is necessary to open the side door and operate the wheelchair lift control and interior lights in a van.

The SONA-ECS transmitter and receiver are microprocessor-based. The transmitter has been interfaced through RS-232C to a microcomputer and is operated under program control. The receiver also has implemented RS-232C serial communication. In addition to simplifying the hardware, the current design enhances the system's capabilities, as many modi-

fications and improvements can be implemented through software. The system is capable of being used with a broad range of input/output devices. In a special application, the transmitter is being controlled through joystick input from an intelligent microprocessor wheelchair controller. The digital coding of the radio signal can be expanded so that transmitters for different uses or disabilities will send a different generic use code in addition to the device code.

**Future Plans**—The Atlanta Veterans Administration Medical Center intends to continue development and evaluation of this system. The project will focus on enhancing the performance and capabilities of the system through the application of microprocessor technology and examination of new areas of application.

The final result of this project is intended to be the development of products which are low cost and easily manufactured. Discussions are currently being held with potential manufacturers to produce the system.

## SONA-Sonic Orientation and Navigational Aid

Gary W. Kelly; Lisa W. McNeal; Theresa M. Ackerman

Atlanta Veterans Administration Medical Center, Rehabilitation Research and Development Unit, Atlanta, GA 30033

Sponsor: VA Core Funding

**Purpose**—The Sonic Orientation and Navigational Aid (SONA) is designed to alleviate the problem of independent mobility for a visually impaired person by providing auditory orientation cues. The SONA consists of a digital, radiofrequency transmitter-receiver system. The microprocessor-based transmitter carried by the visually impaired traveler signals receivers placed over the desired or emergency locations. When the receiver detects its coded signal (which is different for each location), it emits a series of pleasing musical tones called Musical Language.

**Progress**—The human factors aspects of SONA have been of primary importance throughout its development. A pilot study of the prototype SONA system was completed at the Atlanta Veterans Administration Medical Center with subjects representing a wide range of visual impairments from low vision to total blindness. Twenty-three out of 24 volunteer subjects who evaluated the prototype system expressed much enthusiasm about its potential, although opinions were mixed as to whether the system would be most useful in a familiar or unfamiliar environment (indicating that such a judg-

ment depends upon individual user differences). The measures used in the study were purely subjective, and the number of subjects tested was too small for the conclusions drawn to be considered universal; however, their high praise for the system in general has been encouraging and their suggestions for design improvements have been helpful.

Some examples of the suggestions to be incorporated include making the transmitter smaller and easier to carry, and mounting the receivers at consistent heights. Most of the persons who evaluated the SONA system believed it would be very useful in mobility training.

### 3. Reading Aids

#### Tactile Graphic Braille Display

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Gregory L. Goodrich, Ph.D., and David L. Jaffee, M.S.

Rehabilitation Research and Development Center Veterans Administration Medical Center, Palo Alto, CA 94304

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—Computer access is a necessary prerequisite for many vocational and educational tasks today, and this trend is likely to increase over the next decade. It is estimated that by the year 1990, as many as 90 percent of all jobs will involve some interaction with a computer. A major component of the expanded role of computers will be the increased use of graphics to convey information (e.g., graphs, pie charts, or icons). These displays pose a potential problem for visually impaired individuals, since there is currently no way to present graphic computer information to them.

The goal of this project is to assemble the necessary technology to construct an inexpensive tactile graphic display, in an attempt to significantly improve the educational and vocational opportunities for thousands of blind and visually impaired people.

The most common means used by visually impaired people to access computers are synthetic voice, single-line refreshable braille displays, hard-copy braille printers, optical low-

**Future Plans**—Based on further funding, development and evaluation of the SONA system will be continued to enhance the performance and capabilities through the application of microprocessor technology to provide an optimal orientation aid for the visually impaired person. The final result of this research is intended to be the development of an orientation aid which is low cost and easily manufactured. Such a system could be implemented on a national basis using standard coding systems which would be determined through human factors testing.

vision aids, and large-print computers. Although each provides some measure of computer access, all have shortcomings, either in function or in cost, that render them unlikely to solve the basic problem.

The project investigators propose that an electromechanical device can be developed that would display tactile braille, letter outlines, and graphics. Such a display, consisting of a matrix of plastic pins that could be selectively raised or lowered under computer control, would be connected to a standard computer to serve as an output device. It would be a functional substitute for the CRT display system used by sighted computer users.

**Progress**—The American Foundation for the Blind (AFB) has designed a prototype graphic braille display mechanism which is thought to be suitable for presenting graphic and alphanumeric information. The current project will facilitate continued work on that display, the development of companion software, and evalua-

tions of the display in both laboratory and field testing situations.

Software development, being accomplished at the Rehabilitation R&D Center, focusses on providing a transparent interface to commonly available computers such as Apple and IBM product lines. The research program calls for combining the AFB hardware and VA software with concurrent evaluation, so that the design process can immediately benefit from information obtained in the evaluation process.

The computer interface hardware has been procured and some initial programming has been accomplished. Continued development of the prototype mechanical braille display mechanism is under way.

**Future Plans**—Arrival of the first working units from the AFB is expected in early 1986. At that time, an additional effort will be re-

quired to mate the electro-mechanical mechanism to a standard computer. Evaluation of the completed system will begin at that time.

The evaluation process will be facilitated by the initial construction of three prototype displays, to allow two displays to be used in field and laboratory testing and the remaining prototype to be used for hardware refinement. The plan calls for the three units to be rotated from the AFB to the Western Blind Rehabilitation Center, so that advances in hardware may be immediately incorporated into the evaluation process without the loss of time typically encountered when a solitary prototype is returned for repair or modification.

Upon completion of the project, it is expected that the display, with application software, will have been developed and tested to the point where it can be turned over to a manufacturer for production and distribution.

## Establishing Design/Operational Features for Portable Blind Reading Aids

Richard D. Steele, Ph.D., and Gregory Goodrich

Rehabilitation Research and Development Center Veterans Administration Medical Center, Palo Alto, CA 94304

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—There is a need for a practical, portable, voice-output reading aid for the blind. Approximately 500,000 Americans (including 50,000 veterans) are totally blind, and another 1.5 million Americans (including 200,000 veterans) are legally blind. Most of these people have no means of unassisted access to inkprint materials, and would benefit personally or professionally from a useful, inexpensive voice-output reading aid. Existing reading aids have achieved only very limited distribution and use, due in part to their failure to address users' comprehensive needs.

This work seeks up-to-date and detailed specification of user needs experimental clinical findings on how best to address them. It utilizes the Computer-based Adaptable Reading Aid (CARA) recently developed at the Rehabilitation R&D Center. The project also utilizes the strengths of two complementary centers—the Veterans Administration Western Blind Rehabilitation Center (WBRC) and the Palo Alto

RR&D Center.

**Progress**—The RR&D Center has developed the Computer-based Adaptable Reading Aid (CARA) prototype. Utilizing what was learned from the experimental device developed by Telemetry Systems, Inc., in 1980, which combined hand scanning with voice input, the prototype incorporated an easier user access and an expanded reading capability.

The work is organized around three approaches, which are to be addressed sequentially. They are a needs assessment of visually impaired people and blind rehabilitation workers, a critical survey of current commercial reading devices with optical character recognition (OCR), and simulation studies, conducted by a joint clinical-research team and using the flexible CARA prototype. This device is highly flexible in that it allows easy access for device modifications during simulation studies.

The CARA prototype has fully operational

interfaces to the Optacon (a low vision tactile-output device) and the Stereotoner (a device that generates tones that are a function of the shape of a character). Two generations of controller boards for acquiring images of scanned characters are in use.

A first-generation hand-scanning camera has been completed, and a first iteration of front-end image processing and OCR software has been completed.

Current efforts are concentrating on the design of the questionnaires and surveys, and on the functional and logistical aspects of the simulations.

**Future Plans**—Further work will focus on the design of a low-cost tactile tracking aid and page scanner for the hand camera, and an audio tracking aid.

### Facilitating the Use of Tape Recorded Text by Students with a Visual Handicap

A.J. Parkin, Ph.D., and F.K. Aldrich, B.Sc.

Laboratory of Experimental Psychology, University of Sussex, Brighton BN1 9QG, United Kingdom

Sponsor: *Royal National Institute for the Blind*

**Purpose**—Visually handicapped college students are dependent on tape recordings for access to academic texts. Phase I of this project has outlined the problems encountered by these students. Phase II is now exploring ways of alleviating their difficulties.

**Progress**—Phase I: Questionnaire surveys have been conducted to investigate the study methods of visually handicapped students ( $N = 70$ ) and the recording practice and communication

difficulties of volunteer narrators ( $N = 50$ ). Phase II: Experiments are now underway to assess the effectiveness of variable speed and pitch-control devices; tactile line graphs (produced on capsule paper) as a supplement to tape recordings; and restructuring text to be recorded. A 6-letter code to identify recorded books to their users is also being evaluated.

**Future Plans**—Phase II was concluded in late 1986. A project report will be available in 1987.

### Tactile Paper for Visually Handicapped

D. Reginald Traylor and Anita M. Corso

Traylor Products & Services, San Antonio, TX 78217

Sponsor: *National Institutes of Health; National Eye Institute*

**Purpose**—The purpose of this project was to determine the feasibility of developing a paper containing encapsulated particles which, upon stimulation activated by heat, pressure, light, chemicals or other means via an "imaging pen," would produce an immediate raised, colored, impression along the line of the pen. Upon deformation, it should serve as a master for the Thermoform process. Thermoform is a heat vacuum process that "copies" in three-dimensional form.

**Progress**—Research was directed toward the current state of the art in encapsulation tech-

nology and after an extensive search of literature, scientific and industrial sources, a source was identified. The initial prototype effort was performed within the established constraints related to safety, total systems cost, and minimal hardware. Two thermally activateable coatings were developed for the paper. One is a water-based coating containing microcapsules of a dye precursor dissolved in oil; a solid acid is suspended in the coating, the reaction of the dye precursor with the acid produces color (this technology is similar to that used in carbonless paper and thermal print paper). The second is a solvent-based coating containing suspended par-

ticles of a thermally activated blowing agent. The binder for this coating is composed of a specific mixture of polymeric and monomeric materials that initially behave as a thermoplastic mass. The application of heat swells this mass through the decomposition of the blowing agent and simultaneously converts the binder into a thermoset mass.

Of the two identifiable technologies considered for the pen, acid ink or a thermal element, the thermal approach was chosen because of existing technology. (The acid approach imposed a danger of not allowing expanding gas to escape.) Keeping in mind the cost constraint on the hardware, a prototype was fabricated from a pencil soldering iron using a standard light-dimmer to lower the soldering iron tip temperature from 800 degrees Fahrenheit to 400 degrees Fahrenheit. Feasibility was thus established when raised and colored images could be obtained using the coatings and pen.

**Future Plans**—Field test evaluations will be made to research materials, stimulating technologies, color, height and width of lines, and other properties that are necessary to design and produce a quality product. Paper texture

and color contrast will be emphasized. The pen must be lightweight, portable and battery operated. Above all, both paper and pen must be safe, cost efficient, and easy to manufacture. All feedback from the field test evaluators will be analyzed and incorporated into the continuing production until satisfactory results are gained.

