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Clinical Application Study of Reading and Mobility Aids for the Blind

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Technology Transfer Activities

Current Research in Devices for the Blind

In July 1978, a meeting was held at the Army's Night Vision and Electro-Optics Laboratory at Fort Belvoir, Virginia. In attendance were Dr. William De l'Aune and Mary Dolan of the Eastern Blind Rehabilitation Center, Howard Freiberger and Ronald Arroyo of the VA Prosthetics Center in New York, and Dr. Vernon Nickel, VA Central Office. After brief introductory remarks by the VA visitors, the NV&EOL staff described some of their current research thought to be of value in the research and development of devices for the blind.

John Dehne, Chief of the Visual Perception Section, provided the group with information on the laboratory's work with "smart" sensors. Joseph Swistak, a perceptual psychologist, spoke of their simulation testing and evaluation method. Ray Balcerak, a specialist in the far infrared and advanced processing devices, reviewed recent developments in 3-D computer technology. He concluded that very fast, powerful computers would be available in the near future in compact, energy efficient packages, thus allowing additional sophistication in prosthetic devices of the future. Nicholas Diakides, an engineer/electrophysiologist, spoke of his work in the design of CRT phosphors (which have some of the characteristics of human visual receptors) for use in light amplification systems.

It was concluded that our first cooperative effort should be in the

evaluation of the ITT Night Scope, which is based on the light amplification technology developed at NV&EOL. Diakides and Swistak visited the EBRC in September and discussed this matter with Dr. De l'Aune, Mr. Freiberger, and Mr. Arroyo. They agreed that testing of the physical characteristics of the devices could be best carried out at Fort Belvoir and that such testing should be done before and after the devices' evaluation in the VA. Standard systems acceptance testing was conducted on three VA-owned Night Scopes in November 1978, prior to their being sent to the Western Blind Rehabilitation Center for preliminary evaluation.

Mr. Diakides has subsequently been given the responsibility for coordinating the NV&EOL side of what is perceived as a continuing cooperative effort between this Army group and VA Rehabilitative Engineering. A recent proposal from Dr. Diakides for a design study of a laser cane utilizing state-of-the-art components is a positive indication of their ability and interest.

Following a series of exploratory conversations with the Chief, Blind Rehabilitation, VACO, a project development engineer from Teleflex, Inc., Barry Barsky, visited the EBRC's research department. Sensitive to the fragile nature of braille watches for the blind, he proposed a wrist watch with an auditory output. The device would be hermetically sealed, have rechargeable batteries and a bi-tonal output code providing the user with the time in hour and five-minute increments. The projected cost for such a watch was given as fifty dollars.

The staff reaction to this concept was generally favorable, with some reservations. It was felt that the clients experiencing the most difficulty with conventional braille watches were the elderly, a group that might have problems in interpreting the tonal code. A voice output was suggested as an alternative, but price and size presented formidable obstacles. The second observation was that the large majority of blind clients could read the output of a digital watch if the visual display were slightly larger. The possibility of a dual modality output for the watch was to be seriously considered.

After further exploration of this concept, both in terms of engineering and marketing, Mr. Barsky returned to the Center in November. Simulated auditory outputs were provided for testing with blind consumers. Their interpretations of and reactions to the simulated tonal codes were very positive.

Electronic Mobility Aids

In July, Howard Freiberger and William De l'Aune met with Douglas Maure, Chief Engineer, American Foundation for the Blind, and John M. Simpson, Manager of the Optical Design Department of Bausch and Lomb. The purpose of this meeting was to discuss possible direction in electronic mobility aids for the blind and the role that

AFB Engineering could play. Mr. Freiberger and Dr. De l'Aune were able to provide the group with accounts of their experience with the currently available devices. Mr. Freiberger recounted the long history of engineering efforts aimed at assisting the blind traveler. Mr. Maure discussed the possibility of utilizing microprocessor technology to provide the user with a more sophisticated output from his environmental sensor. Mr. Simpson outlined the possibilities of an elaborate optical input system for such a device. Mr. Maure described an acoustical sensing system used by Polaroid having potential as an inexpensive input for an environment sensor for the blind.

