tics of hip muscles and whether these characteristics can be beneficially altered by an electrical stimulation exercise program.

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Patient Evaluation of a Functional Electrical Stimulation Hand Orthosis

VA Hospital
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P. Hunter Peckham, Ph. D.

A new project has begun at the Cleveland VA Hospital to evaluate a hand orthosis, using functional electrical stimulation, which has been designed for high-level spinal cord injury patients. The preliminary feasibility of this orthosis has been demonstrated in studies performed over the past 4 years at Case Western Reserve University.

The orthosis utilizes electrical stimulation of the forearm finger flexor and extensor muscles to provide proportional control of prehension and release, respectively. The patient controls the contraction strength by movement of a shoulder or head position transducer. The stimulator and control will be portable and attached to the patient.

SENSORY AIDS

Edited by

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Research on Audible Outputs of Reading Machines for the Blind

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Introduction

It is now generally recognized that reading aids designed for broad application by both the veteran and civilian blind must be capable of producing a high-quality speech output. From its inception several years ago, the objectives of this research program have been to devise a method of generating automatically a form of high-quality speech from text input. Following a period of basic research that led to the development at Haskins Laboratories of the first set of rules for speech synthesis, the work has progressed to the point where intelligible speech can be synthesized by a computer on a routine basis.

The major task being undertaken at present is to achieve further improvements in the voice quality.

During the first half of 1976, progress was made in several important areas. A revised version of the OVEBORD speech synthesis program was prepared for the Honeywell DD–224 computer and work was initiated on the development of an expanded set of rules for the program. An algorithm for the automatic conversion of proper names from print to phonetics was devised in readiness for computer coding. In addition a so-called "software synthesizer" program was written, and work commenced on the development of a new program for research on synthesis-by-rule that operates on the Laboratories' PDP–11/45 computer. Finally, some new studies of the temporal variations that occur in natural speech were begun, with a view to applying the data toward the improvement of synthetic speech.

Revisions to the Synthesis Programs

Since the development of the Laboratories' first synthesis-by-rule program for the OVE III hardware synthesizer, work has continued on a reorganization of the program structure and on the installation of a number of new features. These features have provided the freedom to manipulate pause durations and formant transitions in a more flexible manner, to introduce a greater number of allophone rules, and to alter special aspects of the parameter calculation. With these new features available, the synthesis rules have been undergoing revision, and recordings of word lists have been made for testing purposes.

Print-to-Sound Conversion for Surnames

Work on the problem of automatically converting the spelling of surnames into phonetic symbols for speech synthesis has been underway

since the third quarter of 1975. At the present time, all but a few minor details of the conversion procedure have been worked out. The rules that form the basis of this procedure have been tested manually and have successfully produced correct pronunciations for hundreds of words collected randomly from a variety of sources. The conversion is carried out in a sequence of seven steps. Following the initial replacement of each individual letter or letter group with its most probable phonetic symbol, the name is subjected to a series of tests scanning first from the right and then from the left to determine the syllable boundaries. With the boundaries established, further stages assign a stress pattern and then output the completed phonetic spelling. Some names that require a full-fledged morphological analysis, and the recognition of morphemes in foreign languages, are sometimes assigned strange stress patterns. However, since the rules are letter-based, an occasional abberant conversion of this type is unavoidable.

A Flexible Software Synthesizer

A group of programs has been prepared, for the Laboratories' PDP-11/45 computer, that simulate the generators and resonators used in "hardware" speech synthesizers built from electronic components. The components of the "software synthesizer" can be easily rearranged so that any desired synthesizer structure can be made available. This flexibility promises to be a considerable asset to the research, since it allows the Experimenter (within minutes) to make modifications to the synthesizer design that, were they to be attempted in hardware, would take many hours. There is a penalty, however, and it appears in synthesis speed. The response of the software synthesizer is not like a hardware unit (essentially immediate) since a delay of a few seconds occurs while the program computes the speech waveform.

The software synthesizer has been tested with some short sequences of parametric values created by hand and has behaved satisfactorily. In a short time a new program for synthesis-by-rule (which is also being written for the PDP-11/45 computer) is expected to become fully operational and provide machine-generated parameters that will drive the software synthesizer.

New Research on Speech Synthesis-by-Rule

A new synthesis system for research in speech synthesis-by-rule is being programed for the PDP-11/45. In an attempt to provide a more direct representation of coarticulatory effects on spectral and temporal patterns of speech than is possible with a segmentally-organized algorithm for synthesis-by-rule, the algorithm for this system is organized around the syllable. The input is a phonetic description of the utterance in terms of syllable features, and a set of rules. The rules translate the

features into a sequence of articulatory influences, such as those of the current vowel, the following vowel, initial and final semivowels, initial and final consonants. Each such influence is represented by a set of target values for formant frequencies and by an exponential function of time; and the targets, the rates of growth and decay of the influence functions, and their timing relative to one another, are specified in the rules. The influences are ordered, and a formant-frequency value at a given time is determined by iteratively computing the sum of the target value associated with the nth influence, weighted according to its influence function, and the value determined by the first $n-1$ influences.

