SENSORY AIDS

Edited by

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Clinical Application Study of Reading and Mobility Aids for the Blind

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Visual and Auditory Impairment Simulation Development

The purpose of this project is to develop devices which are capable of simulating various types of auditory and visual impairments, and to generate manuals providing instruction in the use and limitations of these devices. The simulators are to help professional and lay people acquire an understanding of functional impairment due to losses in the senses of vision and hearing. While most people grasp the basic idea of total blindness or total deafness with little difficulty, insights into the much more commonly encountered problems of partial vision or limited hearing are more difficult to gain. The simulators could be used to assist in explaining to family members the nature of the sensory loss specific to the veteran undergoing rehabilitation. In the course of training in rehabilitation, students would use such devices to understand more fully the different combinations of visual and auditory defects. In the most rigorous application, these devices would provide researchers with the means to design relevant evaluatory techniques and to develop and deploy more helpful sensory aids for this population.

Stages of Development

The project involves several stages. In the first, a group of consultants in the fields of vision and audition will be gathered to define the types of sensory defects appropriate for simulation. In the course

of this meeting, ways of implementing the simulations, within tight fiscal constraints, will be derived. (It is felt that if such simulators are to be used widely they should be priced within reach of educational institutions and rehabilitation centers.)

When, as a result of the first meeting, some simulators are built, several prototypes of the devices will be purchased by the VA and these will be evaluated for acceptability at a second meeting of the consultants. During this time, manuals will also be written and discussed. The prototypes will then be tested for validity of simulation using monocularly or monaurally impaired subjects whenever possible. Through the use of a standard interview, the subjective impressions of visually and auditorily impaired individuals about their sensory deficits will be compared to the impressions of unimpaired individuals using the appropriate simulators—a comparison of the performance of the same individuals in specific mobility, communicative, and avocational tasks will be made. Both the quantity and types of difficulties encountered will be examined. The effectiveness of the simulators as an educational tool will then be determined by distributing the devices to selected private agencies and universities for evaluation.

Many attempts at the fabrication of simulation systems have been made but not one is widely available or generally accepted. The "basement workshop" fabrication techniques, and the inability of the existing devices to simulate the many different losses, are believed to be the major reasons for this. It is hoped that the present attempt will avoid these problems through the use of a diverse group of expert consultants and sufficient engineering input at all stages of development.

Technology Transfer Activities

NUSC Meeting, State-of-the-Art of Devices for the Blind

In April 1978, a meeting was held at the Naval Underwater Systems Center (NUSC) in New London, Connecticut. Through the cooperation of Douglas Maure, Chief of Engineering of the American Foundation for the Blind (AFB), and General Wesley Franklin, Consultant to AFB, initial contact with the naval group had been made and the meeting arranged. The Veterans Administration was represented by William De l'Aune, Research Director of the EBRC, and Mary T. Dolan, Supervisor of the Orientation and Mobility Department of the EBRC. AFB was represented by Mr. Maure, General Franklin, and Mr. Leslie L. Clark, Research Editor of the Journal of Blindness and Visual Impairment.

The preliminary meeting was concerned with communicating to the NUSC scientists the state of the art of devices for the blind. Emphasis was placed on the lack of a broad base of acceptance of current devices. Problems such as high cost, poor reliability, and uncertainty of the relevance of the environmental information provide to the blind traveler were discussed.

Specifications for a proximity-detecting head-protection device were provided to the NUSC group. These were drawn up by Mr. Maure after considerable consultation with researchers, practitioners, and consumers. The device would have a very simple output, a very high level of reliability, a very low cost (under $50) and would be very small and cosmetically acceptable. Mr. Maure made specific mention of a new sonar transceiver integrated circuit which costs approximately $4.50, and which might become the basis of such an aid.

Another concept discussed was the possibility of using an inaudible output of a device as a source for an audible echo. In this system, reflecting objects in the sound field would appear to be the sources of sound. Mr. Timothy Cranmer, of Kentucky Services for the Blind, had suggested this idea to Mr. Maure. (A brief description of the principle and benefits of such a device is given later in this report.)