AFB Glucose/Ketone Analyzer

In December, Dr. De l'Aune and Dr. Joseph Ventimiglia, staff physician at the EBRC, attended a meeting of the Medical Oversight Committee for the AFB Glucose/Ketone analyzer project. The meeting was held at Cornell Medical Center and was chaired by Aaron Bauch, Project Engineer from AFB, who described the system. Designed to be used by a blind diabetic, the device performs a colorimetric assessment of Ames Laboratories Diastix and Ketostix. It then audibly reports the concentrations of glucose or ketones to the user.

Input from the committee was sought on the value of a spoken versus a tonal output, the level of accuracy desired from such a system, and the feasibility of storage and statistical analysis of the test results for subsequent use by the physician. No firm conclusions were reached.

Other Activities

Dr. Robert J. Adrian, Coordinator of Psychological Services, and Dr. Laurence Miller, Supervisor of Psychological Services of the New York Association of the Blind, visited EBRC in July. The possibility of a cooperative effort in their proposed study, "The Utility of the California Psychological Inventory (CPI) and the Minnesota Multiphasic Personality (MMPI) in the Personality Assessment of Congenitally Blind Persons," was explored. Of particular interest to both groups were the development of norms for the CPI and MMPI applicable to blind clients and the investigation of the feasibility of using shortened or combined forms of the test for reducing the effort involved in administration and scoring of the instruments.

EBRC experience with computer analysis of such data and the expansion of the data base to include not only adventitiously blinded clients but also congenitally blinded individuals was seen as valuable by both parties.

In November the research department hosted a visit to EBRC by Mr. Keith Holdsworth of the Royal Guide Dogs for the Blind Associations of Australia. Mr. Holdsworth was primarily interested in re-

search concerning program evaluation. Consequently most of his time was spent in discussions of the EBRC's methods of computer processing patient information, including data concerning their satisfaction with the program.

Because of new developments in within-the-ear hearing aids, preliminary contacts have been made with Adrienne Karp, Audiologist, New York Association for the Blind. The possibility of a cooperative evaluatory project focusing on the directional performance of these aids when used by blind clients is being considered. The importance of this information to the auditorily impaired blind is considerable.

A character-recognition study utilizing the Kurzweil Reading Machine is currently underway in conjunction with the other two VA Blind Rehabilitation Centers.

Ms. Patricia Gadbaw served as a member of the program planning committee for the New England Chapter of the American Association of Workers for the Blind Annual Conference. She and Judith Green of the EBRC presented a seminar, "Practical Application of Optics through Case Presentations," at that conference which was held in Galilee, Rhode Island in September. Ms. Gadbaw also presented a seminar at the New England College of Optometry in Boston this December concerning the "Team Approach to the Low Vision Client."

An essay entitled "Research and the Mobility Specialist," was published in the September issue of the Journal of Visual Impairment and Blindness. This paper was adapted from a chapter by Dr. De l'Aune in the forthcoming book, Foundations of Orientation and Mobility, Richard Welsh and Bruce Blasch, editors.

Clinical Application Study of Mobility Aids for the Blind
Central Rehabilitation Section for Visually Impaired and Blinded Veterans
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John D. Malamazian and Leicester W. Farmer

The primary emphasis during this reporting period has been the training of blinded veterans to use electronic travel aids (ETA's). To this end, seven veterans were admitted to the Electronic Travel Aids Program at the Blind Rehabilitation Center at Hines, Illinois. Another veteran was evaluated with the Mowat Sensor and will return to the program after evaluation with the Sonicguide. Four veterans completed training with the Sonicguide and two others completed the Mowat Sensor training course.

A prototype Ultrasonic System (USS) was delivered to Leicester W. Farmer by Drs. C. F. Sabatta and K. H[illegible]

Institute of Technology (IIT) Chicago, for evaluation and field testing. The USS is being developed to test the feasibility of providing information intermediate in complexity between that afforded by the Lindsay Russell Pathsounder and the Sonicguide. This will be achieved by representing distance, direction and size information by distinct bits, in contrast to the continuous overlapping output of the Sonicguide.