A preliminary version of this program, permitting the computation of formant parameters only for syllables consisting of glides and vowels, is now in operation. At present its only output is a printout of the parameter values and the associated influence function values. But since the software synthesizer is now available, these values can be used to synthesize actual speech as soon as this is required.

Studies of Temporal Variations in Natural Speech

To improve synthesis-by-rule, we need to know more about the temporal patterns of speech. We need information not only about the duration of acoustic segments, but also about the net effect of the presence of a phone on the duration of the syllable and the breath-group in which it occurs. Data from a study recently undertaken suggest that the temporal effect of the consonantal articulation is not necessarily either additive or simply related to the duration of the acoustic segment conventionally associated with the consonant.

Various monosyllables were embedded in turn in a short carrier sentence, and each version of the sentence was read by one speaker 30 times at a carefully controlled tempo. Later the durations of segments, syllables and breath-groups were measured from oscillograms of the sentences, and least pairs (e.g., "say" vs. "slay") were compared. It has been shown that a final stop or final nasal lengthens both syllable and breath-group by an amount roughly equal to the durations of the corresponding acoustic segment. However, an initial stop, liquid or aspirate induces no appreciable lengthening—instead, other segments in the syllable are sharply reduced. On the other hand, an initial "s" lengthens the syllable breath-group by an amount approaching the duration of the fricative segment, the durations of the other acoustic segments being only slightly reduced. It is hoped that these results will contribute toward better quality synthesis-by-rule.

Conclusions

A full assessment of the results of this research must, of course, still await the future. The crucial issue will be whether the quality of synthetic

speech has been enhanced. However, it can be said that the steps taken to break new ground and to develop more flexible facilities have progressed well during the past half-year. There is, therefore, every expectation that work on the synthetic speech will be able to proceed at a better pace on the new computer and be free from many of the constraints imposed by hardware.

Research and Development in the Field of Reading Machines for the Blind

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Hans A. Mauch and Glendon C. Smith

Cognodictor Development

Prior to April 1976, Mauch Laboratories had been developing a character recognition reading machine for the blind (Cognodictor) which was designed to recognize many popular type fonts with an error rate of several percent for uppercase and lowercase letters and ligatures. Its usual output was "spelled speech," a rapid letter-by-letter spelling at rates up to 80–90 wpm. A breadboard which demonstrated that only minor improvements would be needed to reach these goals had been built during the preceding year.

In April, the sponsor approved changes suggested by Mauch Laboratories which will lead to a much higher performance reading machine, one which will have an error rate of less than one percent on letters and numerals of a wider variety of type styles.

New Cognodictor Design Details and Goals

This high-performance Cognodictor will have a synthetic speech output, with spelled speech or direct translation outputs available at the press of a button. It will consist of two units, a high-resolution optical probe designed for hand-held use and a control box containing a minicomputer or microcomputer and a Votrax vocal synthesizer. Initially, the control box will be about 2¼ ft^3 in volume and weigh 30–35 lb. The Cognodictor's cost in September 1977 is estimated to be about $12,000 each in a quantity of 10. The price, size, and weight are expected to decrease substantially with the rapid progress apparent in electronics technology. Additional cost reduction will be possible with increasing production.

The hand-held probe of the Cognodictor, and its direct translation output mode, combine to allow the user to understand the format of his document and to decipher unusual symbols. The additional information thus conveyed is difficult or impossible to obtain from an automatic page-scanning machine without a direct translation capability. The Fair-

child CCD-121 photocell array in the probe will scan a band 1½ in. high, providing a tracking tolerance of ±.675 in. for typewriter-size print. This amount of tracking tolerance will make freehand tracking very fast and easy, and will eliminate the need for tracking aids in most cases.

An automatic page-scanner will be made available in the future, for use with long magazine articles and books.

The new Cognodictor design goals include a wider range of characters (including italics and numerals) over a wider range of type styles. The number of photocells used (~1500) permits a large field of view, and high resolution which will yield reliable detection of lines as fine as .003 in., such as are found in some type fonts (Caslon, Baskerville, Primer, etc.), and do it in the presence of interference from print on the other side. It also allows type size adjustment to be an automatic electronic operation. A manual override will be provided for use in direct translation mode when needed. The photocells will be sampled each time the probe moves .003 in. horizontally as determined by an optical encoding disk which contacts a roller.