Development of the tactile paper and pen is directed toward all ages of the visually handicapped population. The color contrast as well as the tactile reinforcement will benefit the low vision persons; the tactile impression will benefit the blind. Primary markets to be satisfied are educational facilities, institutions serving the blind, employers, state and VA agencies. Applications in school settings include handwriting skills, graphic displays, mapping, and mobility aids, as well as flow charting for computer programmers and as a communication tool in the employment setting. Commercialization of the paper for use in computer generated graphics and illustrations for books for the blind as well as nonhandicapped, particularly kindergarten through second grade, is anticipated.

## Enhancing the Reading Skills of Low Vision Individuals with Macular Loss \_\_\_\_\_

Gale Watson; John Baldasare; Steven Whittaker; and William De l'Aune  
 Pennsylvania College of Optometry, Philadelphia, PA 19141

*Sponsor: National Institute of Handicapped Research, Rehabilitation Research and Demonstration*

**Purpose**—This overall project is an applied research effort designed to quantify measures of visual and reading skills and to develop computerized training protocols and software that assist low vision instructors in the vision rehabilitation of the target population. The present report represents the work done during the second year of this 3-year study.

**Progress**—*Part I.* Development of Measures of Visual and Reading Skills: The Pepper Visual Skills for Reading Test (VSRT) is an instrument designed to quickly assess the visual skills required for reading. Developed and described in a previous project (NIHR, 1983), it is being

refined and revised in the course of the current study.

**Reliability.** Reliability of the various scoring protocols for the test was evaluated in the first year of the project. A sample of fifty macular degeneration patients were recruited from the William Feinbloom Low Vision Rehabilitation Center. All patients had a history of efficient reading before the onset of their visual pathology and indicated a desire to regain reading skills as part of the rehabilitation process.

Inter-observer reliability of the VSRT has been assessed on a subset of twenty patients sampled from the original group of fifty.

An analysis of the test data indicated that

subjects either read inaccurately and slowly, slowly but with accuracy, or with both accuracy and speed. Categorization of the low vision reader into one of these three categories has definite rehabilitation implications.

**Decoding Skills as Related to Reading Comprehension.** The evaluation of the hypothesis that attainment of decoding skills, as measured by the Pepper VSRT, allows subjects with macular loss to attain a reading comprehension level commensurate with the level prior to macular loss is being undertaken. In addition, a study of age-matched controls, not manifesting conditions of maculopathy, compared to macular degeneration patients and those with intact central fields is under way, also using Gray Oral Reading Test and the VSRT.

**Field Testing of the Pepper VSRT.** To date, we have data from Carolina Eye Associates, Southeastern Blind Rehabilitation Center, the Senior Blind Program at the Michigan Commission for the Blind, and the Low Vision Clinic at the University of Wisconsin, Department of Ophthalmology. All four sites administered the test before and after the low vision examination and once after receiving a low vision aid and practice in its use. The results indicate performance on the Pepper Test increased across the three administrations of the test.

*Part II. Expert System for Training Eccen-*

*tric Viewing and Reading:* Experts in vision rehabilitation experienced in eccentric viewing and reading training were surveyed as to which methods of assessment and training were commonly used. The results of this national survey of 80 clinics were analyzed and interpreted by the grant staff and put into the framework of a basic rule base. A number of modules required for the expert system (inference engines, data structures, operator interfaces, etc.) were programmed and are currently being evaluated. The VSRT, which is used as an analytical tool by the system, has been emphasized. A module to score, report, and store data from this test has been designed. The test database has been interfaced with the large research database of client intake, optometric, and functional information already in use at the WFVRC. This database is used both as a source of client specific information for the expert system and as a mechanism for establishment of baseline data measurements on selected characteristics of eccentric viewing.

**Future Plans**—After a model or several models of training possibilities are finalized, coding of variants of the commercial programs or original programs, specifically designed for reading problems of individuals with maculopathy, will be initiated.

## Human Factors Considerations in the Design of Large Print Visual Display Units \_\_\_\_\_

Gary Kelly; David Ross; Lisa McNeal

Atlanta Veterans Administration Medical Center, Rehabilitation Research and Development Center, Atlanta, GA 30033

Sponsor: VA Core Funding

**Purpose**—This research project began in January 1986. Its primary objective is the determination of optimal readability in large-print visual display units (VDUs). Large-print displays (LPDs) are becoming prevalent and have many problems beyond those already encountered in VDUs for persons with normal vision. The present human factors study will examine font or character set, color, inverse versus normal print, spacing between lines/characters, and problems of control in VDUs. Persons with a wide range of visual impairments will be

tested on a software system developed at the Atlanta VA Medical Center to determine these factors.

**Progress**—Previous work by the authors indicated the need for improved controls for the manipulation of text on VDUs designed for display of large print, such as large-print computer systems. The authors indicated that task dependency may be a factor on the format and control requirements.

To date, work has centered around obtain-

ing essential equipment for the research and establishing the specific protocol for testing. This process is now complete; and the software is being written for the Apple IIe computer for control testing and for the Hewlett Packard 310 for the testing of color, font, and spacing considerations of the display. A closed-circuit television system has been acquired for initial assessment of minimum and optimal print size.

**Future Plans**—Persons with visual impairments will be selected for testing on the newly developed systems. Selection to obtain an adequate sample will rely on the expert advice of physicians and a local low vision clinic. Pilot

tests will begin with the selection of appropriate fonts for testing, followed by two phases of testing. Phase one will establish reading comprehension scores and words-per-minute as a baseline, and will test the effectiveness of various control types. Mouse, joystick, track ball, and touch pad controls are being tested. Phase two will test readability of fonts, sizes, spacing, color effects, etc. Another reading comprehension test and words per minutes will also be assessed, using the optimal large-print display, to determine if the visually impaired person improves in his reading. This testing will be followed by statistical analysis and reporting of the project results.

## B. Deafness and Hearing Impairment

### Development of a Digital Hearing Aid and Fitting Procedure

A. Maynard Engelbretson, D.Sc.; Robert E. Morley, Jr., D.Sc.; Gerald R. Popelka, Ph.D.; Bridget Mancano, M.A.; Arnold F. Heidbreder, B.S.E.E.; Michael P. O'Connell, B.S.E.E.; George L. Engel, M.S.E.E.  
Central Institute for the Deaf, St. Louis, MO 63110; Department of Electrical Engineering, Washington University, St. Louis, MO 63130; Veterans Administration Medical Center, Temple, TX 76501

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The purpose of this project is to develop a digital hearing aid and a companion fitting procedure that will improve the precision, flexibility of fit, and utility of hearing aids. Towards this goal, special laboratory-based systems have been assembled to evaluate the overall concept and to develop design specifications for an ear-level digital aid. These systems include a digital hearing aid breadboard (DHAB) and a computer-based audiometer system. The DHAB operates in real time and is better than most analog systems including hearing aids. The DHAB is well suited for parametric laboratory studies of digital processing algorithms intended for hearing aid applications.

**Progress**—Two major accomplishments have taken place this third year of the project. They are: 1) the fabrication of a wearable version of the digital hearing aid (WDHA) and 2) completion of a preliminary design of a low-power digi-

tal signal processor (DSP) that is suitable for use in an ear-level hearing aid. Each is described below.

Four Wearable Digital Hearing Aid units have been fabricated for clinical field studies. The wearable unit fits in a case 5.5 inches long, 3.5 inches wide, and 1.2 inches thick. The system is comprised of two circuit boards of conventional parts, one which contains the DSP and supporting digital circuitry, and a second which contains analog signal conditioning circuitry, multiplexing circuitry, and a codec chip. The analog circuitry is connected via a flexible cable to an ear module containing an input microphone, probe microphone, and receiver. The battery for the system fits in the body-worn case and provides sufficient power for a continuous period of 10 hours.

The processor circuit board contains a Fujitsu MB8764 DSP, five Hitachi 6116 random access memory (RAM) chips for program in-

structions and data, and circuitry for switching to standby power in the event that the primary battery becomes discharged or is removed. The DSP is well suited for processing audio signals and was chosen for the WDHA because of its low power consumption.

Since the computer-based audiometer controls the parameters of the hearing aid during testing of the patient, a serial interface is included in the WDHA. To minimize power consumption and complexity, a simple shift register was used. The control and clock signals for serial communication are controlled by the audiometer, and the communication protocol is purposely simple. Hearing aid parameters and sound pressure measurements of the probe microphone are transmitted between the hearing aid and audiometer during testing and fitting of the patient.

The DSP program resides in RAM and consists of eight finite-impulse-response (FIR) filters arranged in four channels. Each channel consists of a bandpass filter, limiter, and bandpass filter. The filter-limiter-filter structure allows for the maximum output and gain to be separately controlled within each of four channels to match the patient's discomfort threshold and hearing threshold, respectively. The filters reduce distortion products of the limiting process to ensure that they fall below the masked threshold of the ear.

Although the WDHA is not suitable for commercialization because of its size and power consumption, it has the potential for improving our understanding of issues involving digital signal processing with regard to hearing aids. And, although it is possible to simulate natural conditions of signal and noise in the laboratory, additional important insight can be gained by wearing a device in natural surroundings.

*Low Power VLSI Design.* An important factor in achieving a practical ear-level digital hearing aid is overall power consumption. Conventional hearing aids typically consume less than one milliwatt of power at a nominal voltage of 1.5 volts. A suitable digital processing structure that operates within these limitations is a logarithmic multiplier accumulator (LMA)

circuit element arranged in the form of a systolic array. A preliminary design of this element has been completed and submitted for fabrication.

At present, low-power designs are best implemented in CMOS (Complementary Metal Oxide Semiconductor) technology. The major source of power consumption is the energy required to charge and discharge capacitive circuit elements. The power is proportional to the frequency with which the capacitor is charged and discharged, to the capacitance, and to the square of the voltage impressed on the capacitor. A gross estimate of the power consumption of the LMA cell, assuming a battery supply of 1.5 volts, a 1.5 micrometer CMOS process, 1500 transistors per cell, and a clock cycle of 80 microseconds, is about 1 microwatt. Therefore, 500 LMA cells can be incorporated into the processing structure at a total power consumption of about one-half milliwatt. This kind of structure is sufficiently complex for digital hearing aid applications and of sufficiently low power to use in an ear-level configuration.

**Future Plans**—Field studies with the body-wearable digital hearing aids will begin soon. The WDHA will be used to compare the performance of the digital hearing aid to that of conventional hearing aids under natural conditions of signal level and background noise. Selected patients will be fitted with the WDHA using the computer-based method developed for this project and also fitted with the best available commercial hearing aid. Patients will wear each aid for extended periods during normal daily activities. Patients will be asked to compare the two aids on the basis of signal clarity, comfort, and general utility.

The design of an LMA cell has been completed and has been submitted for fabrication. Testing to verify the accuracy of the design will begin in the near future. After the single LMA cell is tested, the design, fabrication and testing of a systolic array of LMA cells suitable for an ear-level aid will begin. Plans call for implementing the array in 1.5 micrometer CMOS to achieve the desired power characteristic.

## Using a Psychophysical Model to Design Hearing Aids for Sensorineural Hearing Loss

E. William Yund, Ph.D.; Robert Efron, M.D.; Helen J. Simon, Ph.D.  
Veterans Administration Medical Center, Martinez, CA 94553

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—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 that 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.