Interactions Between Rehabilitation Specialists and Engineers

In June 1978, a second meeting was held at the Eastern Blind Rehabilitation Center in West Haven, Ct., to provide feedback on the progress of the projects and to facilitate interaction between the rehabilitation specialists and the engineers. Attending this meeting were: James Atkinson, Technology Transfer Coordinator for NUSC; William Konrad, a specialist in non-linear acoustics (parametric sonar); and Henry Rappaport, a summer engineering intern from MIT who was assigned to the proximity device project. Attending the meeting from the VA Prosthetics Center in New York were Howard Freiberger and Ronald Arroyo. The majority of the staff of the EBRC were also present.

The proximity device was reported to be at the initial breadboard stage, with five of the sonar transceiver chips having been purchased. Much discussion took place about the most desirable beam characteristics in such a device. It was decided that the prototype should be equipped with several transducers, having different characteristics, which could be evaluated separately. The desirability of a single-unit head-mounted device was again stressed to the engineers.

When the projected price of $50 to $75 was mentioned, Mr. Freiberger reminded the group of similar predictions of low cost for other devices, and advised against unbounded optimism. It was thought

that the utilization of the sonar technology of Polaroid Corp. might prove helpful in keeping the cost of the devices down and their reliability up. Mr. Maure had made contact with Polaroid and indicated that they produced 7,000 of the sonar camera-focusing units a day at a unit cost of $20 including the drive motors.

Mr. Konrad then gave a demonstration of a parametric sonar system he had developed for demonstration purposes. Two aspects of this device were of interest to the group. Because it emitted two ultrasonic frequencies which were inaudible but created an audible difference-tone in the air, a very narrow beam width was obtainable with a fairly small transducer. The second interesting aspect of the system was the inaudibility of the signal contrasted to the audibility of the reflected difference-tone. Contact with Mr. Cranmer was recommended for exploring possible application of this technique.

ERADCOM/HDL Meeting

Also in June, Dr. De l'Aune and Ms. Dolan visited the Electronics Research and Development Command/Harry Diamond Laboratories (ERADCOM/HDL) in Adelphi, Maryland. The purpose of this meeting with scientists from the Federal Laboratory Consortium for Technology Transfer was to explore the possibility of interaction similar to that with NUSC.

General Franklin provided the assembly with brief introductory remarks as did Mr. Maure. Ms. Dolan demonstrated the standard long cane as well as the electronic travel aids used in the VA system. The lack of acceptance of the devices by the blind was a subject of considerable discussion during her presentation. Dr. De l'Aune provided the group with population characteristics of the users and potential users, and underscored the basic problem of the development of aids without a comprehensive theory of mobility. Mr. Maure forwarded the concept of a mobile microprocessor laboratory which could be used to evaluate various device designs in a real-world setting. Such a laboratory was felt to be a powerful tool, not only in device evaluation but also in the task of acquiring knowledge about the relevance of environmental features to successful mobility.

Dr. Weisman of ERADCOM/HDL summarized some of the research being conducted by various groups in the Federal Laboratory Consortium for Technology Transfer. He also made a very convincing case for the use of computer simulation of a device's input/processing/output characteristics before the device was actually constructed. The primary arguments for such an analysis concerned the flexibility of the computer simulation as opposed to the limits imposed by an actual prototype device.

The research being done on extraction of relevant features from two-dimensional displays was described. This has obvious implications in the design of sophisticated environmental sensors for the blind and in training work with partially sighted clients. Because there are several university grants in this area, it was thought that some of our interests could be economically combined.

Dr. Sheehan, the director of the Night Vision Laboratory at Fort Belvoir, Va., indicated that much of their work was concerned with the understanding of human mobility under limited illumination. Of special interest were their simulation techniques, light amplification systems, and research facilities.

All of the scientists stressed the importance of utilizing extant industrial technology whenever possible. It was thought that a number of corporations under contract to the military might be interested in cooperating with some of our projects. Letters of introduction to appropriate individuals were to be written when specific projects were developed.

New Devices Being Evaluated at the EBRC

The Kurzweil Reading Machine

The Kurzweil Reading Machine (KRM) arrived at the EBRC in May, 2 weeks after Dr. De l'Aune attended a 2-day seminar on its use in Boston. Considerable interest by the staff, patients, and visitors has necessitated a number of presentations and demonstrations of the device. Interested EBRC staff have been trained and given opportunities for utilizing the KRM in their work.