Adjacent-line suppression will also be automatic, based on information obtained by the photocells above and below the line being read. A similar process will be used for the automatic suppression of underlinings. This adjacent-line suppression can be overridden by a control on the main box for the rendition (in the direct translation mode) of mathematical formulae, geometric figures, etc., covering more than one line-space.

Italics will not necessitate slanting the probe but will be automatically accommodated by the Cognodictor. The computer in the Cognodictor will also decide whether the print is typewritten (equally spaced) which will facilitate word separation ("look for the middle of a letter location, if it is white it must be a word space")—or not typewritten, in which case word and letter spaces are sufficiently different to avoid ambiguities in discovering word spaces. Touching letters will initiate a subroutine to separate and recognize them.

The Cognodictor's direct translation mode will initially be 10 tones as in the Stereotoner, but monaural. The tones will be initiated by pressing a button on the probe. Later, an accessory tactile display may be developed, possibly one which embosses a reusable plastic sheet or strip.

The usual output, synthetic speech, will be produced by a vocal synthesizer such as the Votrax unit currently operating at Mauch Laboratories. Its output rate will be adjustable up to 150 wpm. The pitch of the voice will be adjustable by the user to his preference. An additional computer program will allow the synthesizer to produce spelled speech up to about 40 wpm. The speaking of a word will begin as soon as possible after the detection of a word space to eliminate delays which would be present if the program were to require the user to scan to the

end of the line or to the end of the sentence. For this reason, and to keep the size and cost of the machine within reason, syntactical analysis and stress assignments will not be used in the Cognodictor at present. Punctuation marks will be recognized and their names pronounced only when the spelled speech mode is used.

Significant progress was made in the development of the new Cognodictor during April, May, and June 1976. A PDP–11 minicomputer system was delivered and installed at the end of May. A photocell array was purchased and tested. Other work includes designing circuits to interface the photocell array with the PD–11 and designing and/or building parts of a provisional probe for the new Cognodictor including a housing, an illumination system and an optical system to measure horizontal motion. This provisional probe will serve as a test bed to provide signals to the computer during the early portions of the Cognodictor development. Dr. Chung C. Lee, a recent graduate of Syracuse University, was hired to program the PDP–11 starting July 1, 1976.

Synthetic Speech Production

In January 1976 Dr. Scott Allen at National Insitutes of Health provided Mauch Laboratories with a copy of his program for text-to-speech conversion using a Votrax vocal synthesizer and an Intel–8080-based microcomputer. Many pages of listings and other documentation were supplied. This material was studied and the necessary changes were made.

In February 1976, a BASIC program to produce spelled speech was written. Considerable time was required to select the sequences of Votrax phonetic codes to produce acceptable spelled speech at 30–40 wpm which appears to be ample for use as a back-up output for synthetic speech.

Dr. Allen's program was operational in March except for a few minor bugs which were easily corrected. It was tested with a list of 1,100 words which activate most of the rules and exceptions.

During May, about 4 hours of audio recordings of synthetic speech and spelled speech were prepared for Richard Bennett and Gregory Goodrich at Palo Alto VA Hospital. The synthetic speech text and isolated words were produced 6 times using 3 rates (up to about 120 wpm) and 2 pitches of the Votrax unit. The spelled speech was also produced by the Votrax, but at one rate only (about 30 wpm) and 2 pitches. The four reels of tape were shipped to Palo Alto at the end of the month.

Clinical Study of Mobility Aids for the Blind
Central Rehabilitation Section for Visually Impaired and Blinded Veterans

VA Hospital, Hines, Illinois 60141
John D. Malamazian, Leicester W. Farmer, and James J. Whitehead

1. During this reporting period, the two remaining Orientation and Mobility (O/M) Specialists scheduled for the Professional Field Experience (Electronic Travel Aids) Course completed the 6-week postgraduate training at Western Michigan University, Kalamazoo, Michigan, and are thereby certified to teach the use of electronic mobility devices and sensory systems to blinded persons.

2. Also during this period the information newsletter "Electronic Mobility Aids Program for Blinded Veterans" was revised and updated and is now being circulated to prospective candidates and interested persons and organizations. The Newsletter gives a brief explanation of the VA program, guidelines for participation in the program to assist referring agents, the names and addresses of the three VA Blind Rehabilitation Centers from which information about the programs may be obtained, and pictures and brief descriptions of the three electronic mobility devices used in the program.