The initial phase of the project has been completed with the development of the simplest electronic system which would provide the desired information to the user. The purpose of this prototype is to evaluate the information coding scheme in dynamic situations, and to determine the electronic and ultrasonic problems which must be addressed and resolved to obtain a reliable system.

The USS detects objects in the environment by emitting bursts of ultrasonic energy; echoes are detected by receiving transducers and transformed into an audible code. This provides the user with information about the distance, direction and size of the target(s). The difference between this system and that of the Sonicguide is in the coding format which provides discrete bits of information rather than the continuous display of the Sonicguide.

Radial distances from the user of the device are divided into ten zones approximately 1.5 ft wide. The presence of an object in the nearest zone is coded as a low frequency tone (300Hz) while an object in the farthest zone is coded as a high frequency tone (3000Hz.) Distance information is enhanced by the coding scheme since the two different tones are separated in time by about a half second for objects in the nearest and farthest zones.

Objects in an intermediate zone are also coded as tones which are separated in time and frequency. The unique feature of the coding format is the presentation to the user of distance information in distinct tones which do not overlap in time.

The transducer arrangement in the USS is similar to that of the Sonicguide. Azimuth or directional information is achieved in the same manner; relative loudness of the signal in the two ears is the cue to the direction from which the tone is coming.

Information on the size of the object is coded as amplitude (volume) of tone presented to the user—large targets produce louder tones than do small targets.

Evaluation of the USS has begun and some of the observations made thus far are as follows:

1. Distance and direction, observed by the principal investigators, are relatively easy to distinguish;
2. Object size information is considerably more difficult to distinguish; and
3. The azimuth angle over which objects can be detected is approx-

imately ± 30 deg which is not wide enough to provide good stereo information about objects moving across the field of view.

Dr. John Armstrong, psychologist and researcher from Nottingham University, Nottingham, England visited Mr. Farmer at Hines to assess the current state of the distribution and training for the Sonicguide.

Another visitor from England, Alan Wedgbury, Mobility Officer for the Blind in Lincolnshire at Boston, England, also visited Mr. Farmer to get an update on ETA's, to get information about light probes, and to review training formats and evaluation procedures for ETA's during his week's stay at Hines.

Clinical Trials of Reading Machines for the Blind
Central Rehabilitation Section for Visually Impaired and Blinded Veterans
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The major focus continues to be evaluation of the Kurzweil Reading Machine for the Blind. The KRM at Hines continues to perform well and needed no servicing during this reporting period. Veterans here in rehabilitation training read with the machine, as do staff members. An intensive study of the column-reading feature led to the conclusions that the present feature is of token effectiveness, but that with reprogramming it should be more useful. With the hand-scanning option associated with the upcoming model, that feature should be highly useful. In August, John Malamazian and Harvey Lauer conferred in Boston with both VA and manufacturer's personnel regarding VA plans for purchase, evaluation and deployment of the new "desk top" machines. Mr. Lauer also conferred with Howard Freiberger of VAPC who was preparing documents regarding VA evaluation of the KRM and specifications for KRM purchase. A study was made here of print samples, several of which were submitted for inclusion as part of the specifications.

Mr. Lauer conferred with staff at the Western Rehabilitation Center in Palo Alto, California. He also visited the San Francisco Rehabilitation Engineering Center and Telesensory Systems, Inc., where sensory aids are being developed and produced. With Richard Bennett he tested the newly-received KRM at WBRC. As a result, service was requested and obtained from the manufacturer, to bring the machine up to specification.

Mr. Mowinski [illegible]

tion's consumer-oriented handouts about speech compressors and calculators for the visually impaired.

Mr. Lauer and Mr. Mowinski attended the Rehabilitative Engineering Conference in September in Washington, D.C. The program, exhibits and private conferences were unusually helpful. Mr. Lauer attended and participated in the convention of the National Federation of the Blind, in Baltimore, where he conferred with several developers of communication aids for the blind.

Two pre-market models of speech compressors were tested. One is a recorder-player with pitch-correction circuitry, tested for the American Foundation for the Blind. The other, being tested for the VA, is a new model of the Am-Bi-Chron speech compression module.