The ELINFA Digicassette

The ELINFA Digicassette also arrived during this reporting period. (ELINFA is an acronym for Electronique Linguistique Informatique Appliquees, of France, the manufacturer.) This small and lightweight (4-pound) device provides a braille keyboard and 12-character braille reading display. It accepts a cassette which allows either braille or sound to be recorded or played back, alternately, on the same tape if desired. The portable braille recorder may also be connected to various electronic or desk calculators, or other devices which receive or send digital information.

Although the instructions provided with the device were thought to be inadequate, consultation with Harvey Lauer of the Central Rehabilitation Section for Visually Impaired and Blinded Veterans, Hines, Illinois, allowed Caroline McNair, an EBRC braille specialist, to acquire a rudimentary level of skill in its use.

As with the KRM, this device will undergo an extended evaluation.

The Sensory Quill

An institutional model of the Sensory Quill (Mechstat, Inc.) was received by the Center in poor working condition. After reassembling the device and making repeated attempts to align the writing head, a modicum of success was obtained in generating raised line drawings. The device has been used by the mobility department in producing tactile maps, but its performance will have to be improved before a valid evaluation can take place.

The Mowat Sonar Sensor

The Mowat Sonar Sensor is being studied by two EBRC mobility specialists, Donald Milbier and Greg Kevorkian. Working under occlusion in typical travel situations and utilizing lesson plans supplied by TSI, Inc., they hope to gain a better appreciation of the potential of the device and determine if it is a viable sensory aid.

Audible Compass (Vibratonics)

An audible compass produced by Vibratonics (11,310 Ventura Avenue, P.O. 997, Oak View, California 93022; $34.95) is undergoing evaluation. It cannot be used to maintain fine directional control in our hospital setting because of inaccuracy believed to be caused by the large amounts of metal in the hospital structure. In outdoor settings, the directional sensitivity is much better but the blind user is still vulnerable to lateral drifting. It is thought that it may have some applications when blind travelers cross large open fields.

Sonic Dog Repellent

A sonic dog repellent (U.E. Systems, Inc., 1995 Broadway, New York, N.Y. 10023; $42.95) proved difficult to evaluate because of the need for aggressive dogs. Previously published evaluations by the post office were positive and indicated that the device was successful in repelling most dogs at a distance of 5 ft or more. The device does not have to be aimed directly at the dog and causes no damage when used properly.

Wide-Angle Door Viewers

Several one-way, wide-angle door viewers (Sears model 95746: $5.49) were purchased for evaluation as a field expander for patients with restricted visual fields. The possibility of successfully using such a device for this purpose was raised in "A Field Expander for Patients with Retinitis Pigmentosa: A Clinical Study," (Warren L. Kennedy et al, American Journal of Optometry and Physiological

Optics, 54(11), 1977, pp 744-755.) Ms. Gadbaw and Ms. Dolan are directly involved with this evaluation.

Other Activities

A master's thesis concerning hearing aids and their effects on localization of noise bursts was completed by Bruce Bergin of Southern Connecticut State College under the supervision of Dr. De l'Aune. The experiment indicated that the aids were associated with severe problems in localization when performance was compared to the performance of the same visually impaired subjects with unoccluded or partially occluded hearing.

Dianne Duncan, a Western Michigan University intern, is examining the efficacy of the EBRC's family program by means of questionnaires sent to recent participants. This study is to be used as part of a program evaluation system. A survey of Orientation and Mobility instructors in the VA using the COPES environmental assessment questionnaire proved very successful in assessing the instructors' feelings about the adequacy of their work environments as related to service delivery. These data were presented to the VA Orientation and Mobility Conference held at the Hines, Ill., CBRC by Dr. De l'Aune and Ms. Dolan. Similar testing of other departments and of patients in the EBRC will be undertaken in the near future for the purpose of program evaluation.

A visit in March by the Yale University Department of Bioengineering to the EBRC was hosted by Dr. De l'Aune. Demonstrations of various applications of technology to the needs of the blind were conducted and discussed.

Ms. Gadbaw chaired a one-week seminar on low vision in April. During the course of this seminar, Dr. De l'Aune gave a lecture on the auditory needs of the visually impaired.

Ms. Gadbaw was appointed an Adjunct Faculty Member and Clinical Instructor at the New England College of Optometry in Boston, Mass. In this capacity she presented a lecture concerning the Blind Center program and its relevance to optometry.

Dr. De l'Aune was appointed to the Editorial Advisory Board of the Journal of Blindness and Visual Impairment. In this capacity he attended a board meeting in Dallas, Tex., this June.

