SPEECH AND HEARING SCIENCE AS RELATED TO CLINICAL AUDIOLOGY AND SPEECH AND LANGUAGE PATHOLOGY

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Introduction

It is the intent of the authors to comment generally upon the relevance of the discipline of speech and hearing science as the principal substratum upon which the professions of speech and language pathology and audiology are built. This is not meant to deny the importance of other areas that contribute information such as physics, anatomy, neurophysiology, linguistics, or psychology; for in order to explore the important correlates of speech, language, and audition one must call upon information provided for by these disciplines. In a sense, the speech and hearing scientist, if properly prepared, is one who can deal meaningfully with those elements of the other disciplines that bear significantly upon his inquiries into events of speech, language, or audition.

Specifically, this paper will (1) focus upon speech, language, and hearing, as areas for scientific inquiry; (2) suggest methodologies involved in the inquiry; and (3) provide examples of the importance of scientific investigations in speech, language, and hearing to the clinician who would serve those handicapped by disorders of communication.

Speech, Language, and Hearing as Areas of Inquiry

Topics for inquiry within these areas are legion and vary in character from those that are strictly physical questions to those that are principally behavioural. For example, when one asks a question concerning the spectral components of voice, he deals with a physical measurement problem. And when one, in the interests of determining the noxious acoustic elements of airport, factory, or highway environments determines the sound pressure levels and other dimensions of noise, likewise he has a real problem of physical measurement with which to deal. However, as the speech or hearing scientist attempts to determine an absolute threshold (or lower limit of sensation) for a particular acoustic stimulus, he is involved in a problem of psychophysical measurement. He is relating a

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human response to a physical stimulus. Both physical and psychophysical methods of measurement employ numbers in the process, and investigators describe and communicate their findings via the language of mathematics. The precision with which description can be made of psychophysical phenomena concerning the human functions of speech or hearing, is related in no small measure to the progress and maturity of the scientific study of speech and hearing.

The content of the inquiry made by speech and hearing scientists has to do with the (1) neuropsychological processes that are responsible for verbal output (the encoding system), (2) the actual output (speech and language), (3) the media through which the message is passed along (channel capacity, in-line noise, etc.), (4) the neuropsychophysiology of the receiving and perceiving systems, and (5) the behavioural responses that are made to the stimuli.

From an historical point of view, the rigorous approach to the study of hearing has spanned several centuries, and the study of the speech and language processes (from the standpoints of physiological phonetics and psycholinguistics) a little more than a century.

As one looks back to the mid-sixteenth century for example, he sees the first accurate descriptions of the middle ear mechanisms by Vesalius and Fallopius. (Wever, 1957) Eustacius gave good description of the tensor tympani muscle and its function in 1564, and not until 27 years later did Varolius describe the second of the tympanic muscles, the stapedius (in 1591). The first book on the ear was written by Coiter (1566) (DeAuditus Instrumanto). (Wever, 1957).

Following description of the mechanism, theories as to function sprung up on all sides, and from the first resonance theory of hearing by Bauhin (1605) until 1969, there has been speculation and experimentation which has yielded some truth in the matter (Wever, 1957). The early theorists did not have the advantage of knowing of the existence of the inner ear which lies deeply embedded within the temporal bone, and their theories reflected this inadequacy. The development of finer anatomical dissection techniques, and electronics have made for real advances in understanding how the ear works. And today we have available some pretty creditable theory relative to audition. This kind of development has helped in great measure to lay the groundwork for what we refer to as modern clinical audiology.

In so far as the early explorations in speech are concerned, we are reminded of the early work of Von Kemplen and his attempt to make a talking machine as well as the pioneering work of A. G. Bell in his attempts to construct an amplification system to assist his hard of hearing wife understand speech. The development of recording devices from the wire recorder on up through present developments that make high fidelity recording possible on magnetic tapes have made for refinements in research. Analyzing devices were at the outset quite crude with smoke drum tracing, etc. Today we have the finer electronic equipment available for spectrographic analysis of the speech signal. The early significant work of Stetson (Motor Phonetics), Scripture, and Russell, in the first part of this century has laid the groundwork for present day explorations in physiological phonetics. The work of Fairbanks contributed heavily in experimental phonetics toward the development of theory of the speech mechanism as a servosystem; toward understanding the effects of time compression on the comprehension of connected speech; toward the further understanding of organogenesis in articulation. Also, the work of Peterson in specifying the properties of the vowel looms large. The intensive work of Black, Moser and their colleagues holds a prominent place in the stream of events as regards more complete understanding of speech intelligibility. George Kopp is still another name to be added to the list of contributors as one views his successful efforts in translating the acoustic signal of speech to a visible one. The work of scientists at Haskins Laboratories on speech perception is of real significance.