**Progress**—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: 1) 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 2) 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 his hearing loss which 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 will define the appropriate hearing aid for that individual.

The hearing aid defined by the model (as

described above) for each particular hearing-loss subject is being tested using speech stimuli modified to simulate the action of the aid by means of digital signal processing software. These simulated hearing aid outputs are then 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 subjects with their "aided" stimuli can then 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.

**Preliminary Results**—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. In addition, we have compared the performance of the "model hearing aid" with that of an individually-fit conventional hearing aid, using the methods described above, on half of those subjects. The results of these speech recognition experiments support the following conclusions. 1) Both the "model aid" and the conventional aid greatly improve speech recognition in low ambient noise conditions. 2) In a background of speech-band noise, the "model aid" performs at least as well as the conventional aid and, in most subjects, the "model aid" performance is superior to that of the conventional aid. 3) The greatest advantage of the model aid over the conventional aid occurs at low signal-to-noise ratios (+5, 0 and -5 dB), conditions where the SNHL patient usually experiences the most difficulty in understanding speech.

Current work includes testing the remaining subjects in the speech recognition experiments and detailed analysis of all of the data

obtained from these SNHL subjects.

## Electroacoustic and Behavioral Studies of the Effect of Ear Impedance on Hearing Aid Performance

Vernon D. Larson, Ph.D., and William E. Cooper, Ph.D.

Veterans Administration Medical Center, Augusta, GA 30910 and University of South Carolina, Columbia, SC 29208

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The purpose of this research is to study the relative acoustic impedances of hearing aid sound sources, the ear canal and the eardrum as they interact with the impedances of the earmold types, static pressure differences across the tympanic membrane, stapedial muscle contraction, and otic pathology.

**Progress**—A computer-based system (IBM PCXT) was assembled for the purpose of acquiring and processing acoustic data from ear canals. In addition, a computerized system for assessing the acoustic impedances, both real and imaginary parts, of sound sources has been developed and is now undergoing validation.

Data collection and analyses are in progress in three broad areas of study.

*Ear Canal Sound Pressure Levels.* The effect of ear canal volume and eardrum impedance (estimated tympanometrically) on sound pressure levels in the ear canal has been studied in relation to 2 ml coupler sound pressure levels. For subjects with small and large ear canal volumes, the sound pressures in ear canals (relative to 2 ml coupler levels) for frequencies below 1000 Hz were predicted by  $20 \log ((V_e + V_c)/V_{2cc})$  while the sound pressures for higher frequencies (up to approximately 3000 Hz) were predicted by  $20 \log (V_c/V_{2cc})$  where  $V_c$  = ear canal volume,  $V_e$  = eardrum impedance equivalent volume, and  $V_{2cc}$  = 2 ml reference volume. Investigations of the effect of ear canal volume while holding eardrum impedance relatively constant on auditory threshold are in progress.

*Acoustic Reflex and Word Recognition Ability.* The effect of the acoustic reflex elicited by a contralateral 6 kHz signal on word recognition ability has been investigated. Using an adaptive procedure to determine presentation levels at which 30 and 70 percent correct responses were obtained, activation of the reflex facilitated word recognition.

*Alteration of Eardrum Impedance.* The study of the effects of artificially altering the impedance existing in normal subjects at the lateral surface of the tympanic membrane is under way. In one series of studies, eardrum impedance was altered by varying the static pressure in ear canals. Sound pressure in ear canals averages an increase of 3 to 4 dB for frequencies below 1000 Hz while it decreases in the mid-frequency range. These ear canal sound pressure changes appear to be directly related to auditory threshold changes. In each case, however, the changes appear to be directly related to the electromechanical and acoustic properties of the sound source. In another study, static pressure changes in the ear canal have also resulted in an increase in the latency of the early components of auditory evoked potentials and median plane localization ability. In a third series of study, eardrum impedance (increased middle ear and intralabyrinthine pressures) was altered by placing subjects in a position wherein their heads were put downward and backward at an angle of 30 degrees. Ear canal spectrum levels increased by 2 to 6 dB in the 750 to 3500 Hz region.

## Studies in Acoustic Feedback in Hearing Aids

David P. Egolf, Ph.D., and Vernon D. Larson, Ph.D.

Department of Electrical Engineering, University of Wyoming, Laramie, WY 82071 and Veterans Administration Medical Center, Augusta, GA 30910

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The causes of acoustic feedback in hearing aids are not well known and remedies for it are limited. The objectives of this project are 1) to study the causes of unstable acoustic feedback and to determine the physical and electrical parameters and interactions which affect it; 2) to study earmolds designed to reduce acoustic feedback and thus provide greater electroacoustic gain to the user; and 3) to design, build, and test prototype circuitry which suppresses unstable feedback.

**Progress**—The major project phases are complete. A computer model developed for this project includes: 1) an acoustic feedback path from the earmold vent outlet back to the hearing aid microphone; and 2) a direct acoustical path from the sound field to the eardrum (denoted by some authors as a feed-forward path) to account for sound entering the ear canal by the way of the vent. Computer generated and

measured field-to-eardrum transfer functions differ by, at most, 8 dB at some frequencies.

**Preliminary Results**—Three prototypes of the feedback suppression circuit have been produced and are now undergoing further electroacoustic and subjective evaluation on subjects. Preliminary tests indicate that this circuit, based on the "open-loop estimator" concept, reliably produces 6 dB additional stable gain when the hearing aid is coupled to a non-occluding earmold. With the same hearing aid configuration, investigators found that, with considerable fine-tuning this could be increased to 15 to 20 dB additional stable gain. Unfortunately, at these gain settings, the hearing aid became quasi-stable and minor acoustic disturbances (i.e., chewing or wind) would trigger the characteristic squeal of acoustic feedback. Other earmold configurations are now being evaluated.

## The Laura Cochlear Implant

J. Marquet; S. Peeters; E. Officiers; W. Bosiers; M. Van Durm  
University of Antwerp, Belgium

Sponsor: Universities of Antwerp (Antwerpen) and Louvain (Leuven), in collaboration with Forelec N.V. (Wilrijk)

**Purpose**—The two main parts of the Laura Cochlear Implant are separated by the skin. The external portion of the device consists of an input amplifier and speech processor, while the implantable portion is composed of the electronics and the multichannel intracochlear scala tympani microelectrode. The microelectrode is a platinum-iridium 16-wire electrode which is configurable as an 8-channel bipolar electrode or as a 1-to-15 monopolar electrode, depending on the control signals from the speech processor. The electrode is connected to an integrated circuit that decodes the incoming pulse-sequences. The electronics get their energy from an RF link through the skin.

**Preliminary Results**—The system is nearly as transparent as a percutaneous connector. Every 20 microseconds, the device is able to update any electrode with a new current value. (Most telemetry devices rely on simple inductive coupling or an amplitude-modulated carrier providing, essentially, only voltage control of their outputs. Only the most sophisticated telemetry devices allow current control.) On request of other groups, an impedance-measuring system has been built in to send information back through the skin.

The external system consists of a normal hearing aid for preprocessing of the signal, and the speech processor. The output of the hearing

aid goes to a set of bandpass filters which have been optimized by means of simulation experiments. Each filter includes a fast-attack, slow-release averaging circuit with a weighting function for every output. The outputs are scanned by means of a low power 8-bit analog/digital convertor (ADC) integrated in the low-power CMOS microprocessor. The scanning rate is locked to the pitch of the incoming speech signal.

The microprocessor uses the 8-bit ADC value to find patient-related values concerning the perceptive threshold of the patient, the discomfort level of the patient, and the nonlinear compression curve which is adaptable to the loudness perception of the patient. Values for

all eight channels are contained in nonvolatile (but erasable and reprogrammable) memory.

The built-in microprocessor allows flexibility to experiment with averaging phase-locking decoding or other decoding systems to match the optimum speech discrimination. The microprocessor could also compensate the travelling wave time of the basilar membrane. The total current consumption equals 15 mA.

**Future Plans**—The use of an electronic implantable device puts high demands on the packaging of the device, which is still under investigation. Future activities are expected to concentrate on testing and optimizing our biocompatible packaging.

## Development of a Cochlear Prosthesis

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**F. Blair Simmons**

Stanford Medical Center, Division of Otolaryngology, Stanford, CA 94305

**Sponsor:** *National Institutes of Health*

**Purpose**—The objective of this project is to create hearing and at least limited speech comprehension in totally deaf persons by electrical stimulation of the auditory nerve. Deaf human volunteers receive multielectrode implants within the inner ear. Basic psychophysical stimulation experiments measure the range of auditory precepts for each electrode and this data is then used as design criteria for the de-

velopment of computer-generated “speech processors” or acoustic feature detectors. The processors so developed are used to code speech sounds for electrical stimulation. Concomitant with this human research are animal experiments verifying the safety, tissue tolerance, and other features helpful and necessary for human research.

## Matching Speech to Residual Auditory Function

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**Louis D. Braida**

Massachusetts Institute of Technology, Cambridge, MA 02139

**Sponsor:** *National Institutes of Health*

**Purpose**—This research is directed toward improved signal-processing schemes to aid people with sensorineural hearing impairments. We intend either to develop improved schemes or to obtain a fundamental understanding of why such schemes cannot be developed. The proposed work includes study of linear amplification, amplitude compression, and frequency lowering. Also, attempts will be made to determine and understand the effects of variations

in speech production on speech reception by impaired listeners.

**Progress**—The research on linear amplification is concerned with modeling the dependence of speech-reception performance on the speech materials, the background interference, the listener, and the linear amplification system. Initial work on this project involves an attempt to apply articulation theory to speech reception by

impaired listeners.

The research on amplitude compression, directed towards listeners with reduced dynamic range, involves further study of multiband syllabic compression, as well as study of automatic volume control and limiting. The research on frequency continues to focus on pitch-invariant, nonuniform lowering. In both areas, the proposed work involves further exploration of the effects of various system parameters on speech-reception performance, testing of a wider variety of subjects, and attempts to determine the underlying causes of the results obtained.

The research on the effects of variations in speech production is motivated by our belief

that both intersubject and intrasubject variations exist that lead to substantially improved speech reception, and that an understanding of these variations and their effects will provide useful background for the development of improved signal-processing schemes. The proposed work in this area involves the development of speech materials uttered by different speakers under a variety of speaking conditions, the measurement of speech reception by impaired listeners using these materials under a variety of listening conditions, and the attempt to correlate the speech-reception results with properties of the acoustic waveforms.

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## Hearing Aid Characteristic Selection

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Gerald A. Studebaker

Memphis State University/Audiology, Memphis, TN 38105

Sponsor: *National Institutes of Health*

**Purpose**—The overall purposes of the proposed research are 1) to study how the characteristics of amplified speech signals affect the performance and satisfaction of hearing impaired persons; and 2) to identify an adequate means to identify the characteristics an individual needs in order to obtain the most acceptable assistance possible. The two principal tools we will apply in these studies are subjective judgments and articulation theory.

**Future Plans**—Three different subjective methods will be used. First, a magnitude estimation-production method of evaluating speech intelligibility will be developed in order to produce band importance (BI) functions for continuous discourse and sets of nonsense sentences. Second, magnitude estimations of quality and intelligibility will be evaluated for reliability and validity with respect to intelligibility in a format designed for clinical use. The third method is an adaptive paired comparison procedure designed to run with a high degree of efficiency under computer control.