A prototype audible polyphonic output for the Optacon was built by Illinois Institute of Technology electrical engineering graduate student Bernard Vecerek. This very successful device connects to the I/O terminal of the Optacon to yield a 12-tone output similar to that of the Stereotoner. It permits an effective bimodal (touch and hearing) display providing simultaneous audible and tactile direct translation displays. So far, one Optacon student used the device as he learned the Optacon and prefers the two outputs used together. Each code renders certain letter features better than the other. Four Stereotoner users including Mr. Lauer and Ms. Butow prefer the audible code as rendered by the Optacon and the prototype over the code as rendered by the Stereotoner. Prospects for a useful addition to the Optacon appear highly promising.

Further testing is underway and plans are being made for testing the value of additional tones in the code.

IIT engineers are also working with Blind Center Personnel to interface a computer with devices including the ELINFA braille recorder so as to assess the value of upcoming braille and talking terminals.

A tracking aid has been adapted for use with the Optacon Reading Machine. The Colineator tracking aid, developed and manufactured by Mauch Laboratories, is a result of the Visotoner Reading Machine Project. It can now be used in conjunction with the Optacon Reading Machine. With the assistance of the model shop, Mr. Mowinski developed a coupler enabling the Optacon camera to be connected to the Colineator. The results were favorable. The students preferred the Colineator over existing tracking aids. It can be used when reading books as well as single sheets of paper.

Clinical Application Study of Reading and Mobility Aids
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Kurzweil Reading Machine

During the current reporting period, all research staff have attained proficiency in the use of the Kurzweil Reading Machine (KRM). In addition, four visually impaired staff have received training in the use of the machine and numerous demonstrations have been made to blinded veterans.

In July 1978 Mr. Harvey Lauer, Reading Machines Specialist, VAMC, Hines, Illinois visited the WBRC to facilitate Mr. Bennett's and Dr. Goodrich's orientation to the KRM and to compare the functioning of the KRM's at Hines and Palo Alto. Using materials which had been read by the KRM at Hines, it was quickly established that the WBRC's KRM was not operating satisfactorily. A visit by Mr. Max Dannis (Kurzweil Computer Products staff member) revealed a malfunction in the central processing unit and repairs were made. Subsequent performance tests compared favorably to performance by the Hines' KRM.

In accordance with the purchase agreement, Kurzweil Computer Products supplied an RS-232 cable and software program ("Text to Speech") which allows the KRM to function as a voice-output for the WBRC's Tektronix 4051 computer. This interactive arrangement became operable on November 22, 1978, and provides the Tektronix with a "talking computer terminal" allowing it to function as an editor for composition and editing of text by visually impaired users. Among the features are storage and retrieval of large volumes of information, automatic text or letter formatting, and error correction using a voice (or visual) display. It is expected that these features will be available for use by WBRC staff, as well as demonstrating the versatility of computers adapted for use by the visually impaired.

In September 1978, Dr. Goodrich and Mr. Bennett proposed a formal study of the KRM's in use at each of the VA's BRC's. The design allows measurement of optical character recognition (OCR) errors with different type styles and/or print media. The purposes of the cooperative study are to evaluate OCR error rate, compare performances between KRM's, and to evaluate the effectiveness of the KRM "learning" feature. The study will be concluded by all three BRC's in the first quarter of calendar year 1979. Results should be helpful to KCP design and engineering staff, as well as enabling the VA to compare performance on its three KRM's. The OCR error-rate protocol contains extensive definitions of errors and defines optimum contrast setting, thereby allowing comparisons between machines in widely differing locations. It also has the capability of aiding evalua-

ELINFA Digicassette

An ELINFA Digicassette has been undergoing evaluation at the WBRC during the current reporting period. In general the braille display has been of high quality. Two cells, however, of the 12-cell display developed a variable response requiring repair by ELINFA. The unit was shipped for repair in September and returned in November but one pin in one cell continued malfunctioning. The unit was again returned to ELINFA in November and received back at the WBRC on December 28, 1978. At that time the unit was functioning with a legible braille display.

Optacon

During the current reporting period, one veteran received 80 hr of Optacon instruction and was issued an Optacon. Upon completion of training he was reading test material at approximately seven words per minute.