Ms. Gadbaw gave a lecture, concerning techniques for working with restricted fields, to the New England Orientation and Mobility Instructors' Association (NOMA) at their meeting in West Haven in April. She also spoke about the results of the EBRC's low vision followup project at the NOMA meeting in Montreal, Canada, held in May.

Dr. De l'Aune participated in an AFB sponsored workshop on Sensory Awareness training held in Pittsburgh, Pa., in March.

Much energy was expended in the design of a pilot computer program for a nationwide data base in VA Blind Rehabilitation.

Clinical Application Study of Mobility Aids for the Blind

Central Rehabilitation Section for Visually Impaired and Blinded Veterans
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During this reporting period, four veterans were admitted to Electronic Travel Aids Program for Blinded Veterans at the Blind Rehabilitation Center at Hines. One veteran completed training with the Lindsay Russell Pathsounder, one veteran began training with the Sonicguide but withdrew from the program after two weeks of participation, one veteran completed training with the Sonicguide, and the fourth veteran is currently undergoing training with the Sonicguide. (Laser Cane production still has not resumed after the devastating fire of May 1977 at Bionic Instruments, Inc., Bala Cynwyd, Pa.; no training will be offered for the Laser Cane at Hines until production has resumed.)

Dr. Russell Smith, manager of Wormald International Sensory Aids, Ltd, visited Hines to demonstrate and discuss some changes that have recently been made in the battery and battery charger used with the Sonicguide. Dr. Smith showed the Hines research staff a new earpiece which will be evaluated for use with the Sonicguide. He also demonstrated a monitor system which can be used with the Mowat Sensor (a hand-held ultrasonic electronic travel aid which can be carried in a pocket or purse and may be used situationally in certain travel settings).

Messrs. Harvey Lauer and Leicester Farmer appeared on the Lee Phillip WBBM TV "Noonbreak" program in Chicago, April 14, to demonstrate and discuss electronic reading and travel aids. Their participation in the program was part of a three-part series on "Bionic Medicine."

Binaural Two-Way Communication Telemetry System

The development of the prototype of a binaural two-way communication telemetry system, to be used with the Sonicguide, is in the final stage. Dr. Kenneth W. Haag, assistant chairman of the Electrical Engineering Department, Illinois Institute of Technology,

Chicago, is designing the system. This telemetry system, which will be used in training programs utilizing the Sonicguide, has been designed to perform the following functions: (i) transmit the binaural output of the Sonicguide from the student to the instructor a distance of up to one block, (ii) provide voice communication from student to instructor and from instructor to student, and (iii) operate at a low power level to increase battery life.

Three channels are needed to satisfy the communication requirements; one channel for right-ear Sonicguide output, one channel for left-ear Sonicguide output and student voice, and one channel for instructor voice. To save time and parts cost, commercially available transceivers were obtained and modified to provide the required channels.

The modifications included:

1. Replacement of crystals and retuning of circuitry to alter the transmit and receive frequencies. The specific channel frequencies were chosen with consideration of present use by the general public, avoidance of inter-modulation effects, and availability of crystals. The frequencies are 27.325 MHz for right ear information, 27.355 MHz for left ear information and student voice, and 27.375 MHz for the instructor voice.

2. Development of interface circuits to accommodate the impedance-level and signal-level match between the Sonicguide output and the transmitters, between the microphones and the transmitters, and between the earphones and the receivers.

The variable power-level operation of the Sonicguide transmitter channels was accomplished by controlling the applied d.c. voltage. To obtain the same percent modulation at different power levels, special circuits (Fig. 25) were incorporated which vary the signal gain and the d.c. level simultaneously and equally in both channels. The battery drain for the transmitters is variable from 10 mA to 60 mA, with approximately the same percent modulation over the major portion of the range.

In the design stage of the project, it was impossible to predict whether the transmitted voice signal of the instructor could be received by the student when the Sonicguide transmitter channels were operating. The large Sonicguide transmitter signal could conceivably overdrive the receiver input circuit, due to the proximity of the antennas, and make it impossible to receive any signals. This possibility could not be tested until the system was constructed in its final form. (Unfortunately, the overdrive of the receiver circuit has occurred in the field tests and the instructor voice channel is effectively inoperative.)

A possible solution to this problem is to change channel frequencies so that the instructor voice channel is far enough away from the Sonicguide channels to allow selectivity by filtering; i.e., to allow rejection of the Sonicguide channel frequencies so that overloading does not occur. Appropriate crystals have been obtained for use with these frequency changes.

