DOCUMENT RESUME

ED 031 851 40 EC 004 216

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Conference on Speech Analyzing Communication Aids for the Deaf (Washington, D.C., June 14 and 15, 1967.)
Gallaudet College, Washington, D.C.
Spons Agency-Office of Education (DHEW), Washington, D.C. Bureau of Education for the Handicapped.
Bureau No-BR-7-0630
Pub Date Apr 69
Grant-OEG-2-7-070630-3024
Note-8p.
EDRS Price MF-$0.25 HC-$0.50
Descriptors-*Aurally Handicapped, Electronic Equipment, *Exceptional Child Education, Hearing Aids, *Sensory Aids, Spectrograms, Tactual Perception, Visible Speech

An introduction and description of conference purposes precede a list of participants who presented technical papers and demonstrations along with their titles and institutions. Accounts are given of the following types of aids described and demonstrated: frequency transposition for hearing aids, tactual aids, and visual speech aids. Conclusions and recommendations are included. (RJ)

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HEALTH, EDUCATION AND WELFARE

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The research reported herein was performed pursuant to a grant with the Office of Education, U. S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

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INTRODUCTION

During the past two decades, 1947-1967, there have been large technical advances in automatic acoustical analysis of speech sounds. In addition we now know a great deal more about how certain acoustic features of speech are related to the movements and states of the speech organs. A number of acoustic research workers in this field have developed special analyzers as prototypes of new aids to speech communication for the deaf and hard-of-hearing.

These advances were based on the previous work of Bell Telephone Laboratories where research on automatic acoustical analysis of speech began in the mid-1930's. Bell Laboratories' scientists were among the first to appreciate that automatic analysis of speech sounds might provide a valuable aid to speech communication for the deaf and severely hard-of-hearing. Bell engineers designed and tested a device, called the Visible Speech Translator, which painted a picture of the spectrum patterns of speech that was spoken into it. The visual patterns were somewhat complicated, as are the changing spectral patterns of speech. Also, knowledge of the salient pattern cues was, at that time, relatively undeveloped. Even so, one deaf subject learned eventually to "read" a large number of separate words by Visible Speech.

More recent research work in speech analysis has led to methods for indicating certain selected speech characteristics which are more closely related to the basic articulatory activity than were the patterns of the original Visible Speech. These specific characteristics are the voice pitch and intensity patterns, simplified vowel spectrum patterns, and some of the consonant features. Any one or combination of these may be used in a display as an aid for the deaf.

Speech analysis has also been the basis for a new approach to hearing aids for severe auditory impairment. The automatic analysis of speech provides continuous representations of the changing frequency patterns of speech. Most of the important patterns normally occur in frequency regions where the most severe hearing impairments are located. However the analyzed pattern, or parts of it, can be automatically re-located in frequency to a lower region where the hearing of many "deaf" persons remains more normal. Several devices for this purpose have been built and tested as special hearing aids.

The sensory presentation of analyzed speech patterns is not limited to vision and audition. Tactual representation of speech acoustic patterns has also been developed and tested on deaf subjects.

Those scientists who have developed new electronic aids for the deaf have also been concerned to develop the most efficient training procedures for retraining speech and auditory discrimination using the radically new aids.

PURPOSES OF CONFERENCE

It appeared extremely important to hold a research conference and demonstration of the developing new aids for the deaf. The reasons were as follows:

Considerable research and testing in this field had recently taken place outside the United States, whereas the work in the United States was less extensive; new U.S. contributions might be considerably stimulated and extended by direct contact with the foreign work; this potential benefit was especially likely because of the large reservoir of technical knowledge and facilities for speech research in the United States. At the same time, some of the foreign workers would have the opportunity to benefit from contact with American technical methods.

It seemed also that future practical work with special speech aids of this type would profit considerably by providing a direct and wider acquaintance with the devices currently under development. Both the potentialities and the limitations of these devices need to be considered in the planning of graduate education so that future teachers may acquire enough technical background to understand the basic principles of special aids.