3. In February, Mr. Leicester W. Farmer met with Dr. Leslie Kay, inventor of the Binaural Sensory Aid (BSA) and currently head of the Department of Engineering, University of Canterbury, Christchurch, New Zealand. The two discussed the work of Dr. Kay's group of investigators on sensory perception relating to O/M, the introduction of a new family of sensory aids-to-mobility, the development of new training techniques using audio-visual aids, exploration of the value of sensory aids-to-mobility in the laboratory, training of spatial perception in children with sensory devices specially designed for the child, the measurement of O/M performance, and the use of new and sophisticated equipment and techniques in the laboratory to determine what the individual's task is when he is mobile.

4. In March, Dr. Robert Weisgerber of American Institutes for Research (AIR), Palo Alto, California, visited Hines and "debriefed" the O/M staff on the "Environmental Sensing Skills and Behaviors" project which he and AIR personnel developed for, and with the cooperation of, the VA. Dr. Weisgerber discussed the adoption or adaption of the AIR "Evaluation Procedures for Environmental Sensing, Orientation, and Mobility by the Blind" among the VA BRC's. He recommended the appointment of an O/M Research Specialist to coordinate the verification and field-test activities of a VA-oriented version of the AIR evaluation procedures. Mr. Farmer was appointed to undertake the role of coordinator.

5. Between January 1 and June 30, 1976, five veterans were admitted for training with electronic mobility travel aids at Hines BRC. Three veterans were trained with the C5 Laser Cane, one was trained with the Mk II Sonicguide, and one candidate terminated his training with the Sonicguide after two weeks of participation in the program. Both of the veterans who were admitted with the Sonicguide were dog guide users.

6. Followup site visitations were made in the home areas of eight veterans living in six nearby states. Of this number, two were Laser Cane users and six used Sonicguides.

Two of the Sonicguide users were involved in post-followup evaluations. Part of the followup protocol consisted of the following:

a. An "open-ended interview" with the responses to the questions being recorded on a cassette tape recorder. The questions covered four basic areas of interest: 1. Device utility; 2. Device information display; 3. User characteristics; and 4. Travel information.

b. Videotaping of the device user's O/M performance while traveling along a familiar route using his primary travel mode. Another videotape was made of the veteran traveling with the combination of his primary travel mode and the electronic travel aid. (Two of the Sonicguide users were dog guide users.)

c. A questionnaire which included virtually every aspect of O/M performance with primary and secondary tools, modes and techniques. The responses to the questionnaire, as well as to the open-ended interview, are being compiled for a comparative analysis among the veterans trained with the electric mobility devices at Hines. The results of the questionnaire which addresses itself to the Sonicguide users will be compared with an earlier evaluation of the Binaural Sensory Aid (BSA) conducted by Peter W. Airasian, of Boston College, in 1972.

7. In April, Mr. Farmer gave a lecture and demonstration of electronic mobility devices and sensory systems to the Rotary International Club of Maywood, Illinois. In July he journeyed to Nashville, Tennessee, to lecture and demonstrate the electronic travel aids at a workshop on "Aging and Blindness" at the Howard Johnson Motor Lodge. The workshop was sponsored by Services for the Blind, the American Foundation for the Blind, and the Tennessee Commission on Aging.

8. Mr. James J. Whitehead, who has worked for many years with Mr. Farmer in the O/M Research Section at Hines, has been appointed Assistant Chief of the BRC at Hines. His services and contributions in the area of training, evaluation, and research with electronic mobility travel aids and sensory systems will be missed.

Clinical Trials of Reading Machines for the Blind

Central Rehabilitation Section for Visually Impaired and Blinded Veterans
VA Hospital, Hines, Illinois 60141
John D. Malamazian and Harvey Lauer

This project deals with the testing and evaluation of ink print reading machines and other communication aids for the blind. There are six major activities and developments during this reporting period.

1. Mr. Harvey Lauer (Research Staff) and Mr. Leonard Mowinski (Blind Center Staff) took a 2-week Optacon teacher-training course at Telesensory Systems, Inc., Palo Alto, California. They also met with staff members of the Western Blind Rehabilitation Center.

2. Three veterans were given training in the use of the Optacon: two by Mr. Mowinski and one by Harvey Lauer. A fourth veteran elected to terminate training prior to completion.

3. The project to evaluate the Stereotoner conducted by the American Institutes for Research for the VA was completed. Final reports were sent to the Research Center for Prosthetics in New York. The other products of the project are teaching materials which were also sent to the Research Center for Prosthetics.

Two of these are of special interest here: the Auditory Selection Test for evaluating the potential of candidates for using the Stereotoner, and a series of three pretraining tapes intended for home study use. These materials are available from either the Blind Rehabilitation Centers of the VA, or the Hadley School for the Blind. If the availability of these materials is publicized, they will provide potential consumers with needed informaton and experience in making an informed choice of a reading aid. Potential users should also be familiarized with and assessed for the Optacon. This can usually be done locally because Optacons are more widely used now.