A second problem which has appeared in the field tests is that the Sonicguide transmitter signal interacts with the Sonicguide circuitry to produce an extraneous signal in the student's earphones. This seems to be due to harmonics of the difference frequency (30 MHz) between right ear and left ear transmitter channels interacting with the 80 KHz to 40 KHz sweep frequency of the Sonicguide (in the nonlinear field-effect transistors contained in the eyeglass frames). This problem will be solved by changing the right channel transmitter frequency, so that the difference frequency between right channel and left channel is above the range of the Sonicguide processing frequencies.

The final problem with the unit is its relative bulkiness in the present form. After field tests at the Blind Center at VA Hospital, Hines, have been conducted and modifications have been incorporated to correct defects which may appear, the system will be repackaged to minimize the bulkiness and the external connections and controls of the present prototype unit.

Clinical Trials of Reading Machines for the Blind

Central Rehabilitation Section for Visually Impaired and Blinded Veterans
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The main work of this project is to evaluate reading aids and accessories for totally blind people. There are two staff members, Messrs. Harvey Lauer and Leonard Mowinski.

Evaluation of Reading Aids and Accessories for the Totally Blind

Kurzweil Reading Machine

Evaluation of the Kurzweil Reading Machine (KRM) continues. Using newly-developed instructional tapes by Mr. Lauer, subjects learned more quickly to operate the machine. (The use of tapes preceded personal instructions.) On high-quality print, the optical character recognition accuracy was above 99 percent and reading

speeds averaged about 90 wpm.

Mr. Lauer and Mr. Mowinski participated in a Kurzweil Reading Machine evaluators' conference, sponsored by the Department of HEW, February 1978, in Chicago, Ill. A conference report was made by Dr. Lawrence Scadden, and Mr. Lauer wrote a second interim report on this work.

Varispeech II

A much-needed recorded version of the owner's manual for the Varispeech II was written and produced under Mr. Lauer's supervision. It was done, with the cooperation of the manufacturer of the speech-compressing tape recorder, by Mr. B. T. Kimbrough who is a former managing editor of the publication, Dialogue. This manual is a model for other manuals for items modified for use by blind people.

Research Projects

Several research projects have been initiated with the help of students at Illinois Institute of Technology. They are:

1. Interface the ELINFA Digicassette recorder with a typewriter for a braille monitor;
2. Interface the Votrax speech generator with a typewriter through a microcomputer, for a talking typewriter;
3. Interface the Kurzweil machine with the ELINFA to provide a braille output for the KRM;
4. Produce a tonal output for the Optacon, as a test of a bi-modal display for touch and hearing (preliminary breadboard models have proven most promising); and
5. Determine the optimum number of tones for the Stereotoner code.

The greatest need at present is to develop capability to test braille and talking terminals, much-needed by blind employees in offices converting to visually read cathode-ray-tube terminals.

Evaluation of the ELINFA Digicassette Braille Recorder was begun. The 12-cell braille display is proving very functional for all regular braille users. The machine is an excellent note-taking device and has many other uses, including use as the display giving a blind person access to a computer terminal.

A liaison with the Data Processing Center is being developed. The center has a braille page printer/terminal for its blind programmer. This will expand our capability to interface with and evaluate various system components.

Mr. Mowinski wrote a note about speech compressors for consumers and shared it with VA personnel in the blind centers.

Clinical Application Study of Reading and Mobility Aids for the Blind

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During the current reporting period, three centrally purchased sensory aids were delivered to the WBRC: The Mechstat Sensory Quill, the ELINFA Digicassette, and the Kurzweil Reading Machine (KRM).

Reading Aids and Training

The Mechstat Sensory Quill has been shown to both orientation and mobility staff and written communication staff, and has been made available for their use as part of the evaluation program.

The KRM was delivered and installed on May 16, 1978. Prior to delivery, Mr. Bennett attended a 2-day seminar at Kurzweil Computer Products, Inc. (Cambridge, Mass.), to gain hands-on experience with the KRM. Other VA participants at the seminar were Mr. Howard Freiberger (VA Prosthetics Center, New York) and Dr. William De l'Aune (EBRC, West Haven, Conn.).