DESCRIPTION OF CONFERENCE

An invited technical conference was held June 14 and 15, 1967, at the Hearing and Speech Center, Gallaudet College. Twenty-four technical papers were presented which were distributed as follows: ten on visual speech aids, four on transposer hearing aids, one on tactual speech coding, three on programmed language instruction for deaf children, two on the speech patterns of deaf talkers as compared with normal speech, one on general electronic techniques for speech analysis,and threeon theoretical problems in the recoding of speech.

A wide range of speech analyzing aids were brought for demonstration by those participants actively engaged in research and development in this field. The demonstrations were held in organized sequences on June 16 and June 17, and they were conducted for small groups by the authors and designers of the aids.

A list follows of the participants who presented technical papers and demonstrations (not including co-authors):

Participant	Title	Institution
Arne Risberg	Associate Director	Speech Transmission Laboratory Royal Institute of Technology Stockholm, Sweden

Participant	Title	Institution
B. Johansson	Head	Technical Audiology Lab Karolinska Institute Stockholm, Sweden
Janos Mártony	Dipl. Eng. (ETH) Engineer and Graduate Teacher	Speech Transmission Lab and State School for the Deaf Stockholm, Sweden
R. B. Stewart	Phonetician	Dept. of Education of the Deaf Manchester University Manchester, England
Sven Amcoff	Research Associate	Department of Education Uppsala University Uppsala, Sweden
R. Mazéas	Docteur	Centre Réeducation Fougeres, France
L. Piminow	Docteur	Centre Nationale des Études Telecommunication Paris, France
Knud Børrild	Laboratory Chief	State School for the Deaf Fredericia, Denmark
M. Kringlebotn	Dozent	Physics Department Norwegian Technical Institute Trondheim, Norway
K. Minami	Teacher	Mie School for the Deaf Tsu City, Japan
T. Sakai	Professor	Electrical Engineering Dept. Kyoto University Kyoto, Japan
A. S. House	Professor	Department of Audiology and Speech Sciences Purdue University Lafayette, Indiana
W. Pronovost	Program Director Speech, Hearing and Deafness	School of Education Boston University Boston, Massachusetts
J. M. Pickett	Research Professor	Hearing and Speech Center Gallaudet College Washington, D. C.

Participant	Title	Institution
A. Constam	Research Associate	Hearing and Speech Center Gallaudet College Washington, D. C.
R. Stark	Research Associate	Neurocommunications Lab Johns Hopkins University Baltimore, Maryland
N. Guttman	Speech Scientist	Bell Telephone Labs Murray Hill, New Jersey
J. Black	Professor	Speech Department Ohio State University Columbus, Ohio
P. Denes	Speech Scientist	Bell Telephone Labs Murray Hill, New Jersey
A. Liberman	Research Professor	Haskins Laboratories 345 East 43rd Street New York, New York
D. Sherman	Professor	Department of Audiology and Speech, Stanford University Palo Alto, California
D. Ling	Head	Project for Deaf Children McGill University Montreal, Canada

RESULTS

The following section gives a brief account of the types of aids described and demonstrated at the Conference. For detailed information the reader is referred to the published Proceedings of the Conference. These Proceedings were edited by the Conference Director and appeared as a sequence of 24 technical papers and related discussion in the American Annals of the Deaf, Volume 113, Number 2, pp. 116-330, March 1968.

Frequency transposition for hearing aids. It is possible to transpose the speech information in middle- and high-frequency ranges down to lower ranges. One such transposer operates on a mid-frequency band of speech between 2000 and 3000 Hz, a range that is usually inaudible to severely deaf persons. The transposer recodes the sounds to place them between 750 and 1000 Hz. Results of training and tests of deaf children showed no improvement in communication.

Another transposer leaves the mid-frequencies unchanged and transposes only the higher frequencies, above 4000 Hz. Tests with this transposer showed dramatic improvements in discrimination of fricative and stop consonants by profoundly deaf children.