4. Mr. Lauer continued the study and testing of speech-compressing tape recorders, and braille and talking calculators. The results are shared with staff members of blind centers. In part, these results take the form of instructional tape recordings.

5. Mr. Lauer wrote a protocol to evaluate the Kurzweil Reading Machine. This instrument incorporates a microcomputer which controls three functions: automatic scanning, optical character recognition,

and speech synthesis. It is being purchased in prototype form with VA Research Funding.

6. Mr. Lauer gave a presentation on reading aids research at a staff meeting of the American Foundation for the Blind in New York City in February. He and Mr. Mowinski demonstrated equipment and conferred with guests at the Blind Center at Hines.

Instruction In, and Evaluation of, Reading Machine Techniques
The Hadley School for the Blind
700 Elm Street
Winnetka, Illinois 60093
Michael Carbery, Ph. D., Margaret Butow, and Roger D. Rouse

The report on activities in the period of January 1 through June 30, 1976, is incorporated in the final report on this contract, presented elsewhere in this issue as an article under the title "Research and Evaluation of Audible Output Print Reading Aids for the Blind — A Final Report."

Clinical Application Study of Reading and Mobility Aids for the Blind
Western Blind Rehabilitation Center
VA Hospital
3801 Miranda Avenue, Palo Alto, California 94304
J. Kenneth Wiley, Greg Goodrich, Ph. D., Nancy Darling, and Richard Bennett

Mobility Aids and Training

During the current reporting period, from January 1 to June 30, 1976, two Orientation and Mobility instructors received training on electronic mobility aids at Western Michigan University. Additionally, three veterans received instruction in the use of the Sonicguide at the WBRC. Two new mobility research projects were initiated. Mr. Stan Paul and Dr. Greg Goodrich began a study on the feasibility of applying the ITT "Clinical Pocketscope" to the mobility training of night-blind veterans, and Miss Nancy Darling began a followup study of students trained with electronic mobility aids at the WBRC.

Low Vision Aids and Training

Development and evaluation of eccentric viewing procedures continued at the WBRC. Several series of flash cards (in various letter sizes) and several pieces of apparatus were developed. Current plans are to

continue data collection, as well as the development and refinement of training techniques.

Static and dynamic visual field tests were conducted on six monoculars used in the WBRC's low vision program. Additionally, their minimum focal distances were determined. Results indicate a smaller field for the monoculars than indicated by the manufacturers' published data, and a new series of telescopes (by Walters Camera and Binocular Repair, Los Angeles, California) appears to have the greatest flexibility of focal distance making them a good low vision aid for a variety of uses, including near and distance tasks.

The closed-circuit television followup study was completed and data on 101 veterans from the three Veterans Administration Blind Rehabilitation Centers were gathered. Two papers on this project have been completed, and a final report is being prepared.

The building of reading speed and duration, during the first 10 days of reading with optical aids and CCTV, was the subject of a project undertaken in June 1976. Preliminary results indicate a great deal of similarity in the rate of increase in reading speed between optical aids and CCTVs. However, it appears that reading durations increase at a greater rate for CCTVs than for optical aids.

Reading Aids and Training

In response to a request from the Research Center for Prosthetics, (RCP), Mr. Richard Bennett and Dr. Greg Goodrich conducted an evaluation of electronic calculators for the blind. Only WBRC staff were used as subjects for the evaluation of the calculators. While all calculators exhibited some mechanical difficulties, all seven subjects were able to utilize them accurately to solve simple mathematical problems. The subjects' order of preference for the calculators was: 1. Telesensory Systems, Inc. "Speech+," 2. Master Specialties Co. "ARC 9500," 3. Science for the Blind "CALCU-TAC T–8B," and 4. American Foundation for the Blind "MAS 200." While the Speech+ was the preferred voice-output calculator, the CALCU–TAC T–8B was the preferred braille-output calculator. The WBRC report to RCP also evaluated the quality of training tapes for each calculator, and suggested cognitive strategies for utilizing them. The cognitive strategies include "chunking" long strings of digits to facilitate remembering them, and conceptualizing the expected output prior to the calculator's readout (which also facilitates the memory process).

Approval was granted to the WBRC, by the local Research and Development Committee and Subcommittee on Human Studies, for a research study on the output of synthetic speech reading machines. The initial phase of the study will evaluate the intelligibility of synthetic speech devices. The design will use single letters, single words (of 2, 3, 4,

5, 6 and 7 letters) and short stories—3 output speeds and 2 pitch levels will also be used. Recordings of the Cognodictor output have been provided by Mauch Laboratories, Dayton, Ohio.

Also during this reporting period, Mr. Richard Bennett maintained contact with Stereotoner trainees by letter, tape recordings, and telephone. One veteran received training on the Optacon; however, upon completion of Phase 1, the instructors and student agreed to discontinue further training.