The adaptive paired comparison method

will be used to 1) investigate the relative importance of the characteristics of hearing aid reproduced sound to the acceptability of a hearing aid where acceptability is defined as the best combination of intelligibility and pleasantness; and 2) evaluate the intelligibility and other judged characteristics of new hearing aids or hearing aid types using juries of normal hearing persons.

Articulation theory will be used in an investigation of the relationship between the functional characteristics of frequency-by-intensity regions of impaired auditory systems and the speech intelligibility provided by those regions. Also, the distribution of the proficiency factor (PF) will be measured in narrowly defined linguistic groups. Finally, hearing aid performance will be evaluated using the concept of hearing aid efficiency in which frequency response and S/N ratio effects are "controlled" by the use of the articulation index. Standard and nonstandard measures of electroacoustic performance will then be related to hearing aid efficiency.

## Rehabilitation Strategies for the Hearing Impaired: A Digitally Programmable Master Aid

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Harry Levitt

CUNY Graduate School, New York, NY 10036

Sponsor: *National Institutes of Health*

**Purpose**—Rehabilitation strategies for the hearing impaired will be developed and evaluated. Strategies for speech and auditory training of hearing impaired children and adults will be considered. The impact of tactile and visual sensory aids on learning rates will be investigated and new types of sensory aids will be developed, including computer-simulated experimental hearing aids and wearable multichan-

nel tactile displays. Methods of rehabilitation training for cochlear implant recipients will be developed and evaluated. Analytic and global methods of training will be compared. Comparisons with tactile aids and conventional hearing aids will also be undertaken. The proposed research should result in improved rehabilitation techniques for a wide range of hearing impairments and methods of intervention.

## High-Frequency Acoustics in the External Human Ear (Phase I)

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George F. Kuhn

Vibrasound Research Corporation, Aurora, CO 80014

Sponsor: *National Institutes of Health*

**Purpose**—Recent research pertaining to 1) high frequency audiometry up to 20 kHz; 2) to the measurement of in-the-ear pressures produced by hearing aids; and 3) to the research and diagnostic applications of so-called cochlear distortion products have necessitated accurate knowledge of the acoustic wave motion in the external meatus.

The acoustic wave motion within the external meatus is a function of frequency, of the size (length, cross-sectional shape) of the canal, of the physical properties of the eardrum, of the eardrum inclination relative to the ear canal axis, of the location and impedance of the microphone to be used for the pressure measurement in the ear canal.

**Future Plans**—The proposed Phase I research is to collect a set of molds of the external meatus and of the conchae of human cadavers in order to determine the range of sizes and shapes of the canals and conchae and the inclination of the eardrum relative to the ear canal axis. The physical dimensions and shapes of these earmolds will be measured in order to design some scaled models which have acousti-

cally significant yet realistic features.

Initially, miniature microphones will be used to determine the acoustical significance or order of importance of each feature, such as curvature of the canal, eccentricity of the cross section, eardrum inclination relative to the canal axis, off-axis placement of the source, etc. Specific microphone designs will then be tested which will either cause a minimum of interference with the sound pressure at the microphone's location and at the eardrum or cause a systematic predictable deviation from the true pressure so that a proper correction can be made. Such microphones might be of a segmented, annular type or of a multi-element circumferential type.

Theoretical models will be used as a guide for such microphone designs in terms of shapes and placement and for the prediction of sound pressures at the eardrum. The long range goals for Phase II are to develop experimental and theoretical models for sound sources, microphones, and wave-propagation models in the external ear which extend to the high frequencies. The goal of Phase III is to produce such instrumentation commercially.

## Multimicrophone Monaural Aids for the Hearing Impaired

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Patrick M. Zurek

Massachusetts Institute of Technology, Cambridge, MA 02139

Sponsor: *National Institutes of Health*

**Purpose**—The ultimate goal of this research is the development of sensory aids which sample the acoustic environment at more than one point in space (multimicrophone aids) to improve the ability of hearing-impaired subjects to function more effectively in complex environments containing interference and reverberation. The more immediate goal is to explore the potential of multimicrophone systems for monaural listening in such environments. The results of this research, combined with research on binaural interaction in impaired listeners, will provide solid background for the development of multimicrophone aids to assist impaired listeners who have significant hearing in either one or two ears.

**Future Plans**—The proposed research, which draws heavily from previous work on both nat-

ural and artificial spatially diversified sensor systems (binaural hearing and antenna/signal-processing theory), is concerned primarily with reduction of interference and coding of spatially resolved information. The techniques considered for reducing interference include both linear and nonlinear processing, and both fixed and adaptive processing. The study of spatial coding, which is motivated by the need to monitor the general acoustic environment as well as to focus upon a particular source, is concerned with the extent to which signals that are spatially resolved physically can be processed for monaural listening so that the resolution is preserved at the perceptual level.

Results on the reduction of interference should be applicable to cochlear implant aids and sensory substitution aids as well as conventional acoustic aids.

## Processor-Controlled Hearing Aid

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Samuel Gilman

Sam Gilman Associates, West Los Angeles, CA 90025

Sponsor: *National Institutes of Health*

**Purpose**—The long-term objective of the proposed program is the development, design, and manufacture of a signal processor-controlled hearing aid to maintain the overall sound pressure level (SPL) and the spectrum at the eardrum within optimum limits of the hearing impaired individual for all expected input spectra and input levels. An additional feature will be an increase in signal-to-noise ratio of the aided signal.

**Future Plans**—The signal processing will be based on the actual eardrum SPL, determined from an acoustic feedback signal obtained by a microphone or probe in the ear canal. For all expected input levels, the spectrum of the ear-

drum sound pressure is controlled by the processor, so that the peak SPL in any  $\frac{1}{3}$ -octave interval does not exceed the individual's loudness discomfort level (LDL) while still maintaining the desired spectrum and SPL at its most effective value. The processor compares the inputs and outputs for each filter, and the gain in each channel is then adjusted (on a real-time basis) to obtain the desired output for the band. Determination of averaging times for both the input and output signals are significant and will constitute a major element in the study. Phase I objective is to breadboard this system (without the signal-to-noise ratio improvement), and test it on a manikin equipped with an ANSI S3.25-1979 simulator.

## Direct Measurement of Loudness Recruitment in Hearing-Impaired Veterans

Rhona P. Hellman, M.S.

Veterans Administration Outpatient Clinic, Boston, MA 02108

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The goal of the current investigation is to determine whether the psychophysical scaling procedures developed in the 1950s by S.S. Stevens for the measurement of loudness in normal hearing can be adapted for routine clinical testing and diagnosis of hearing impairment. To achieve this goal, a battery of psychophysical procedures has been devised to measure, assess, and predict the exponent of the loudness function in normal-hearing and hearing-impaired listeners. Prediction is based on the assumption that a transitive interconnected network of power-function exponents obtained for groups of people can also be obtained for individuals. To test this assumption, a systematic study of the relation among power-function exponents for individuals is necessary. Three different psychophysical procedures are used for the measurements: absolute magnitude estimation (AME), absolute magnitude production (AMP), and cross-modality matching (CMM). Measurements involve two sensory continua, perceived line length, and loudness.

**Progress**—In a first experimental series, lines of light that varied in length from 0.52 to 65 cm were constructed. Perceived line length was judged in total darkness (10 observers) and in partial darkness (17 observers) by AME. No statistically significant difference was found between the two viewing conditions. Data analysis showed that line length is a power function of physical length in cm. The mean exponent in total darkness was 0.96; in partial darkness it was 0.93.

Subsequently, to calibrate and standardize the line-length stimuli, a different group of 51 normal-hearing observers judged perceived length in partial darkness by AME. The same 51 observers also judged the loudness of a 1000 Hz tone by AME and by AMP. In addition, CMM was used to obtain the matching relation between the loudness of a 1000 Hz tone and

perceived line length.

**Preliminary Results**—Four sensation-magnitude functions, one for each series of measurements, were generated for each observer. Using the method of least squares, the results show that individual sensation-magnitude functions are well described by power functions to the form  $\Psi = K\Phi^\Theta$ , where  $\Theta$  is the exponent of the power function. Perceived length is a power function of measured length with an average exponent of 0.96, loudness is a power function of sound pressure with an average exponent of 0.43 for AME and 0.67 for AMP, and CMM yields a power function between line length and loudness with an average exponent of 0.60. The geometric mean of 0.43 and 0.67 (AME and AMP) gives a measured exponent for loudness of 0.54, and the product of 0.96 and 0.60 (Perceived length x CMM) gives a predicted exponent for loudness of 0.58.

The average difference of +0.04 between the predicted and measured exponents is within the experimental error expected for psychophysical judgments. It amounts to a measured deviation of only 7 percent. Furthermore, the distributions of measured and predicted exponents closely agree. The measured exponents range from 0.32 to 1.14; the predicted exponents range from 0.33 to 1.02. Both the average exponents and the range of exponent values suggest that the battery of procedures standardized in normal ears is suitable for use in impaired ears.

In additional experiments, nine listeners with bilateral sloping high-frequency cochlear losses judged loudness by AME, and by AMP at two test frequencies in the normal-hearing region. The main objectives were to evaluate the loudness-growth range in detail, and to determine the appropriate test frequency for the measurement of loudness recruitment.

**Future Plans**—The results described in this report will be used as a basis for the development and implementation of a direct clinical

test of loudness recruitment. Future experiments will involve large-scale testing of hearing-impaired listeners.

## Changes in Frequency Organization of the Cochlea During Aging

**Brenda M. Ryals, Ph.D. and Edwin W. Rubel, Ph.D.**

Audiology and Speech Pathology Service, Veterans Administration Medical Center, Richmond, VA 23249 and University of Virginia Medical Center, Laboratory of Developmental Neuro-Otology, Charlottesville, VA 22908

*Sponsor: VA Rehabilitation Research and Development Service*

**Purpose**—Our hypothesis for the current project has been that changes in the place/frequency organization of the cochlea are taking place in late life. Specifically, we have hypothesized that a shift in the maximal stimulation pattern on the basilar membrane toward the apex occurs in old age. We think that this apical shift may be a fundamental mechanism in presbycusis or old age hearing loss.

**Results**—Our first experiment was designed to determine whether or not there was a functional correlate to the anatomical shift in frequency/place organization that we had reported. Chicks were exposed to a 1500 Hz pure tone at 125 dB SPL for 12 hours at two ages: post-hatch day 1 and post-hatch day 30. To reduce the biasing variables of survival time versus age, chicks were tested at both equal survival time and equal age. Our results show that the maximum position of hair cell loss was located differentially depending upon the age of stimulation. Chicks exposed early in life incurred a higher frequency maximum hearing loss than did chicks exposed later in life. These results were independent of survival time.

The second set of experiments has been designed to show the normal aspects of anatomical and electrophysiological changes in the Japanese Quail during aging. Anatomical analysis of the basilar papilla at the light microscope level at 45 and 85 days after hatch has shown a similar morphology to chick inner ear.