ETA Followup

The electronic travel aid followup study was completed early in the reporting period, with a total of 101 visits to veterans who had been trained in orientation and mobility by WBRC staff. The visits were made to veterans using electronic travel aids and to electronic travel aid non-users, so that a control population would be available for data analysis and interpretation. The results of the followup will be analyzed as soon as possible.

The WBRC electronic travel aid program continued evaluating and training veterans in the use of these supplemental mobility aids. Between July 1 and December 31, 1978, five veterans were trained in the use of the Mowat Sensor, with Mowats being issued to three. Two additional veterans received training with (and were issued) the Sonicguide.

IT&T Clinical Pocketscopes

Also during that period three IT&T Clinical Pocketscopes were received at the WBRC for investigation of their efficacy as travel aids for "night blind" veterans. In October the three devices were shipped to the U.S. Army Night Vision and Electro-Optics Laboratory, Ft. Belvoir, Virginia, for calibration testing by Mr. Nicholas Diakides. The devices and their calibrations were returned to the WBRC in early December. During this time, the WBRC developed an outdoor mobility run for testing the effect of the devices on veterans' travel performances, and an objective scoring system for the run. An indoor experimental course was also developed. Upon completion of the WBRC's evaluation of the scoring procedure and the three Pock-

etscopes, the protocol and one device each will be shipped to the EBRC, West Haven, Connecticut, and CBRC, Hines, Illinois, for further evaluation. In November Mr. Paul Lighty, Program Manager of IT&T's Night Vision Aids Program, visited the WBRC to discuss their program and the evaluation being developed at the WBRC.

Personal Information System

The development of a "personal information system," a computer-based storage and retrieval system with multiple input/output formats, has begun. Currently Dr. John Linvill (Project Leader at Stanford University) and Mr. Greg Fowler are utilizing a PDP-11 computer to develop a simulated system so that initial design criteria can be developed and the necessary components of a personal information system designed.

CCTV

Data analysis of information on 96 experienced closed-circuit television (CCTV) users has been completed. The mean length of time subjects had their CCTV was about 4 yr. The data indicate that 87 percent of these users have continued using the CCTV on a regular basis over this period. It may be concluded that CCTVs are an extremely useful aid, and that use patterns are at least as good as (and perhaps better than) those developed with conventional optical aids.

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

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The Clinical and Acoustic Parameters of Hearing Aid Performance

Study of Transient Distortion

A portion of this work has been aimed at developing a means of quantifying transient distortion in hearing aids and applying the transient distortion data to an investigation of the relation of this form of distortion to listeners' perception of speech quality.

Success in reaching [illegible]

conducted by Talkin and Opauski (1977) at Gallaudet College. Their work was aimed at developing a digital inverse-filtering technique that might be used in hearing aid frequency response measurements. Their general aim was to achieve a flat-spectrum broadband signal, to serve as the acoustic input to the hearing aid in the conduct of frequency response testing. We have adapted the technique, which makes use of impulse technology, to our work in transient distortion. The method is described in detail by Talkin and Opauski (1977).

Using this digital technique, the impulse response of 20 conventional, noncompression, over-the-ear hearing aids was measured. For these preliminary measurements, gain controls were set to the test-reference position specified by the ANSI S3.22 (1976) Standard. Standard No. 13 tubing was used in conjunction with a Zwislocki-type occluded-ear simulator. Output level was held constant at 80 dB peak-equivalent SPL, re the amplitude of a 1 kHz tone. Output impulse responses of the aids were digitized and stored in the computer. Storage in computer memory means that subsequent analysis of the data can be virtually instantaneous, a distinct advantage of the method.

Four different optimization algorithms were used to match the actual signals measured to an approximated second-order linear system impulse response. These optimizations yielded three parameters that were ultimately used to specify the impulse response of the aids tested: (1) β, a decay constant (related to decay time, or ring time), (2) w, the number of zero-crossings in the impulse response divided by time, and (3) w_p, the zero-crossings in the differenced impluse response divided by time. Values on each of these parameters differed substantially across the 20 hearing aids.