Since delivery of the KRM, Mr. Bennett and Dr. Goodrich have used the machine extensively to gain personal competency in its use and to define any abnormalities in its operation. This initial experience has found few problems, and those that have occurred have been promptly corrected by KRM field engineers. Current plans for further evaluation of the KRM are to indoctrinate staff in its use and make the device available for their use beginning in July 1978. Detailed records of staff use of the KRM will be maintained, so that patterns of use can be defined. Volunteer patients at the WBRC will also be utilized for extensive testing of the KRM's intelligibility, ease of use, and patterns of use.

The arrival of the KRM has resulted in widespread interest among patients and WBRC staff, and research and administrative personnel, at Palo Alto. Consequently, a number of demonstrations have been planned to acquaint these individuals with the device.

In March and April of this year three additional members of the written-communications staff received Optacon Instructor training at Telesensory Systems, Inc., (Palo Alto, Calif.).

During this reporting period no new Optacon or Stereotoner students were trained.

Orientation and Mobility Evaluation

The orientation and mobility evaluation of the electronic travel-aid program was continued during the past 6 months. As of this date, approximately 75 percent of the target population has been visited in the home communities. The completion date for the study will probably be the end of the current fiscal year.

Research Projects

Two new research projects have been proposed for the coming fiscal year. One project is an evaluation of the ITT image-intensifier (Clinical Pocketscope) designed for use by "night blind" travelers. The evaluation sequence has been designed, and will be submitted locally for approval by the Research and Development Committee, Palo Alto. The second project is a joint venture between the WBRC and Dr. John Linvill, School of Electrical Engineering, Stanford University. The project involves the development of a portable "personal information system" which would allow blind individuals to record, retrieve, and edit information in any one of a number of forms including typewritten, braille, and voice.

Students trained with electronic travel aids included one Laser Cane user, two Sonicguide users, and five Mowat Sensor users. While eight devices were issued, only seven students received training; one individual received both Sonicguide and Mowat Sensor Training, and he was issued both devices. All students receiving ETA training were issued the device on which they were trained.

Research on Audible Outputs of Reading Machines for the Blind

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The objective of the research reported below is the improvement of the intelligibility and naturalness of speech produced by an automatic synthesis-by-rule system. Such a system would be a major component of a reading machine for the blind. Work is reported below on the development and testing of a synthesis program and of rules of synthesis, and on phonetic investigations in support of rule development.

Software Synthesizer

The software synthesizer has been reconfigured. In its earlier form, the synthesizer computed the filter coefficients for the five poles of the vowel branch, the pole and zero of the nasal branch, and the pole and zero of the consonant branch. Within each branch, the poles and zeros were in series, and the output of each was computed separately and served as the input to the next.

However, it is computationally far more efficient to combine the coefficients for all poles with the same source into a higher-order polynomial that is the denominator of the transfer function for a single filter system; similarly, all zero coefficients for this source may be combined to form the numerator of the transfer function. This is the approach adopted in the new version of the synthesizer: the nasal branch, the vowel branch, the radiation filter, and the pre-emphasis filter are regarded as a single system, the output for which is computed in one step. The consonant branch, having a different source of excitation, must be treated as a separate higher-order system. This approach makes much more rapid computation possible, and makes it more feasible to produce nasalized vowels.

Direct Synthesis

SYA, the program for synthesis from arrays of parameter values, is now sufficiently free of bugs to be a useful research tool, although further minor repairs remain to be carried out and the command mnemonics have to be reorganized.

Recently, the program has been used to explore the phonetic possibilities of the synthesizer and to develop a synthesis strategy. In the case of the vowels, it was found that the rather low value, 55 Hz, used for B1 and B2, the first- and second-formant bandwidths, resulted in clipping for vowels where two formants are relatively close in frequency; e.g., [u]. Increasing B1 and B2 to 80 Hz mitigated this difficulty. The alternative solution of reducing Ao, the excitation amplitude, complicates the problem of equating the force with which the different vowels appear to be articulated.

Clipping may also result when formants are moving rapidly, as in consonantal transitions. Here again, the appropriate solution, and the theoretically correct one, is to increase the bandwidths of the moving formants.

The fricatives [s̀] and [ś] and stop bursts for [p], [t], [k] were synthesized acceptably even though the fricative branch of the synthesizer has only one pole and one zero. The zero is used to achieve a fairly sharp cut-off for the spectral region below the frequency of the pole.