We have now determined an appropriate anesthesia/analgesic combination to use so that multiple AP threshold recordings can be made in the same animal over time. A t-Test for Homogeneity of Variance showed no significant

difference between initial and repeat tests. To date we have determined thresholds on birds at 3 months, 6 months, 2 years, and 3+ years of age (actuarial lifespan = 2 years). Results indicate no change in hearing up to 1 year of age. After 1 year of age thresholds gradually decline, particularly for frequencies above 1,000 Hz. A colony of animals is now established so that multiple measures of hearing can be made in the same animal over its own aging course. These results will be used to determine individual variability in threshold shift with age. Anatomical correlation of these evoked potential findings show no change in the number of hair cells present from 3 months to 3+ years of age as counted from 3 micron serial sections at the light microscopic level. The number of ganglion cells, on the other hand, decreases dramatically as a function of age. Further study of neural tissue is under way to determine if this degeneration is generalized or is specific to the auditory system.

**Future Plans**—We plan to complete our determination of the normal effects of aging on hair cell loss, ganglion cell loss, and auditory threshold shift during the lifespan of one species. These data are valuable to corroborate the generality of auditory acuity degeneration in vertebrates with aging. They will form the basis of the rest of our experiments on frequency organization. We also plan to investigate the influences of traumatic agents such as ototoxic drugs and/or noise during the aging process. These results will help determine whether chronological age acts synergistically with trauma.

After the normal effects of aging have been

determined, we will proceed to study possible frequency organization changes as a function of aging. If we see changes in a fundamental audi-

tory process such as place coding, it will have far reaching implications for the prevention and/or rehabilitation of hearing loss in old age.

### Clinical Trials with the Cochlear Implant Prosthesis: Speech and Voice Characteristics, Part I

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Jaelyn B. Spitzer, Ph.D.; Steven B. Leder, Ph.D.; J. Cameron Kirchner, M.D.; Frederick Richardson, M.D.; Paul Milner, Ph.D.; Carole Flevaris-Phillips, Ph.D.

Veterans Administration Medical Center, West Haven, CT 06516

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The main objective of this investigation is to assess acoustically and perceptually speech and voice characteristics of adventitiously profoundly deaf subjects and cochlear implanted subjects, both at the time of evaluation and longitudinally.

**Progress**—To date, 27 adventitiously profoundly deaf subjects have been seen for voice and speech evaluations. Eight subjects have had cochlear implants and three are awaiting surgery. Results showed that fundamental frequency was significantly higher, intensity significantly louder, and duration significantly longer in the speech of the adventitiously profoundly deaf than in normal-hearing control subjects. In

pre- and postimplant comparisons, longitudinal use of a cochlear implant significantly enhanced production of general American English contrasting stress patterns.

**Future Plans**—Continued longitudinal assessment of speech and voice characteristics in cochlear implant subjects will center on the acoustic features of voice-onset-time, consonant closure duration, vowel duration, vowel formants, and fundamental frequency. A perceptual study between adventitiously deaf and normal hearing subjects will be performed to determine the effect, if any, of adventitious deafness on speech and voice quality.

### Clinical Trials with the Cochlear Implant Prosthesis: Speech and Voice Characteristics, Part II

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Jaelyn B. Spitzer, Ph.D.; J. Cameron Kirchner, M.D.; Frederick Richardson, M.D.; Steven B. Leder, Ph.D.; Paul Milner, Ph.D.; Carole Flevaris-Phillips, Ph.D.

Veterans Administration Medical Center, West Haven, CT 06516

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The project is in the third year of a 3-year grant to develop evaluation methods and assess the rehabilitative benefits of cochlear implantation. The trials entail use of the 3M-House single channel device. Subjects undergo an intensive pre-implant evaluation protocol described previously. If selected, based on meeting rigorous criteria for profound sensorineural hearing loss without benefit of conventional amplification and other medical and psychological indices, the patient undergoes implantation. All implanted subjects undergo post-surgical rehabilitation and reevaluation to determine pos-

sible improvements in communicative function, handicap perception, and psychological status. A longitudinal (6-month and annually thereafter) design is employed.

**Progress**—Subjects in all phases of the protocol resulted in 33 admissions through the summer of 1986. Eight subjects have been implanted with the 3M-House device and received a course of 40 hours of post-fitting rehabilitation. The course consisted of auditory training with the new auditory code, training in synthesis of auditory and visual input, and counselling regard-

ing communicative strategies). Three surgeries were accomplished by the end of the summer. Nonselected subjects have received alternative rehabilitation, including powerful auditory or tactile aids.

**Preliminary Results**—Findings in pre- and post-implantation comparisons have demonstrated: 1) significant auditory threshold improvement following implantation; 2) highly variable improved abilities in word and stress recognition;

3) improved ability to control voice parameters, as reflected in appropriate production of contrasting stress, and fundamental frequency and duration values which approximated age norms. We also have shown the utility of a two-forced choice speech intelligibility task, and use of evoked potentials with stimuli presented via an auditory trainer. Final data analysis will focus on statistical prediction of cochlear implant candidacy.

## Implementation of Digital Measurement of Aural Acoustic Immittance

David J. Thompson, Ph.D. and Larry N. Robinette, Ph.D.  
Audiology Research Program, Dorn Veterans Hospital, Columbia, SC 29201  
Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The purpose of this project is the evaluation and clinical implementation of a programmable acoustic immittance instrument. Immittance (impedance or admittance) is used with reference to measurements obtained in the ear canal and is displayed in admittance units ( $Y_a$  and phase angle, or  $B_a$  and  $G_a$ ), with option for conversion to impedance units ( $Z_a$  and phase angle, or  $R_a$  and  $-X_a$ ). This digital instrument is a computer peripheral (Micro Audiometrics MA1.1) with measurement capacities exceeding those of analog acoustic immittance instruments. Exploitation of the potential of digital measurement requires: 1) development of sophisticated control software on a host computer (IBM-PC); 2) laboratory validation of the hardware/software system and measurement protocols; and 3) clinical evaluation on normal ears and ears with hearing loss.

**Progress**—During the second year of the project, emphasis was on the development of research-oriented software using a single digital instrument. The software developed for this work used the high-level language called "BetterBASIC" (Summit Software). Routines were written in BetterBASIC for automated calibration and for acquisition, measurement, storage, and graphing of tympanograms and acoustic reflex responses. The acquisition mode includes the capacity for signal averaging, routines for

tympanograms, scaling of data, assigning of labels, finding maximum and minimum acoustic admittance, recording the location of maximum admittance, computing static admittance with phase angle, and computing the change in phase angle over the course of the tympanogram. Finally, acoustic reflex thresholds were determined through interaction with an on-screen display of the stackplots of acoustic reflex responses.

The amplitude and temporal characteristics of single acoustic reflex responses can be analyzed. Reduced data are also provided for the input-output function and perstimulatory adaptation. Summary data is derived from raw immittance data. All data are displayed on a single screen and can be saved to disk or printed out.

**Preliminary Results**—Laboratory assessment of the hardware/software system showed the digital AAI instrument to be more reliable and accurate than commercial acoustic-immittance instruments built with analog circuitry. The system is now being adapted for laboratory studies intended to explore and extend its limits. Other efforts have included initiation of a comparative study of digital and analog acoustic immittance instruments, and application of a commercial data analysis package (ASYST; Macmillan Software Company) to re-

duction of acoustic immittance data. Work in the final year of the project will concentrate on

the development of software to support clinical utilization of the digital instrument.

## A Microprocessor and Signal Processor-Based Speech Training System for the Hearing Impaired

Cliff Kushler, MS

Funakubo Laboratory, Department of Precision Machinery Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan 113

Sponsor: *Japanese Ministry of Education*

**Purpose**—The purpose of this project was to design and build a compact and inexpensive speech training system for the hearing impaired which is capable of providing visual feedback in a variety of training modes. The objective was to be able to provide support for each of the five stages in language acquisition defined by Daniel Ling: 1) abundant vocalization; 2) variation in intensity, duration, and pitch; 3) vowel and diphthong production; 4) consonants; and 5) consonant blends with respect to the target language, Japanese. To minimize costs and to facilitate the use of the system in a small group as well as an individual setting, all feedback is visual as opposed to tactile, and all input is done using microphones rather than sensors which must be physically attached to the user.

**Progress**—The first prototype built was a completely stand-alone system based on a Z-80 main processor and four NEC uPD-7720 signal processors, which can also be interfaced with a personal computer. The system is menu-driven and controlled by six pushbutton switches, and can be used independently even by fairly young children. A number of game-type displays are also under development. This system can provide training appropriate to the first three of the above stages. Real-time displays of variation in intensity, pitch, or a combined display of both can be generated along with a variety of standard or special targets. Vowel and diphthong training uses a real-time display (with a lag of less than 0.1 sec) of the first two formants in the F1-F2 plane which are extracted from the LPC spectrum. A microphone with a baffle is used as a nasality sensor, so that the

presence of excessive nasalization can be detected with respect to the first formant frequency, since a certain level of nasalance is natural in Japanese vowels with a low first formant. The level of nasality is reflected in the shape of the cursor in the F1-F2 display so a simple one-point display characterizes both vowel articulation and the level of nasalance. Preliminary field testing with this system indicates that significant progress can be attained even in a difficult subject (a congenitally profoundly deaf 11-year-old boy who remained undiagnosed and did not receive a hearing aid until the age of 7).

**Future Plans**—A second system is under development to provide training in the 105 consonant-vowel syllables of Japanese. This system is based on a 68000 microprocessor and two Fujitsu MB8764 high-speed signal processors. The current development system performs all of the required signal analysis, but the color displays are generated using a host personal computer. The display includes voicing and formant information, other spectral parameters including the center of gravity and spectral maximum, as well as a number of time domain parameters such as the short time energy and zero crossing rate. These are used to convey voicing and manner distinctions among the various consonants. Target patterns are being defined which will be temporally expanded or compressed to match the timing of the training attempt and simplify comparison. A simple heuristic algorithm for estimating the closed glottis interval is under development to aid in the attempt to extract place information from the acoustic signal and improve reliability of the spectral analysis in cases of high-pitched speech.

## An Experienced User of Tactile Information as a Supplement to Lipreading: An Evaluative Study

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**Geoff Plant and Karl-Erik Spens**

Speech Transmission Laboratory, Royal Institute of Technology, 100 44 Stockholm, Sweden

*Sponsor: Royal Institute of Technology*

**Purpose**—A 48-year-old Swedish male deafened by meningitis at age 8 has developed a unique method whereby he can perceive a speaker's laryngeal vibrations and use this information as a supplement to lipreading. The method consists of placing his hand on the speaker's shoulder with his thumb pressed lightly against the side of the neck.

**Progress**—Testing of the subject using this method revealed improvements in lipreading ability with materials ranging in complexity from nonsense syllables to connected discourse.

Testing via tactile stimulation alone showed that the subject was able to perceive consonant voicing almost perfectly (99.3 percent correct), and consonant manner of articulation was identified at a high level of proficiency. Performance with materials assessing perception of syllables in words and sentences and emphatic stress in sentences was also relatively high. Testing was also conducted using two experimental vibrotactile aids. Performance with these was consistently lower than that using the subject's own method across almost all testing materials.