Presentations by WBRC staff during the period January 1 to June 30, 1976.

1. Voorhies, Mark: Demonstration of Electronic Mobility Aids for School Age Children. Vocationally Handicapped Teachers of San Mateo County Schools, Jan. 1976.
2. Ault, Carroll and Gail Horst: Preparing Facilities and Staff for Blind and Low Vision Patients. Arndts Convalescent Home, San Jose, Calif., Feb. 1976.
3. Goodrich, G. L.: Technology and Blind Rehabilitation. Psi Chi, San Jose State University, San Jose, California, Feb. 1976.
4. Ekstrom, William and Richard Bennett: Architectural Barriers. San Jose Architectural Barriers Committee, San Jose, Calif., March 1976.
5. Syverson, Phillip: Electronic Travel Aids. Peninsula Center for the Blind and Visually Impaired, Palo Alto, Calif., March 1976.
6. Goodrich, G. L. and J. G. Holcomb: Eccentric Viewing Training. Vision Rehabilitation Center of Santa Clara County, Santa Clara, Calif., April 1976.
7. Voorhies, Mark: Demonstration of Electronic Mobility Aids. Physically Limited Program, De Anza College, San Jose, Calif., June 1976.

Publications by WBRC staff during the period January 1 to June 30, 1976

1. Cory, Pamela L.: Low Vision Aids and their Practical Applications to Activities of Daily Living. Low Vision Abstracts, II(1): 1-11, 1976.
2. Goodrich, G. L., L. E. Apple, A. B. Frost, A. Wood, and N. Darling: A Preliminary Report on Experienced Closed-Circuit Television Users. Am. J. Optom. Phys. Optics, 53(1):(7-15), 1976.
3. Holcomb, J. G., and G. L. Goodrich: Eccentric Fixation Training. J. Am. Optom. Assoc., Fall 1976 (in press).
4. Quillman, R. D., A. B. Frost, H. K. Shaw, and G. L. Goodrich: Low Vision Monocular Field Study. Optometric Weekly, Oct. 1976 (in press).
5. Wiley, J. Kenneth. Greg L. Goodrich, Richard R. Bennett, and Nancy Darling: Clinical Application Study of Reading and Mobility Aids for the Blind. Bull. Prosthetics Res., BPR 10-24:(267-268), Fall, 1975.

Development of Test Procedures for Evaluation of Binaural Hearing Aids

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The final report on this contract, plus a summary of work completed

under earlier contracts, appears elsewhere in this issue as an article under the above title.

The Development of Improved Techniques for the Analysis of Hearing-Aid Performance
BioCommunications Laboratory, University of Maryland
College Park, Md. 20742
G. Donald Causey, Ph. D., Earleen Elkins, Ph. D., and Lucille Beck

The pilot study pertaining to work on hearing aid processing has been completed using both the 2cc and Zwislocki couplers. Portions of the data were presented at the November 1975 and April 1976 meetings of the American Speech and Hearing Association and Acoustical Society of America, respectively. A manuscript containing the combined data is being prepared for submission to the Journal of Speech and Hearing Research. This work is considered substantive in itself, but is also viewed as preliminary to the investigation of hearing aid quality judgments.

Data on reliability of hearing aid quality judgments are presently being collected on normal-hearing listeners. These tape recorded paired-comparison judgments utilize speech stimuli spoken by a male and a female talker, as well as music. Data analysis will be directed towards examining the correlations of quality judgments, as well as in the inherent test-retest reliability of judgments made for each of the three types of signals. Similar data collection on sensorineural listeners is planned for mid-August. Data from this investigation are expected to lead to a definition of some of the more significant independent variables to be manipulated in subsequent work on hearing aid quality judgments.

Auxilary work on an approach to the measurement of attack-release times in compression hearing aids has led to a novel means by which especially short attack times can be measured accurately. Heretofore, these measurements have been most difficult. This same measurement technique holds promise as one that can be fruitfully employed in the measurement of transient distortion in hearing aids. The technique, developed in cooperation with William Lawrence, a doctoral candidate in electrical engineering, is expected to permit an acoustically pure signal, free of the transient characteristics of the loudspeaker itself, to be delivered to the microphone of the hearing aid. Some basic features of systems used in attack-release time measurements will be presented in a paper at the American Speech and Hearing Association convention in November of 1976.

A series of studies were conducted in which nonlinear distortion in hearing aids was examined using non-standard methodology. Nonlinear distortion includes both harmonic and intermodulation distortion (HD and IMD) products in the output signal. Conventional tests use

single-frequency test tones and overly simplify the expression of nonlinear characteristics in hearing aids.