Therefore a method that appears to hold promise in offering a means by which transient response in hearing aids may be quantified has been found. Furthermore, several specific parameters associated with the impulse response have been identified.

These data were analyzed in terms of their effect on listener judgments of speech quality in the context of a larger experiment, the results of which are discussed below.

Speech Quality Judgments and Hearing Aid Electroacoustic Characteristics

Previous research has established that listeners' subjective preferences for hearing aids, based on the quality of speech transduced by the instruments, are reasonably strong in differentiating among different aids, and are reliable indices of behavioral performance, particularly if obtained by a paired-comparison procedure (Witter and Goldstein, 1971; Punch, 1978). The basis for a listener's judgment that aided speech is of high or low quality, however, is largely unknown. This lack of information led to the investigation of quality

judgments of hearing aid-processed speech as related to the electroacoustic characteristics of hearing aids, in order to determine those characteristics responsible for producing improved speech quality. A post hoc multidimensional scaling technique was used in the data analysis.

Each of 20 conventional hearing aids, 16 of which were on VA contract, was subjected to an extensive electroacoustic analysis. Measurements included low and high-cutoff frequency; bandwidth; Index of Response Irregularity (IRI, as specified by Jerger and Thelin, 1968); total harmonic distortion at 500, 800, and 1600 Hz; intermodulation distortion at f2-f1, f1+f2, 2f1-f2 and 2f2+f1; equivalent input noise level (L_n); and three measures of transient response, β, w, and w_p, as described in the preceding section. Measurements, in general, were made with the aid situated on the acoustic manikin KEMAR (Burkhard and Sachs, 1975) at input signal levels and gain controls set according to the ANSI S3.22 (1976) Standard, where applicable.

A single 20-sec passage of connected discourse was processed by the hearing aids and tape-recorded via KEMAR in paired-comparison format. Each of the 20 aids was randomly paired with every other aid, for a total of 190 pairings. The recorded signals were delivered at a comfortable listening level through a wideband external-type hearing aid receiver attached to standard custom-fitted earmolds. A ⅓-octave spectrum equalizer was used in the playback system to adjust the receiver to an effective flat response on a Zwislocki-type occluded ear simulator.

Ten normal listeners and ten listeners with high-frequency sensorineural hearing loss were instructed to make sound quality judgments of preference and similarity for each of the 190 paired comparisons. Both types of judgments were made by the subject during presentation of a given paired comparison. Three replications were performed on each subject, one per test session, with data analysis based only on the latter two replications.

The mean similarity ratings of replications 2 and 3 were analyzed by use of INDSCAL (Carroll and Chang, 1970), a scaling technique whose output is a graphic reconstruction of the stimuli (20 aids) in a multidimensional psychological space. For normal listeners, the mean correlation within subjects between ratings in sessions 2 and 3 was .84, and the mean correlation among subjects was .74. The normal listeners therefore were a highly reliable and homogeneous group. The hearing-impaired subjects produced somewhat less reliable similarity judgments: their mean correlation between the second and third sessions was .70, and the correlation among subjects was .60.

Three-dimensional solutions were selected for the primary analysis because higher dimensional solutions yielded no appreciable increase

tion explained 71 percent of the variance. The most salient dimension, D1, correlated .91 with low-cutoff frequency. Subjects assigned ratings of "most dissimilar" to the hearing aids when the aids differed in this specific characteristic. Therefore, the data indicate strongly that normal listeners utilized low-cutoff frequency as one of the bases for their judgments. Similarly, IRI and L_n appeared to be the bases for D2 and D3, with correlations of these factors with the dimensions being .66 and .63, respectively. Preference data indicated essentially identical bases for preference judgments, as normal-hearing subjects preferred aids with lower low-cutoff frequencies, less irregular responses, and reduced equivalent input noise level.

The pattern observed for the ten listeners with sensorineural hearing loss was similar with respect to only one dimension, low-cutoff frequency. This was the only dimension that could be clearly labeled by the analysis, which showed a correlation of .86 between D1 and low-cutoff frequency. As in the case of normal listeners, this group of listeners subjectively preferred aids with extended low-frequency emphasis. It must be emphasized that this conclusion must be limited for the present time to subjects having high-frequency sensorineural loss, with relatively good hearing in the low frequencies, and to the closed earmold condition studied in this specific experiment. (For this reason, a group of hearing-impaired listeners having relatively flat audiometric configurations are currently being tested under identical conditions.)