## The Effects of Cochlear Implantation on Speech Production

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**Geoff Plant and Anne-Marie Oster**

Speech Transmission Laboratory, Royal Institute of Technology, 100 44 Stockholm, Sweden

*Sponsor: Royal Institute of Technology*

**Purpose**—An investigation was undertaken to determine if any changes had occurred in the speech of a Swedish female speaker 2 years after implantation.

**Progress**—The subject had been profoundly deaf for 10 years when recordings of her speech were made just prior to implantation. The subject was rerecorded using the same materials 2 years after implantation. Analysis of the recordings pre- and postimplant revealed that a number of changes had occurred after implan-

tation. At the prosodic level, these include a more normal range of fundamental frequency (F), improved F control in signaling emphatic stress contrasts, and improvements in durational aspects. Changes also were noted at the segmental level. These involved a generalized backwards shift of the subject's vowel space. This may, however, be attributable to training effects rather than the information provided by the implant. Subjective evaluations of the subject's vowel quality and overall speech quality also were undertaken.

## A Single-Transducer Vibrotactile Aid to Lipreading

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**Geoff Plant**

Speech Transmission Laboratory, Royal Institute of Technology, 100 44 Stockholm, Sweden

*Sponsor: Royal Institute of Technology*

**Purpose**—Four deaf subjects were tested using a vibrotactile aid to lipreading presenting voic-

ing information and a cue to signal the presence of high-frequency consonants. Testing at

the level of consonant perception presented lipreading alone, and lipreading supplemented by the aid showed improvements in the perception of consonant voicing and manner of articulation in the aided condition. Testing at the word and sentence level showed differing results for the subjects completing the tasks.

**Progress**—A congenitally deaf subject with a history of non-hearing aid use showed no improvements in the aided conditions, whereas another subject with a history of very success-

ful hearing aid use evidenced improvements in the aided condition for both sets of materials. Testing at the level of connected discourse revealed improvements in the aided condition for two subjects but equivalent scores aided/unaided for the subject with limited hearing aid experience. Testing in the tactile-alone condition showed that the subjects were able to perceive the presence/absence of /s/ and word syllable number and type with a high degree of proficiency.

### Development of Materials for Computer-Assisted Instruction in Lipreading

Lennart L. Kopra, Ph.D.; Martha A. Kopra, M.Ed.; Judy E. Abrahamson, M.A.; Robert J. Dunlop, Ph.D.  
University of Texas at Austin, Department of Speech Communication, Austin, TX 78712 and Olin E. Teague Veterans Center, Temple, TX 76501

**Sponsor:** VA Rehabilitation Research and Development Service

**Purpose**—The goal of this program is to examine the effects of supplementary drill and practice with an auditory-visual laser videodisc interactive system (ALVIS) on the development of lipreading skill. A computer system has been designed, and software has been written for ALVIS and is being used for drill and practice in computer-assisted interactive video (CAIV) instruction in lipreading. The system includes: a laser videodisc player, microcomputer, keyboard, video monitor, two microfloppy disk drives, dot-matrix printer, external amplifier and attenuator, programmable attenuator with associated accessories, and earphones.

**Progress**—Twelve lists of 25 sentences each have been standardized and arranged in order of difficulty as lipreading stimuli. These five- to eight-word sentences were recorded on 1-inch videotape and then pressed on videodisc. Presentation of the 300 sentences is under software control by ALVIS in each of two conditions. In the first condition, no sound is given; word clues are presented on the video monitor for a

maximum of five trials. In the second condition, auditory clues accompany the visual stimulus (0 dB, 5 dB, 10 dB, and 15 dB, relative to the subject's binaural speech detection threshold) for a maximum of five trials. Student response data are recorded on microfloppy disk.

ALVIS is being used experimentally with postlingually hearing impaired adults in a program of aural rehabilitation which includes lipreading instruction. Six subjects received group lipreading lessons twice per week for 6 weeks. On days following group instruction, each of two subjects received lipreading drill and practice in one of three conditions: 1) with ALVIS clue words; 2) with ALVIS auditory clues; and 3) face-to-face with the lipreading instructor. Thirty-six subjects have participated in group listening instruction: 12 have received drill and practice with ALVIS word clues, 12 with auditory clues, and 12 face-to-face with the lipreading instructor. Data from this study are currently being analyzed to determine the effects of CAIV instruction on the development of lipreading performance.

## Robotic Finger-Spelling Hand

Arthur Jampolsky, M.D.; J.A. Brabyn, Ph.D.; Deborah Gilden, Ph.D.

Rehabilitation Engineering Center, The Smith-Kettlewell Eye Research Foundation, San Francisco, CA 94115

Sponsor: *National Institute of Handicapped Research; The Smith-Kettlewell Eye Research Foundation*

**Purpose**—Telecommunication for those without sight or hearing poses especially severe problems. Some of these individuals can utilize volatile braille displays for remote communication, but in practice the majority of the deaf-blind lose their sight only after being deaf for an extended period, and are therefore more familiar with methods of communication used by the deaf than those used by the blind. Many of these individuals communicate by a technique known as finger spelling—similar to the sign language used by the deaf but with the principal difference that the person receiving the information places his hand over that of the person who is doing the “signing.”

**Progress**—We have recently undertaken a research project to determine the potential applications of robotics in this field. In collaboration with Stanford University and the Veterans Administration RR&D Center in Palo Alto, Dr. Deborah Gilden of our staff has arranged for the construction of a prototype robotic hand capable of performing the functions necessary for finger spelling. An earlier project along these lines was undertaken by the Southwest Research Institute, whose kindness in lending us their prototype we gratefully acknowledge. A

new prototype has been specially designed for research into the possible reduction of the necessary number of degrees of freedom. Each joint within each finger can be locked up, effectively eliminating any movement by that joint, so that methods of sending the desired codes utilizing fewer fingers and joints can be explored. Our initial studies indicate that it may be possible to eliminate two fingers and some joints on the remaining fingers, from the robotic hand. Initial testing of the prototype by deaf-blind individuals has been successful, and Mr. David Jaffe of the VA Rehabilitation Research and Development Center is currently constructing an appropriate computer interface for the device to enable our staff to perform the necessary evaluation studies with the simplified codes.

Our initial prototype uses electropneumatic activation to move the fingers via wire cables, but future versions will use simplified and less expensive means of electromechanical motivation. Possible applications of this technology include computer access, telephone communication, reading (in conjunction with optical character recognition), and face-to-face communication by deaf-blind individuals with those who are not familiar with the finger-spelling code.

## C. Speech Impairment

### Prescription Guide for Nonvocal Communication Devices

Cheryl Goodenough-Trepagnier, Ph.D. and Michael J. Rosen, Ph.D.

New England Medical Center Hospital, Boston, MA 02111 and Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139

Sponsor: *National Institute of Neurological and Communicative Disorders and Stroke; National Institute of Handicapped Research; M.I.T. Undergraduate Research Opportunities Program*

**Purpose**—A system has been developed which includes a set of computer-guided evaluation procedures, testing hardware, and processing

programs to guide selection of a most suitable augmentative communication device for a motor-disabled, speech-impaired client. The

purpose of this system is to cast current knowledge about appropriate prescription in a form which makes it readily useable by the clinician who is not necessarily experienced with this low-incidence disability.

**Progress**—The Tufts-MIT Prescription Guide includes client evaluation protocols (need, cognitive, and motor), a device evaluation protocol, and software which processes client and device information in various ways to come up with scores reflecting the predicted suitability of each device for the client. It also has the capacity to display information representing how each device could be expected to meet or fail to meet the client's needs. In addition, the system contains software which guides the clinician through the client evaluation procedures, so that the clinician has no need to become familiar with the workings of the processing software. The current version of the Prescription Guide completed pilot testing by August 1986, and revisions, if indicated, and documentation were completed by October 15. The system was then operable for assessment of clients who are candidates for using devices which include the

alphabet. Device evaluation to date has included 27 electronic aids and numerous personal and standard inert language boards.

Pilot testing of motor and cognitive evaluations have been carried out with at least 20 nondisabled and 20 motor-disabled, communicatively impaired people. Cognitive assessment tools developed for this project evaluate spelling and learning of new verbal associative and spatial information, without requiring spoken or complex motor responses. Motor assessment protocols and hardware measure the dependence of movement time on the physical parameters which characterize planar keyboard devices, reaction time with preview for switch closure and closure-release-closure, and inter-switch closure time using pairs of body sites. Assessments for breath pressure and EMG as control modes are also included. These data are processed to predict user device communication rate ceiling.

The next stage of work will focus on finding a commercial distributor, and on further development of the system to make it applicable to children and people with more severe cognitive and perceptual impairment.

## **DEXTER: A Mechanical Finger-Spelling Hand for the Deaf-Blind**

Deborah Gilden, Ph.D., and David L. Jaffe, M.S.

Rehabilitation Research and Development Center, Veterans Administration Medical Center, Palo Alto, CA 94304

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The explosive growth of technology has provided new methods of electronic communication and has increased the amount of information to which people are exposed. Unfortunately, however, the new channels of information exchange are not always readily available to individuals with sensory disabilities, resulting in a widening gap between them and the able-bodied community. In particular, the needs of deaf-blind individuals have not been adequately addressed.

Communication with deaf-blind individuals is most often accomplished with the aid of a human interpreter. When using finger-spelling, each letter to be communicated is represented by a particular hand and finger position as de-

finied by the One-Hand Manual Alphabet. The words are spelled into the palm of the deaf-blind listener, one letter at a time.

While this tactile mode of communication allows for interactions with those familiar with the technique, it does require the presence of and direct contact with an interpreter. Without such human aid, the contents of books, magazines, and other printed documents are inaccessible to the deaf-blind individual. In addition, able-bodied persons who do not know finger-spelling are unable to engage them in effective communication.

Few aids have been developed for those with the double sensory impairments of blindness and deafness. Aids for people with im-

paired vision or hearing cannot alleviate the isolation, dependency, and restriction of activities experienced by those who are both deaf and blind, since those devices typically employ either a visual substitution system for the hearing impaired or a sound substitution system for the visually impaired. However, devices which harness the tactile channel would improve the quality of life for deaf-blind individuals.

**Progress**—In 1978, the Southwest Research Institute (SwRI) in San Antonio, Texas, developed a mechanical hand designed to form the symbols of the deaf-blind finger-spelling alphabet on command from a standard keyboard. It sought to mimic the finger positions produced by a human interpreter engaged in finger-spelling. During the testing phase, subjects were able to identify a majority of the letters reliably, but disagreed on the finger positions corresponding to others. They also experienced difficulty during the hand's flexion and rotation maneuvers and when the letters were presented too rapidly.

It was proposed that the initial SWRI concept could be improved upon by the power and flexibility provided by microcomputer technology to resolve the problems of their prototype unit. Smith-Kettlewell sponsored a Stanford student project in a graduate-level class in Mechanical Engineering: Dexter, an improved mechanical hand, is the result of that effort. The mechanical portion of the hand is similar to the SwRI device. Each finger operates independently of the others and has a range of motion comparable to that of human fingers. All finger and thumb motions are actuated through drive cables pulled by pneumatic cylinders; spring-driven return cables open the finger joints to the extended position.

A microcomputer and companion software control the opening and closing of valves which operate the pneumatic cylinders. Each letter is

formed by a timed sequence of these valve operations. Letters to be displayed are typed on the computer's keyboard. The inclusion of the microcomputer will allow the optimization of timing and finger motions during the design and evaluation phases.