A representative sample of aids was tested with two-tone signals using a variety of input conditions and measurement criteria. Test protocol included adaptations of existing audio engineering IMD standards and new strategies based on vowel data and individual hearing aid bandwidth. Input frequencies and the relative levels of the test tones were shown to be determinants of the amount and location of measured distortion. The criterion for expressing the amount of distortion was a variable of less, but measureable, significance. A method of normalizing all aids to a hypothetical flat frequency response was also incorporated as an additional measurement strategy.

The preponderance of two-tones results indicated that the rank order for IMD for a group of hearing aids will vary substantially, and significantly on a statistical basis, as a function of changes in any of the test variables. (Reported in IEEE Conference on Acoustics, Speech, and Signal Processing, April 1976, Philadelphia, Penna.)

Two other tests were designed to examine nonlinear behavior of hearing aids.

The first involved a random noise signal with a notch filtered out in the center of the speech frequencies (1.2 kHz). Recordings of this filtered noise, as processed by a group of hearing aids, were presented to normal-hearing young adults. A pulsed tone of 1.2 kHz was presented for threshold measurements. A monotonic function relating the degree of nonlinear distortion (the filling in of the notch) and the threshold elevation was observed. This study has been submitted for presentation at the 1976 convention of the American Speech and Hearing Association.

The other study utilized synthetically generated vowels (a, i, and æ) as test signals for nonlinearity. The hearing aid outputs were examined on a real time spectrum analyzer and the results were compared to previous IMD and HD measurements.

Additional work will examine the feasibility of using broadband noise rather than sinusoids for the testing of nonlinear distortion. Specifically, a modification of a swept-notch technique and a high-pass filtering strategy are anticipated.

Other work currently in progress includes a comparison of listener performance on a closed set (Modified Rhyme Test) intelligibility test for material transduced by hearing aids differing in nonlinear distortion only.

Finally, a study of the discrimination of second formant transitions as a function of transient characteristics of hearing aids will commence in the next quarter.

Problems Inherent in Use of KEMAR

In a paper presented at the Lexington Hearing Conference in New York City, Beck and Causey reviewed the problems inherent in the use of KEMAR for measuring hearing aid performance. The differences in measurement provided by the orthotelephonic (etymotic) method and the substitution method were compared. The differences in the two methods are observed primarily in the frequency range above 1500 Hz with the substitution method showing more gain.

The difference between the two methods is explained by the procedures inherent in preparation of the test signal. For the orthotelephonic method, the signal stored on tape and presented to the hearing aid under test was a sweep frequency signal which provides a constant SPL at the eardrum microphone. In order to be flat at the eardrum microphone, the recorded signal was required to add and subtract the gain provided by KEMAR's head diffraction, ear canal resonance, and any effects of loudspeaker response.

For the substitution method, the signal stored on tape represents the voltage-versus-frequency which provides a constant SPL at the test point. In order to be flat at the test point (the actual point in the free field marking the intersection of the plane perpendicular to the loudspeaker cone and the midpoint of an imaginary line drawn between KEMAR's eardrums) the compressor microphone circuit adds and subtracts gain as necessary to compensate for loudspeaker effects.

The difference between the signals stored on tape for the two methods is in the range of 1.5 to 8 kHz where the orthotelephonic taped signal provides the additional de-emphasis necessary to achieve a flat signal at the eardrum microphone. The de-emphasis in this frequency range is the gain difference above 1.5 kHz for each hearing aid.

The question then becomes which method should be used for measurement of aids on KEMAR. It is our feeling that both methods are valuable.

At the present time behavioral studies are underway which attempt to relate gain of the hearing aids obtained by both etymotic and substitution methods to gain achieved by the individual patient using two distinct behavioral techniques.

Progress on the speech intelligibility materials is slow, but steady. We seem to put this work aside when other pressures mount. However, the consonant-neutral-consonant (CNC) recordings appear to be ready for dissemination. Data on normal and impaired ears are ready for publication. A cooperative study at Walter Reed Army Hospital of binaural versus monaural listening tasks utilizing the CNC materials has borne fruit. We expect to publish the data soon showing a decided advantage

for binaural aids using the CNC materials in the presence of babble as a competing message.

Clinical Application Study of Reading and Mobility Aids for the Blind
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Report of Research Activities: January 1–June 30, 1976.

Center research on the use of prismatically displaced images for veterans with visual field restrictions has progressed to a stage involving evaluation in the home. Veterans' responses to a questionnaire concerning their use of prisms in their home environments subsequent to their training at the Eastern Blind Rehabilitation Center, have been coded and initial computer analysis has taken place. Prism application and training are continuing because of the positive responses obtained in this questionnaire.