Transient response, the topic of the preceding section, did not emerge as a dimension for either subject group as a basis of speech quality. If the derived indices of transient response adequately represent differential transient characteristics of the hearing aids studied, the preliminary results indicate that transient response is not a dominant characteristic in speech quality judgments, at least for conversational-level speech in quiet. The area of transient distortion deserves additional study in this regard, particularly as related to measurement technique and application of the data to situations involving speech in the presence of background competition.

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The Application of the Maryland Speech Intelligibility Materals

A. In Dichotic Listening

The effect of dichotic amplification on the speech discrimination ability of hearing-impaired subjects was examined in this study by means of comparative evaluation with monaural and binaural amplification. The speech discrimination scores of 12 subjects with sloping sensorineural hearing loss were measured in quiet and speech-babble competing-message listening conditions for monaural, binaural, and dichotic amplification modes.

A 2-channel device, consisting of a master hearing aid and digital multifilter with hearing-aid microphones and receivers mounted in post-auricular hearing-aid chassis, provided amplification in the 3 modes. One channel of the device was used for monaural amplification while both channels were used for binaural amplification. For the dichotic amplification mode, the frequency response was divided at 1000 Hz and 1 channel of the device delivered the low-frequency portion of the signal while the other channel simultaneously delivered the high-frequency portion of the signal. Electroacoustic measurements were obtained to ensure that Saturation Sound Pressure Level, total harmonic distortion, inherent noise values, and frequency response characteristics as a function of volume control setting were similar for the amplification modes.

Subjects were seated in a foam-insulated IAC room, equidistant 1 meter from 4 loudspeakers, at 0 deg, 90 deg, 180 deg, and 270 deg azimuth. The speech discrimination stimulus, the Maryland recording of the CNC lists, was presented through the 0 deg azimuth loudspeaker. Noncoherent speech babble was delivered through the other 4 loudspeakers in the competing message condition. Functional gain measures were obtained to ensure that real-ear frequency-gain characteristics were essentially equivalent for the 3 amplification modes. Seven subjects returned for replication of experimental procedures to evaluate test-retest reliability.

A two-factor analysis of variance and the Newman-Kuels multiple range test were used to analyze the data. A Pearson product-moment correlation coefficient was computed between test and retest speech discrimination scores.

Significant differences in speech discrimination ability were not obtained among the amplification modes in quiet. In the competing

better than the monaural mode and the binaural mode was also significantly better than the monaural mode. Significant differences in speech discrimination ability were not observed between the dichotic and binaural modes in the competing message condition. However, a trend favoring the dichotic mode was evident in the data.

A Pearson product-moment correlation coefficient (r) was computed between the word discrimination scores measured on the experimental test and the scores measured on the retest for seven subjects. The test-retest reliability coefficient of .95 was significant ($p<0.05$). The high correlation coefficient obtained on the test-retest conditions indicates that the experimental test procedure was reliable.

A t-test for testing differences between correlated variances was used to determine whether or not the subjects' variance on performance of the task changed from test to retest (Guilford, 1973). A non-significant t-ratio of .46 ($p>0.05$) indicated that there was no significant difference in subjects' variability from test to retest. In other words, the group variance was similar from test to retest.

Correlational analyses indicated that speech discrimination performance in one amplification mode for both quiet and speech-babble competing message listening conditions was highly related to speech discrimination performance in the other amplification modes. This result was particularly meaningful for dichotic amplification since it implied that the subjects in this study were able to discriminate speech with dichotic amplification in a manner closely related to speech discrimination in the more traditional monaural and binaural amplification modes.