**Preliminary Results**—On May 29, 1985, feasibility tests were conducted with two subjects at the Lions Center in Oakland, California. One consultant was blind and deaf; the other was blind but had partial hearing. Each test session began with a 30-minute period in which the subjects were allowed to become acquainted with Dexter. During that time, the hand's purpose and motions were related to the testers by a human interpreter. By the end of each session, both subjects could recognize most letters and could read complete sentences from the hand.

Current activity is concerned with the replacement of the Stanford-owned computer system with a Zilog-based microcomputer system donated by Prolog Corporation. The software has been rewritten to 1) to achieve software compatibility with the new hardware; 2) to accommodate changing of critical parameters such as timing variables; 3) to allow new characters to be accepted while previous ones are being displayed; 4) to permit easy modification of finger movements for any letter; and 5) to incorporate both modem and serial input of characters.

The current project has built upon the successes of the previous tactile aid and contains features which overcome the deficiencies noted by its users. In particular, timing factors and the adjustability of finger positions have been addressed. The resultant device has potential application in facilitating interpersonal interactions, in making computer-based information more accessible, and in promoting increased telephone communication.

## A Study of Speech Intelligibility Over a Public Address System

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Fred J. Lundin

Speech Transmission Laboratory, Royal Institute of Technology, 100 44 Stockholm, Sweden

Sponsor: *Royal Institute of Technology*

**Purpose**—Speech intelligibility over the public address system at Arlanda Airport, Stockholm, has been calculated by different methods. The articulation index method (AI) is based on frequency characteristics and provides merely a rough correction for room reverberation. On the other hand, a method suggested by Peutz (1971) and by Klein (1971) based on room acoustics, does not employ frequency characteristics. A compromise is the SRR-method presented in this paper, which utilizes the direct-to-reverberant sound intensity. It is based on the theory of Peutz and extended to handle the sound levels of the direct sound, of the reverberant sound, and of the noise. The analysis is performed in frequency bands and is applicable to rooms with multiple sources and ambient noise. Finally, the method of modulation transfer function (MTF) has been used. By this method the reduction in modulation depth of speech signals

within separate octave bands caused by reverberation is calculated. It is more complex than the other methods. The outcome from these four prediction methods has been compared to measured values recorded by use of a dummy head in two rooms and evaluated by a listening group of ten people. The intelligibility is tested at two background noise levels (with a signal-to-noise ratio of 10 and 20 dB, respectively).

**Results**—The results show a fairly good agreement between measured and predicted data of lower speech levels but when both noise and reverberation interfere, the methods will underestimate the articulation loss. Under these conditions the MTF-method will give the most appropriate result. Our study also indicates that the more complex methods are not much superior to the simpler ones.

## Measurement and Prediction of Benefit from Amplification

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Robyn M. Cox, Ph.D.; Kay M. Pusakulich, M.A.; Genevieve C. Alexander; Christine Gilmore, M.A.

Department of Audiology and Speech Pathology, Memphis State University, Memphis, TN 38152 and Memphis Veterans Administration Medical Center, Memphis, TN 38104

Sponsor: *VA Rehabilitation Research and Development Service*

**Purpose**—The objective of this project is to develop and validate a test of intelligibility of everyday speech—the Connected Speech Intelligibility (CSI) Test. The project plan calls for four major experimental phases. 1) Investigation of the intelligibility characteristics of a typical talker and selection of a typical talker to record the initial pool of test items will be made. 2) Generation of the initial pool of CSI test items. Seventy-two passages of connected speech will be audio-visually recorded. Forty key words per passage, having a range of identification probabilities, will be empirically determined. Twenty normally hearing subjects will participate in this phase; 3) Generation of final CSI test forms. Twenty to 30 hearing impaired sub-

jects will respond to test passages generated in phase two. Twelve equivalent test forms will be developed by combining passages into 12 groups having essentially equal means, variances, and correlations with true score; 4) Evaluation of final CSI test forms. Thirty different hearing impaired subjects will listen to the test forms generated in phase three. Scores will be analyzed to determine equivalence and reliability data for the final test forms. In addition, relationship between monosyllabic word recognition scores and CSI scores will be investigated.

**Progress**—Phase one has been completed. Three male and three female talkers participated in this study of the intelligibility of average

talkers producing conversational speech in four different everyday listening environments. The four environments were characterized by: low noise/low reverberation; low noise/high reverberation; high noise/low reverberation; and high noise/high reverberation.

**Preliminary Results**—Preliminary results indicate that the intelligibility of the six talkers

differed significantly but that the rank order of talkers' intelligibility tended to remain the same across environments. Intelligibility tended to remain the same across environments. Intelligibility of eight speech features was analyzed for each talker. These data were used as the basis for selection of an average talker. Investigations required for phase two have been initiated. No results are yet available.

## The Application of Microcomputers for the Treatment of Aphasic Adults

F.L. Loverso, Ph.D. and T.E. Prescott, Ph.D.

Harry S. Truman Veterans Administration Hospital, Columbia, MO 65201 and Veterans Administration Medical Center, Denver, CO 80220

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The use of microcomputers in rehabilitation of brain damaged patients continues to win popularity in some clinical settings. Cost effectiveness, operational efficiency, and increased treatment-time allocations without additional human resources are the high tech features which bolster their acceptance and application. Yet databased research in speech/language pathology concerning treatment efficacy remain sparse. In this age of high tech applications to almost every phase of our professional lives, there appears an urgent necessity to know the efficacy of treating patients with microcomputers. The field presently lacks convincing data as to the efficacy of using microcomputers for the rehabilitation of aphasic adults. It is unfortunate, however, that many clinicians are getting into the computer business without collecting this efficacy data first. The purpose, then, of the present study is designed to answer the following question: Are microcomputers more effective in teaching a criterion performance than the same procedure presented by a clinician?

**Progress**—The study population is being made up of 20 chronic aphasic patients who have sustained a single lesion to the left hemisphere. Each aphasic person within this study population will be in the mild to moderate range of aphasia severity. To study treatment effectiveness an alternating treatment design with mul-

iple problems (single case) is utilized. By using this type of design, baseline performance, the effects of treatment, maintenance of behavior, and generalization can easily be viewed. All patients receive two modes of treatment (clinician and microcomputer) daily in a rapid alternating fashion.

The microcomputer and clinician treatment packages are identical in terms of types of stimuli, modality and randomization of presentation, type of feedback, and scoring. The treatment itself is a well established protocol which has been demonstrated to be effective with this population of patients. In this treatment approach, verbs are presented as pivots and wh- questions provide strategic cues to elicit sentences in an actor-action-object framework. There are six hierarchical levels to this program ranging from copying a subject + verb combination to self-generation of subject + verb + object sequences. This treatment paradigm, in the traditional patient/clinician environment, is now being used nationally with adult brain injured patients as well as with children with specific language and learning disabilities.

**Preliminary Results**—As of June 1, 1986, 7 of the 20 patient/subjects have been entered into the study and have completed the treatment package. For all subjects studied, the clinician mode was more efficient in bringing the apha-

sic subjects to criteria than was the computer mode. On the average it took approximately twice as many sessions with the computer versus the clinician to complete this treatment protocol. Noteworthy is that although the clinician was far more efficient in terms of total visits, the microcomputer was shown to be an effective treatment tool for this particular protocol. Maintenance of behaviors were observed across all clinician treatment levels and four of the six treatment levels via computer presentation. Generalization to standardized language tests were also observed with statistically significant ( $p < .01$ ) improvement noted between standardized overall test scores for treatment levels compared to the stable baselines in the clinician mode of treatment. These gains have been maintained by the patient/subjects for 3 months following termination of the treatment.

In each case thus far, the computer mode has been far less flexible in terms of stimuli and wh- cue presentations than in the clinician

mode of treatment. It appeared that when the patient/subject interacted with the computer, the patient's ability to control stimuli presentation was much faster than for the clinician-controlled stimulus presentation. In addition to the comparative results of clinician versus microcomputer, the present study is a systematic replication of our previous work for the clinician mode of treatment, indicating that this treatment approach is a viable protocol in the rehabilitation of brain injured aphasic adults.

**Future Plans**—Research needs to continue on measuring the effects of this program with more subjects, more types of aphasia, and more severity levels of this disorder for both the clinician and computer modes of treatment. These future efforts should make available a reliable, effective treatment program for both the microcomputer and clinician modes of treatment in the rehabilitation of aphasic adults to other facilities with similar case loads.

## **Drawing: Its Use as a Communicative Aid with Aphasic and Normal Adults**

Jon G. Lyon, Ph.D.

Rehabilitative Medicine, Veterans Administration Medical Center, Reno, NV 89520

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—Aphasic adults who remain functionally nonverbal, despite an understanding of common spoken language, have been restricted to communiques where the normal participant searches for probable intents through 'yes-no' questions. Although some of these expressively restricted aphasic adults have successfully incorporated gestures, many still remain noncommunicative. Drawing represents an avenue that might enhance communicative skills with aphasic adults who appear to possess the internal concept they wish to express but lack adequate verbal or gestural abilities to express it. Earlier case studies of the use of drawing with such patients have been reported in the literature. These studies have pointed to either the spontaneous appearance of drawing in the aphasic adult's communicative attempts or the successful incorporation of it as a treatment aid. However, a systematic, detailed examination of the

worth of drawing as a communicative tool has yet to be explored with a larger subject sample.

The purpose of this investigation is to assess the value of drawing as a communicative aid with a sample of ten expressively restricted aphasic adults, before and after a 3-month treatment period. In addition, a comparison of the drawing skills of aphasic adults to those of normal adults, using dominant and nondominant hands, was obtained.

**Progress**—To date, five expressively restricted aphasic adults and five normal adults have completed the study protocol. Findings suggest that aphasic adults demonstrate marked improvement in communicative effectiveness simply through the exposure to drawing as a communicative aid (comparison of drawing versus nondrawing communication, pre-treatment). Further communicative gains were ob-

tained following the 3 month treatment period. Normal adults drew well enough to successfully communicate their intent (verbally they were restricted to the use of "yes" or "no") whether using dominant or nondominant hands. Should

these trends hold for the remaining half of the subject samples to be collected, we propose to study generalization of communicative gains to nonclinical, natural settings.

## Maxillofacial Prosthetic Management of Neurogenic Tongue Dysfunction

Michele J. Saunders, D.M.D., and Carol A. Venus, Ph.D.  
Veterans Administration Medical Center, San Antonio, TX  
Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The purpose of this project is to determine whether the mastication, swallowing, and speech of patients with neurogenic tongue dysfunction will be improved by maxillofacial prostheses designed to compensate for reduced tongue function.