Research Synthesis by Rule

SYLSYN, the program which calculates parameter values from a phonetic input, has been renamed SYR and made a subprogram called by a command in SYA; functions in SYR duplicating those of SYA have been eliminated. The output of SYR is a file containing a parameter-value array, and further steps in synthesis are the same as for directly-created arrays.

A computer routine is being programed that will convert a statement, in user's language, of rules for synthesis into an object that can be rapidly processed by the RULRUN subroutine called by SYR. Previously the rules had been statements in a Fortran subroutine; changing a rule required building a new task. Once the new compiler becomes available, this step will not be necessary.

Development of a Hearing Aid System with Independently Adjustable Subranges of its Spectrum Using Microprocessor Hardware

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The work during the six-month period of this report, from January 1, 1978, to June 30, 1978, was concerned with the construction and design of test devices for audiology laboratories, based on utilizing systems theory and digital technology, and with the testing and implementing of devices previously designed and constructed under the same project.

The overshoot-distortion generator, designed and constructed previously under the present project, has been tested and put into use at the Biocommunications Laboratory of the University of Maryland to generate overshoot distortion in speech at selected frequencies, with independently adjustable gains and overshoot rates. A harmonics-distortion generator, as designed under this contract,

[a]As of June 1, 1978, Dr. Graupe has transferred to Department of Electrical Engineering, Illinois Institute of Technology, Chicago, Illinois, 60616.

has also been constructed during the period covered by this report. This distortion generator has further been extended to generate subharmonic distortions of speech (in addition to higher harmonic distortions), at selectable frequencies and with adjustable amplitude. A microcomputer programer for controlling the system is now in its final stages of construction.

Work on utilizing an earlier design to construct a laboratory staircase spectrum-shaper (to test and print-out the spectrum of a patient's hearing with and/or without a hearing aid, and to adjust the spectrum of any given hearing aid to the spectrum of the user's ear) has progressed, and a real-time on-line design is virtually complete. Work on this aspect is expected to require a 16-bit microcomputer, which we hope to obtain during the next fiscal year.

The Development of Improved Techniques for the Analysis of Hearing-Aid Performance

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Four objectives were outlined in this research project on the clinical and acoustic parameters of hearing-aid effectiveness. These were: (i) the refinement of speech intelligibility test materials; (ii) the development of a hearing-aid system with adjustable subranges of its spectrums; (iii) the evaluation of intermodulation distortion and transient distortion in hearing aids; and (iv) the assessment of objective and subjective methods of hearing-aid selection.

The work on CNC (consonant-nucleus-consonant) speech intelligibility materials has gone well. Performance-intensity functions have been obtained on 60 young normal-hearing adults. The relationship between scores obtained on the W-22 word lists and the new CNC lists has been described. Also performance-intensity functions and equivalency studies have been conducted on groups of hearing-impaired listeners.

Furthermore, the CNC lists performed very well, in describing performance differences between monaural and binaural hearing aids, in studies conducted at Walter Reed Army Medical Center and at VAH Washington, D.C.

Cassette copies of the CNC tapes will be available for distribution to VA Audiology Clinics by the end of summer, 1978.

A concentrated examination of the intermodulation form of nonlinear distortion in hearing aids resulted in four papers and two publications. A variety of test techniques, many entirely innovative, were incorporated, as were several methods for expressing and/or specifying the amount of intermodulation distortion. The interactions of measurement approach and hearing aid irregularities made it extremely difficult to formulate a single best technique. As summarized in our 1977 article in the Journal of the American Audiology Society: "Although we cannot at this time recommend a single 'preferred' test . . . , we contend that a test which measures both harmonic and intermodulation products will be more valuable than conventional . . . techniques." We feel this is a conceptual departure from traditional approaches which is significant in and of itself. While we were somewhat frustrated in not finding hearing aids to be easily incorporated into an intermodulation test protocol, our suggestion to integrate all forms of nonlinear distortion measures seems supported by recent work conducted in Sweden (Gabrielson et al., 1977).

While efforts during the contract period did accomplish the securing (on indefinite loan) of a formant synthesizer and ramp generator, the work with hearing-aid characteristics and second-forman transitions was stalled due to technical difficulties. Several months of set-up and preliminary data collection, using an on-line adaptive technique, were obfuscated by the discovery of periodic irregularities in the borrowed equipment.