In terms of the future, we shall probably see as a result of speech research that there will be automatic recognition and translation of speech by machines. There are presently some primative recognizers built, but they can handle only a very small vocabulary of words. Just imagine what could happen in terms of application of such devices—automatic dialing of phones—automatic voice operated typewriters—automatic translation of foreign languages, with two people speaking different languages holding a telephone conversation with each other, etc. The technique of speech synthesis is fast being perfected to the point of producing highly intelligible speech via machines. Also, it is possible to look ahead hopefully toward bandwidth compression systems so that much more effective use can be made of channels of communication. Another area that will undoubtedly develop is that of diagnosis of early neurological deficit through analysis of the oral output. Such a development will proceed only as neurophysiology *per se* develops as an area of inquiry and as speech and hearing scientists keep abreast of that development. Much of what sounds like science fiction today will in large measure be fact in the future.

Methodologies Involved in the Inquiry

In the main, the search for truth in modern speech and hearing inquiry follows some rather well-described methods and procedures. The study for the most part could be described as empirical or experimental in nature. Historical or critical review finds little place in the scheme of things, except for delineating the background against which an inquiry is to be made. Much of the measurement follows traditional psychophysics—(the method of average error, minimal changes, and the constant method), and the psychological scaling methods such as pair, comparisons, ranking method, rating scales, equal appearing intervals. These methods and variations of them have assisted in inquiry where strictly psychophysical methods would be clearly inappropriate. For in some instances there is no physical stimulus present, for example studies that seek to determine a stutterer's attitudes toward certain aspects of his environment, or perhaps those seeking to determine the features of family solidarity or marital tensions in a group of hard of hearing parents and a group of normally hearing parents.

Since there is still so much basic information yet to be derived about human hearing and speech, normative studies are quite in order before experimental kinds of questions become appropriate.

Treating those with disorders of communication is an applied science. If progress is to be made in treating those who are handicapped by disorders of communication the profession must make constant demand of the speech, language, and hearing scientists for new theories and new facts. Just as biochemistry, pharmacology, anatomy, physiology are to medicine or dentistry, so must speech, language, and hearing sciences be to speech and language pathology and audiology. Any group that purports to offer specified procedures and techniques to ameliorate the disorders or handicaps of individuals must have continuous input from the discipline(s) supporting it lest the profession becomes out-dated and eventually of little value. Speech and language, pathology and audiology are no exceptions. Fortunately there has been and continues to be input from scientific investigations in language, speech, and hearing to speech and language pathology and audiology. A few notable examples highlight this assertion.

Inputs from Speech, Language, and Hearing Sciences to Speech and Language Pathology and Audiology

It is imperative that, to understand the abnormal in a manner permitting adequate remediation, it is necessary to have a thorough knowledge of the acoustic and physiologic processes underlying speech, language and hearing. A strong foundation in the speech and hearing sciences provides such a background. At Michigan State University, for example, during their preprofessional training, students are exposed to general human anatomy and physiology prior to courses in anatomy and physiology of the speech and hearing mechanism. In addition, they must satisfactorily complete courses in physics and mathematics. In introductory speech and hearing science courses, they are presented the basic acoustic and physiological information involved in the normal human speech and hearing processes, and are trained to determine when those processes are not normal based upon their knowledge of normal speech and hearing behaviour.

A firm understanding of the physiological correlates of speech and hearing include knowledge of the breathing mechanism and how it functions during speech and language production; the laryngeal correlates of intensity, pitch and quality; the physiological correlates associated with the acoustic signal and subsequent resonance characteristic during speech production; and of course, the anatomical and physiological characteristics of the human hearing mechanism. It is also necessary to understand the underlying neurological system which coordinates and programmes the speech, language and hearing processes. Speech and hearing science, then, provides the knowledge necessary to understand the acoustic, physiologic, and neuroanatomic characteristics of the speech and hearing process. The therapist who has this knowledge is prepared to understand and remediate problems which may not always be discussed in the 'textbooks'.

In the area of speech and language training for the deaf, for example, the therapist who has a clear understanding of the acoustic characteristics of speech production and how the acoustic signal represents the underlying physiological mechanism can use this knowledge to determine how he might best modify articulatory production, and thus provide resonance chambers in the oral cavity that may result in an acoustic signal that approximates that of the normal speaker. A clear understanding of the breathing mechanism permits the speech and language pathologist to better remediate the speech behaviour, for example, of the cerebral palsied speaker. An understanding of the acoustic and physiologic correlates of nasality permit a clearer understanding of the speech production of the cleft palate speaker and the speaker who exhibits velopharyngeal incompetencies (Hardy, 1965). Thus, speech science not only provides a backdrop against which to compare the abnormal, but allows an understanding of the abnormal. And, as noted by Peterson (1958), in order to determine what is abnormal and what to do about it, we must understand the normal.