**Future Plans**—From dysarthric and dysphagic patients referred to speech and hearing clinics at two VA medical centers, patients with speech articulation profiles consistent with tongue dysfunction and oral stasis of oral intake following swallow will be selected. During the preprosthetic phase of the study, complete or partial dentures will be modified or fabricated to assure adequacy of fit. Then, baseline tongue function will be assessed, with and without the prosthesis in place, through 1) examination of the oral peripheral mechanism; 2) palatography; 3) modified barium swallow; and

4) intelligibility and articulation tests. During the prosthetic phase, the contour of the palatal surfaces of the prostheses will be modified to facilitate lingua-palatal contact during mastication, swallow, and speech. Final extent of modification will be determined by results of 1) articulation tests; 2) palatography; 3) patient report; 4) clinical swallowing evaluation; and 5) modified barium swallow. Patients will be followed by a speech pathologist and dentist until they are stabilized in terms of acclimation to the prosthesis and refinement of speech and swallowing with prosthesis in place. During the postprosthetic phase, measures of tongue function taken during the preprosthetic phase will be repeated. Statistical comparisons will be made of measures of mastication, swallowing, and speech with and without the prosthesis, and before and after modification/fabrication of the prosthesis.

## Efficacy of Remote Treatment of Aphasia by TEL-Communicology

Gwenyth R. Vaughn, Ph.D.; Walter W. Amster, Ph.D.; John C. Bess, Ph.D.; Douglas J. Gilbert, Ph.D.; Kevin P. Kearns, Ph.D.; Amy Key Rudd, Sc.D.; Angela A. Tidwell, M.S.  
Veterans Administration Medical Center, Birmingham, AL 35233  
Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—Four Veterans Administration Medical Centers participated in an investigation designed to compare the efficacy of remote treatment of aphasia by TEL-Communicology (TEL-C) with traditional face-to-face treatment. Only patients who had suffered a left hemisphere cerebral vascular accident were admitted. Those who met selection criteria were assigned randomly to either the traditional face-to-face

treatment program or to the treatment program delivered by TEL-C. Any patient who rejected the group placement selected for him by the randomization process was given the option of entering a self-selected group that received treatment by the other delivery system. This option resulted in the formation of four groups—two randomized and two self-selected.

An evaluation battery of language meas-

ures was administered at entry, 8, 16, and 24 weeks. Neurological evaluations were administered upon entry and upon completion of the 24 weeks of treatment. Any time a change in the performance of a subject was detected, an interim neurological evaluation was undertaken. For those subjects who did not complete the entire treatment period, the information recorded at each 8-week evaluation was reported under 8- or 16-week cohort data. These data were analyzed separately for each group. As a result of having the four groups, it was possible to increase the number of subjects in the project, and to establish whether there were any differences between the randomized and self-selected groups. All subjects received 5 hours of treatment a week for 6 months, or for as long as they remained in the study. Two groups received treatment delivered face-to-face; two groups had treatment delivered by a combination of clinician-assisted and REMATE computer-assisted delivery (Remote Machine-Assisted Treatment and Evaluation).

**Progress**—The data showed no differences between the face-to-face and the TEL-C groups, nor between the randomized selection and self-selection groups in regard to age, education, or initial severity levels. All groups improved during the treatment period, and there were no significant differences in the amount of change from pre- to posttesting. It appeared that face-to-face and TEL-C treatments were equally effective. TEL-C groups also did slightly better in auditory functioning than the face-to-face

groups.

What strengthened the argument that TEL-C was as effective as face-to-face treatment was the fact that all the significant differences found were in favor of TEL-C. There were no significant differences in favor of the face-to-face groups. The use of restrictive criteria greatly reduced the number of subjects. If the number of subjects had been larger, the differences in favor of the TEL-C groups would probably have been more conclusive. In view of what evidence was available, it was apparent that TEL-C served as an effective delivery system for treatment, especially in the areas of verbal and auditory skills.

**Preliminary Results**—The RR&D study showed that on a national basis, the VA traditional face-to-face delivery was 17 percent more costly than TEL-C clinician-assisted delivery and 110 percent more costly than TEL-C REMATE-assisted delivery. A study of the annual cost savings per 1,000 patients for a national TEL-C program for the Veterans Administration showed that TEL-C clinician-assisted delivery saved \$3,626,393, and that TEL-C REMATE computer-assisted delivery saved \$5,091,316 for each hour of treatment delivered. Three hours of treatment a week are often recommended for patients with communicative disorders. The savings over face-to-face delivery for 3 hours of treatment a week for 1,000 veterans would be \$10,879,179 for TEL-C clinician-assisted delivery and \$15,273,948 for TEL-C REMATE computer-assisted delivery.

## Computer-Aided Visual Communication for Severely Impaired Aphasics

Richard D. Steele, Ph. D., and Michael Weinrich, M.D.

Rehabilitation Research and Development Center, Veterans Administration Medical Center, Palo Alto, CA 94304

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—Aphasia is the loss (partial or total) of ability to use one's natural language(s) for receptive or expressive communication. The loss arises from damage to the language processing faculties of the brain. There are approximately 84,000 new cases of aphasia each year, due primarily to cerebral vascular accidents

(strokes) and to traumatic head injury (as from motorcycle accidents). Because of improved treatment and better medication, individuals are surviving such occurrences in greater numbers, and subsequently are living longer. Despite current speech rehabilitation work, approximately half the new cases of aphasia each

year remain severely language impaired, and these individuals need some new form of communicative assistance.

This project aims at the ultimate development of an entirely new alternative communication device for severely impaired aphasics. This device would allow such persons to communicate thoughts which are currently beyond their communicative abilities, using pictographs and a language-like grammar. The work is also expected to help neuroscientists specify more precisely the nature and extent of preserved cognitive ability and communicative function which can coexist with global language impairment.

This work builds upon earlier studies using pictographs drawn on index cards. In the mid-70's, neurologists and aphasiologists in Boston and New York, inspired by special languages developed for chimpanzees, investigated two similar visually based communication systems. Both research groups found subjects who could learn to use the visual communication systems and employ them in selected communicative tasks. Subjects' performance using these systems far surpassed performance in English on equivalent tasks. Error rates among successful trainees were found to be low, and the patterns of error were similar across subjects, and stable. Despite positive clinical findings, the systems were almost never used by subjects outside training sessions, being judged cumbersome, demanding to use, and of limited practical utility.

Our three hypotheses are: 1) that by building on previous experience, we can develop a functionally useful Visual Communication (VIC) system, which will be operable by many severely impaired aphasic individuals; 2) that the use of contemporary computer technology will permit this computerized VIC (C-VIC) system to be implemented on a portable device;

and 3) that severely impaired aphasic persons using the C-VIC system will communicate more effectively than they will using any alternative means of communication.

A high-resolution screen allows the construction of easily recognizable pictographs, or icons. The sole use of the "mouse" pointing device, operable by one hand, makes operation of the interface accessible to subjects with the common right hemiparesis. Parsing and other language processing routines make the generation of natural-sounding English translations possible, and the eventual incorporation of Artificial Intelligence routines will make possible contextual cueing of the subject, appropriate new forms of feedback, and heuristic analyses of transactions.

**Preliminary Results**—A first version of the C-VIC system has been implemented on a Macintosh XL (LISA) computer, and we are currently training two severely aphasic subjects in its use. Our work to date has demonstrated that: 1) both subjects can perform, using C-VIC, at a level far exceeding their capabilities in equivalent tasks using English; 2) both subjects can discriminate between, and respond appropriately to, commands, statements, and questions; 3) both subjects have been able to master the principles of the computer interface operation quickly and accurately; and 4) the time required to access and correctly place an icon on the computer is acceptably short and consistent. An improved version of C-VIC is now being developed on the more portable Macintosh computer. It will allow greater resolution of icons, greater flexibility in the structure of the lexicon, a second tier of blank communication icons to allow more communication space for both investigator and subject, and more powerful language processing routines.

## Effects of Real-Time Biofeedback on Dysarthric Speech

James A. Till, Ph.D. and Richard W. Light

Veterans Administration Medical Center, Long Beach, CA 90822 and University of California College of Medicine, Irvine, CA 92716

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The goals of this research are: 1) to develop and test the effectiveness of computer controlled real-time high resolution color visual biofeedback in inducing mild to moderate changes in respiration and speech rate among dysarthric patients; and 2) to measure other speech parameters that may covary with changes in speech rate and respiration. Of particular interest are changes in speech intelligibility that may occur with changes in speech rate and respiration. Cerebellar ataxic and Parkinson subjects will be compared to normal control subjects during time-series experiments. Measures of vocal fold movement, fundamental frequency, speech intensity, and speech intelligibility will be made in addition to the measures of speech rate and respiration. Simultaneous real-time extraction of all parameters except intelligibility and rate will be made by dedicated analog instruments connected to a laboratory computer.

**Progress**—During the first year, project personnel, all analog instrumentation, and computer

hardware have been acquired. Software for calibration, data acquisition, data achieving, and data analyses has been written and validated for speech parameters and aerodynamic signals. We are currently working on derivation of valid weighting factors to allow accurate noninvasive measurement of speech respiration through monitoring of abdominal and chest-wall movement.

Concurrent speech respiration and speech rate data have been collected for a group of normal adults in order to investigate the effects of speaking task variables on the measures proposed in this research. The effects of reading versus monologue, linguistic structure, and phonetic composition have been studied in a group of normals and selected dysarthric subjects. The results suggest that extreme variations in phonetic and linguistic structure are necessary to induce unusual speech respiration. However, monologue talking and oral reading do result in different patterns of speech respiration and speech rate for many subjects.

## Experimental Analysis of Acquisition and Generalization of Syntax

Patrick J. Doyle, M.A.

Veterans Administration Medical Center, Pittsburgh, PA 15206

Sponsor: VA Rehabilitation Research and Development Service

**Purpose**—The purpose of this project was to evaluate the effects of a syntax training program on the speech production skills of four Broca's aphasia patients and to socially validate the treatment effects by having naive judges rate the "adequacy" of responses before and after treatment.

**Preliminary Results**—Subjects were trained to produce five exemplars of five sentence types from *Helm's Elicited Language Program for Syntax Stimulation* (Helm-Estabrooks, 1981).

Experimental control was demonstrated by employing a within-subject multiple baseline design across sentence types. A multiple probe technique was utilized to pinpoint the occurrence of generalization and maintenance of trained sentence types to novel exemplars and novel stimulus conditions. In addition, naive judges rated subjects' responses on wh- interrogative and declarative responses before and following treatment in terms of their communicative "adequacy."

Rapid acquisition, with generalization

within response classes, was replicated across three subjects for five sentence types; the remaining subject demonstrated generalization for three of the five sentence types trained. Maintenance and generalization to nontrained stimuli, to conversational speech, and to novel setting conditions was limited to all subjects. Under experimental conditions, adequacy judgments revealed improved communication skills for wh interrogatives but limited changes in the perceived adequacy of subjects' declarative responses. These findings indicate that the effects of syntax training procedures are limited to those grammatical constructions taught, that generalization of learned forms to novel stimulus conditions is not an automatic consequence of acquisition, and that the effect of such training on the adequacy of subjects' responses may be limited.

**Future Plans**—Funding has been obtained to continue to empirically evaluate treatments that promote functional language use in aphasic adults. The overall purpose of the research is to determine whether programming specifically designed to promote generalization will have an effect on the verbal behavior of adults with acquired aphasia under conditions of spontaneous language use across a variety of natural contexts. Three separate investigations employing single case methodology will address the programming techniques of loose training, incidental teaching, and programming common stimuli. The results from these studies will allow us to generate hypotheses concerning the relative strength of critical variables and to identify variables necessary for the generalization of language training to other situations to occur.