Tactual aids. For the profound and totally deaf it is possible to present tactual representations of speech acoustic patterns. Skin reception of speech is a rather restricted communication channel compared with the normal ear or even with the severely hard-of-hearing ear. A main difficulty is the limited frequency-analyzing capacity of the skin. The spatial spread of masking on the skin makes it hard to substitute spatial patterns for the speech frequency patterns. Nevertheless various tactual speech analyzers have recently been built and tested on deaf children.

One tactual aid tested was a 10-channel vocoder where each channel control signal modulates a signal which vibrates a finger tip of the deaf subject. The speech intensity patterns over the ten frequency channels of the vocoder are represented by the amplitude patterns over ten vibrations applied to the ten finger tips. This device seemed fairly helpful on some of the speech distinctions that are extremely difficult to lipread. Reception of these features through the tactual vocoder was far from perfect but it was much better than the chance scores obtained with lipreading alone.

A simplified tactual vocoder employs only five vibrators fed by cascaded stages of pulse-frequency division to distribute five frequency ranges of the speech signal to vibrate the individual fingers. Results with this vocoder were better than those previously obtained.

Visual speech aids. One major application of speech analysis as an aid for the deaf is to provide visual indicators or pattern displays especially designed to serve as speech communication aids. Visual speech aids may be used to improve both speech reception and speech production, but they seem best as speech training aids.

There have been five basically different displays used in visual speech trainers. First there is the speech-spectrographic display of frequency and intensity, as patterned in time, of the Bell Visible Speech Translator. This consists of a 19-channel frequency analyzer, with associated intensity-measuring and time-scanning circuits, and an oscilloscope display. In the display, frequency is represented vertically, time horizontally, and intensity is represented by brightness. The first results of research on speech training of deaf speakers with the spectrographic display have been mildly encouraging. A second type of spectral pattern display eliminates the time dimension in favor of presenting a more detailed display of intensity and frequency. It consists of a 20-channel frequency analyzer which controls the patterns of a 10 x 20 matrix of lights. The intensity in each channel lights a column of bulbs proportional in height to the speech intensity in that channel.

A third spectral display simplifies the indication even further by presenting a single spot of light which moves on an oscilloscope screen in a plane representing the position in frequency of the two main vowel peaks which differentiate the vowels and some of the consonants. The fourth class of display is a time-swept trace on a screen, of some prosodic speech feature, such as voice pitch, or voice intensity, or of the rhythm of the vowel and consonant articulations.

In the fifth type of display, the presence or quality of a particular speech feature, such as nasality or fricative sharpness is indicated by a meter needle or light flash.

CONCLUSIONS

As noted at the Conference, quite a few new speech communication aids have been developed. Some are already in use in schools for the deaf. A variety of these aids are now available for purchase. However, the experimental testing of the effects of these aids is still only in its first stages. It is probable that many of the current aids will be only modestly useful, and that the best ones will be highly successful only in restricted areas. There are several reasons: 1) the lack of any thoroughly systematic knowledge of the normal process of speech acquisition, 2) limitations in our knowledge of relations between acoustic patterns and articulatory patterns, 3) the possibility that speech recoding for other than auditory presentation will meet "inherent" obstacles of incompatibility, and 4) that residual auditory capacity may be too limited to accomodate transposed speech.

RECOMMENDATIONS

Two avenues of approach are recommended for further work to develop the best possible speech communication aids based on current scientific and engineering capabilities in speech analysis. One approach should stress basic research on normal speech acquisition and particularly with respect to the role of the sensory models that operate in the speech learning process, the nature of optimum feedback properties, and the reinforcement conditions. At the same time a second, more applied approach should be taken to evaluate those speech-analyzing aids currently available. This evaluation research should be done in educational settings, or at least with active participation of teachers. The evaluations would develop ways of using current devices and it would also provide practical tests of the theories of speech acquisition processes that develop in the basic research.