It appears that an important variable in the decision to utilize prisms is the visual acuity of the veteran — with visual acuity being inversely related to the probability of success in home use of prisms. This is attributed to the ability of individuals with restricted fields and better visual acuities to perceive obstacles at greater distances, thereby including more information in their limited visual fields. These people do not have the motivation to adapt to the prismatically induced perceptual distortion which works to the advantage of the veterans with restricted fields in conjunction with poor visual acuities.

The data from the results of an ongoing survey of blinded veterans issued low-vision aids from the EBRC have been computer coded and are undergoing analysis for significant trends. Among other things the interrelationship between visual pathology, psychological "health," and the usefulness of a low vision aid as seen by the veteran will be explored. The emerging patterns of use when various aids are employed in the home environment are providing the low vision staff with valuable insights into potentially useful changes in training program emphasis.

Demographic, psychological, and medical data on veterans involved with the EBRC's programs have been expanded to include information on all clients prior to January 1976. These data, in conjunction with user oriented questionnaires, have been valuable in determining the adequacy of training for different subgroups of the blinded veteran population. The data base also provides ready access to many user variables when the relationships between a sensory aid's function and the charac-

teristics of its user population are to be assessed. All of the programing has been designed so as to be interfaced with both the prism and the low vision data bases.

Input is currently being obtained from blinded veterans trained in the use of Optacon. This information concerns the amount and type of tasks to which the aid is applied. The user is also requested to assess his perception of the value of this device. Information concerning a comparison of blinded-veteran Optacon users with users described in other studies is to be published in the near future.

The effects of hearing aids on mobility performance in the blind are being studied. In tasks such as auditory localization it is generally found that the blind hearing aid user performs in a more accurate fashion if he undertakes the task without his aid. Several avenues are being explored in an attempt to improve this situation, including increased training in the use of a hearing aid, and experiments designed to test the efficacy of new hearing-aid microphone placements or expanded band widths of the amplifiers.

An evaluation of several different models of calculators for the blind is underway. Two models of speech-output devices and two models of braille-output devices are being shown to blinded veterans, who are asked to comment on their design and on their own potential need for such devices. Veterans who demonstrate a need for a calculator and the ability to use the instrument successfully for the required task are issued the calculator of their choice. They are requested to provide the research department with feedback about the serviceability of the aid.

From the preliminary responses it would appear that very few of the blinded veterans are interested in the braille-output format. The

TABLE 7.—*Number of People Screened, Trained, and Issued Major Electronic Training Aids January 1–June 30, 1976.*

Training aid	Number of veterans screened	Number of veterans trained	Number of devices issued
Sonicguide	a	4	3
Laser Cane	a	0	0
Pathsounder	a	0	0
Stereotoner	4	0	0
Optacon	5	1	1
Speech compressor	13	8	7
Closed circuit television	48	10	10
Electronic calculators	a	20	6

[a] All blinded veterans in the EBRC's Programs are shown these devices and screened at that time as potential users.

synthetic-speech output is much more favorably received. The operation of all the calculators seems well within the capabilities of the interested individuals, but access to the numbers upon which the computation is to be carried out (i.e., the business records, the checking account statement, etc.) seems to be a problem. This obstacle does not occur in scholastic situations where mathematical exercises are presented to the blind student either in braille or recorded form and a reader is normally assigned.

A listing of the number of people screened, trained, and issued major electronic prosthetic aids in this reporting period is shown in Table 7.

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

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During the first half of 1976, work on developing a microprocessor hearing aid system with independently adjustable sub-ranges of its spectrum has been concerned with hardware and software problems arising in the real time clinical testing, and subsequent clinical use, of the above system—which was previously designed and tested only in a partly off-line fashion.

On the hardware side, we have modified the complete digital-to-analog conversion circuitry, to make it compatible with the Intellec 8 mod 80 microcomputer system that is presently used for our cascaded filtering system above. The converter itself has subsequently been interfaced with the microcomputer to yield analog (continuous) audio frequency output to a speaker and to related output instrumentation and

spectrum analyzers. In an effort to speed up computation, which was previously too slow for real time requirements, the hardware multipliers used in conjunction with the microcomputer have been replaced with new and faster hardware multipliers which had not been available previously.

On the software side, the main effort was, again, concentrated at speeding up computation. Consequently, changes in algorithms were made, to obtain more efficient and hence faster microprocessor utilization via modification of sequences of multiplication, addition, and shifting. Work on the off-line aspects of parameter setting for the cascaded low pass filters has been concerned with means for obtaining pure MA (moving-average) reference models via tabulation of impulse models via tabulation of impulse responses of low pass filters on the basis of theoretically exact transformation, and comparing the resulting model to others derived in the literature (1), (2).

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