B. In Monaural-Binaural Hearing-aid Performance

A total of 50 subjects participated in four experiments examining speech discrimination ability and/or localization response time to determine if the use of binaural aids would demonstrate an advantage over monaural aids. In the first experiment 5 loudspeakers were used, the signal emanating from each loudspeaker in turn. Uncorrelated babble from all 5 loudspeakers served as the competing message. In the second experiment 3 loudspeakers were used with the signal coming from the loudspeaker positioned at 0 deg azimuth and the babble coming from the loudspeakers at 315 deg and 45 deg azimuth. In the third experiment the same loudspeaker configuration was used to determine the effect of two different competing messages on the binaural and monaural modes. In the fourth experiment a signal below the average conversational level was used to determine differences between binaural and monaural listening. In the first two studies subjects were selected who had symmetry between ears; in the last two studies, subjects were selected if a hearing aid could be fitted for each ear without regard to symmetry.

In each instance, the differences between the group means ranged from 5.6 percent to 12 percent improvement in speech discrimination in favor of binaural amplification. With 6 percent improvement as the criterion, within each experiment, from 50 to 100 percent of the subjects obtained binaural performance scores better than monaural scores. Individual improvement ranged from 6 to 23 percent. These benefits were present even without an opportunity for prior practice with binaural aids.

With regard to localization, all of the subjects made correct responses as to speaker location whether they wore monaural or binaural aids. However, with the binaural aids, the responses were significantly faster.

It is believed that with proper selection of stimulus, competing message, loudspeaker location, and hearing aids, audiologists will be able to determine which patients have sufficiently better performance to warrant consideration of binaural hearing aids. This can be accomplished without taking advantage of head shadow effects. The binaural benefit does exist for some patients and can be demonstrated clinically through discrimination tests with competing messages. The ease of listening and improved quality of sound reportedly gained through binaural amplification have yet to be quantified.

In analyzing the results of these four studies the following statements appear most salient:

1. Localization response time is significantly improved with binaural hearing aids.
2. A test paradigm utilizing the Maryland CNC Test presented in presence of competing messages is effective in demonstrating clinically the benefits of binaural amplification.
3. Although it is possible to demonstrate a binaural advantage with a three loudspeaker arrangement, the most successful test configuration incorporated the 5 loudspeaker design with stimuli coming from each loudspeaker in turn. However, head-shadow effects made a contribution in the latter configuration.
4. Stimulus presentation levels that are lower than those usually employed clinically do not further enhance the demonstration of binaural advantage.

Interlist equivalency of the Maryland recordings of the CNC lists was demonstrated in the first experiment. Average scores ranged from 72.7 to 76.7 percent in the presence of babble.

Although interlist equivalency had previously been determined by Bender (1977), his research was conducted using low pass and speech spectrum noise.

All lists were within plus or minus 2 percent of the overall mean of

Test can be recommended for tasks different from those discussed above.

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

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Previous work by this group on the generation and mixing of harmonics and subharmonics indicates the possibility that speech spectrum contraction may be incorporated into this prognostic device. Again, this feature would be fully controllable, permitting optimization of the signal for the hearing-impaired veteran who has only frequencies below 1 kHz remaining.

Digital Spectrum Shaping and Contraction Applied to Audiological Instrumentation

From July 1, 1978 to December 31, 1978, the project efforts have been mainly on completing the design for digital deterministic spectrum-shaping and the system for producing known amounts of nonlinear distortion. The work on these two systems is a continuation of the research begun when Dr. Graupe was Professor of Electrical Engineering at Colorado State University, Fort Collins, Colorado. The digital microprocessor-based control system for the distortion

generator is capable of producing harmonic distortions of speech or other acoustic signals at controllable amplitudes and at controllable ranges of the frequency spectrum, the control and mixing with the original speech signal being operated by digital keyboard. This device similarly provides for generating subharmonics of speech and other audio signals, again at controlled amplitudes and frequency ranges, and mixing these with the original speech signal for experimental purposes.

The design for optimal staircase fitting of spectra uses microprocessor hardware to achieve a small audiometric device. Here, control of overall frequency range and staircase width are provided, as is the coding and generation of signals that control amplitudes, facilitating a keyboard-operated mapping of optimal amplification for the individual patient.

Research on Audible Outputs of Reading Machines for the Blind
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This research project has been terminated. A final report will appear in a future issue of the BPR.