One positive development, which occurred as an indirect result of the difficulties with the formant synthesizer, was the setting-up of an evaluative scheme to examine the signal-in-noise operations of hearing aids. Two papers have already been presented on this spin-off subject and one comprehensive article has been submitted to the Journal of Speech and Hearing Research. The Central Institute for the Deaf in St. Louis has begun using a version of this test technique, which offers considerable promise for improving the "sufficiency" of hearing aid electroacoustic measures.

The work on transient distortion continues with the help of a transient generator developed for the study. It is expected that this work will be finished within 1 year.

The work on quality judgments has come to a conclusion with the publication of results employing 90 listeners.

Thus far, the work on intermodulation distortion, transient distortion, and quality judgments has led us to the conclusion that the clinical evaluation of hearing aids will have to become more specific and more objective in technique. Work on the hearing aid evaluation

procedure will continue.

Papers and Publications

Schweitzer, H. C. and G. D. Causey: Intermodulation Distortion in Hearing Aids: The Need for Measurement Standards and Inherent Complications. Conference Record, IEEE International Conference on Acoustics, Speech and Signal Processing, 579-582, 1976.

Schweitzer, H. C., G. D. Causey, and M. C. Tolton: Nonlinear Distortion in Hearing Aids: The Need for Re-evaluation of Measurement Philosophy and Technique. J. Am. Audiol. Soc. 2:(4), 132-141, 1977.

Gabrielsson, A., P. Nyberg, H. Sjogren, and L. Svensson: Detection of Amplitude Distortion by Normal Hearing and Hearing Impaired Subjects. Karolinska Institutet Report TA No. 83, 1976.

Schweitzer, H. C.: Dynamic Signal in Noise Processing of AGC Hearing Aids. Paper presented at Am. Speech & Hearing Assoc. Convention, Chicago, 1977.

Schweitzer, H. C.: Evaluation of Hearing Aid Signal in Noise Measures. Paper presented at Spring meeting of the Acoustical Society of America, Providence, R. I., 1978.

Punch, J. L. and M. T. Howard: Listener-Assessed Intelligibility of Hearing Aid-Processed Speech. In press, J. Am. Audiol. Soc., 1978.

Development and Evaluation of a New Artificial Larynx

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The first year of effort, now half completed, involves four phases of work. Each phase was estimated to require, on a time basis, one quarter. This report will summarize the first two phases.

Phase I—Design

Phase I involved design, assembly, and preliminary testing of instrumentaiton and data-acquisition systems. The measurement systems were designed to acquire experimental data on (i) performance characteristics of electronic components of artificial larynx devices; (ii) amplitude and frequency of electro-mechanical vibrations, (iii) the mechanical impedance of human neck tissue and (iv) amplitude and frequency of acoustic signals.

Phase II—Measurement and Analysis

Phase II of the project was the measurement and analysis of human neck tissue. A small vibrator (mini-shaker) is driven by the output of a beat frequency oscillator (BFO). Mounted on the vibrator table is a small impedance head comprising an accelerometer and force transducer. The acceleration signal is preamplified and integrated, then amplified to become the input to the compressor circuit of the BFO. In this way the velocity at the impedance head is held constant. The force transducer output is therefore a direct measure of the mechanical impedance (force divided by velocity) of the vibrating system.

The force signal is preamplified by a charge amplifier and the output is then read from a measuring amplifier. The frequency response of the system falls off below 30 Hz and above 500 Hz. However, this range brackets the frequency range of interest, from around 40 Hz up to 400 Hz.

To obtain a hard copy of the data, the BFO is swept through the frequency range. A signal from the BFO, and the force signal from the measuring amplifier, are fed to a graphic level-recorder. The outputs of the vibration preamplifier and the measuring amplifier are fed to a dual-trace oscilloscope to determine the phase angle (after accounting for phase shifts of the amplifiers in the system).

In addition to the measurement of impedance, a vibration model of the vibrator, impedance head and neck tissue has been developed. The neck-tissue model is a nine-degrees-of-freedom system and has been programed for computer analysis.

The results to date have established conclusions as follows:

1. Neck tissue (from a vibrational viewpoint) is a high-damped system with a very low resonant frequency. Damping appears to exceed critical damping by an order of magnitude.
2. There exist no frequency "windows" for neck tissue which will permit improved vibration transmission.
3. Vibration transmission through neck tissue will require inputs similar to a square wave and the output will resemble shock spectra.