The theoretical description of speech production as a series of syllable or chest pulses has led to the sensori-motor theory of speech correction and the development of a deep test of articulation, whereby misarticulations are diagnosed in a linguistic context (MacDonald, 1967). In addition, cineradiography has provided a basis for discussion of the overlapping articulatory movements (known as coarticulation) that occur during speech production. Therapeutic procedures resulting from such information has subsequently been initiated. This information has been correlated to the effect the several resonators of the oral cavity have upon each other. In recent years speech production and perception have been correlated to linguistic data, an example of which is the area of distinctive features. Here the features of the phonemes of a language are determined, and therapeutic procedures are then applied that are directed toward modification of these features of phonemes, rather than modification of the phonemes *per se*. Another area which the speech and hearing scientist studies is that of neurolinguistics, i.e., the relationship of neurological programming and perception of linguistic messages. Knowledge of this area permits the speech and language pathologist to better understand the problems of aphasia and central auditory disorders. Such interests are exemplified in the study of the temporal processing involved in speech and hearing. Speech production models have been devised that suggest that speech and language are neurologically programmed on a temporal basis (Henke, 1967). On the perceptual side, a speech and hearing scientist, Grant Fairbanks, was one of the early pioneers of time-compressed speech. In fact, he developed one of the first electro-mechanical time compressors (Fairbanks, *et al.,* 1954). When the speech signal was time-compressed, persons who put a premium on listening were provided a method that decreased the time needed for listening, while adequate intelligibility of the signal was retained. The blind found a great deal of use for such stimuli (Foulke, 1966), and such signals apparently may well provide an added advantage to diagnosis of central auditory disorders (Beasley, *et al.,* 1972). The hearing scientist has provided the audiologist the basic information to permit development of sophisticated psychoacoustic measures of hearing, including the short-increment sensitivity index (SISI) (Jerger, *et al,* 1959), Bekesy audiometry (Bekesy, 1947) and electroencephalographic (EEG) audiometry (Lane, *et ah,* 1971). In addition, from the hearing science laboratory has come information on the effect of loud rock and roll music on human hearing (Smitley and Rintelmann, 1971).

Speech and hearing science in recent years has developed and made use of extremely sophisticated instrumentation. As mentioned above, the use of motion picture radiography (cineradiography) has permitted direct observation of the physiological functioning of the articulators during normal speech production (Moll, 1965). Studies using electromyographic instrumentation has permitted refined observation of the neuromuscular activity of the speech mechanism (Cooper, 1965). Procedures to assist clients in learning improved breathing for speech, e.g., in cerebral palsy, have been developed using the respirometer. The development of an inexpensive portable time-compressor has made the use of this instrument a feasible reality in areas other than the laboratory, e.g., in the classroom and perhaps even the home. The determination of the spectrographic characteristics of the 'abnormal' voice is currently being determined, and will subsequently be compared to the acoustic characteristics of the 'normal' voice. Again, such information provides the speech and language pathologist with an 'acoustic goal' to aim for during therapy. The normal physiological data, on the other hand, gives him the knowledge of how best to attain that goal, i.e., what behaviours to modify.

Of course, the speech scientist can provide information to areas of communication other than those pertaining to remediation. For example, acoustic data in the form of spectrographs have been employed in speaker identification (Tosi, *et al.,* 1972). Temporal and spatial modifications of speech signals have been used in communication systems. Prior to such use, however, it was necessary to determine the practical limits of such signals. These limitations have been, for the most part, determined in the speech and hearing science laboratory.

Another application of a sort provided by training in speech science is that it provides the speech and language pathologist with 'a way of thinking'. The speech scientist must derive his information from systematic observation, which often takes the form of formal research. A student of speech science learns to observe and record information and 'think' in a systematic and quantitative manner. He develops a strong 'show me' attitude. Unsubstantiated feelings and intuitions have minimal use to the speech and language pathologist who has a firm foundation in speech and hearing science. He knows the necessity of keeping current on new information and has developed a critical eye for evaluating this new information, and determining ways and means to which it may be applied. His training in speech science has permitted him a firm understanding of modern technology, and more importantly, the limitations of that technology. He cannot be deceived into thinking that a new piece of 'equipment' will solve all his therapeutic problems, or that a new test or technique will provide 'the answer' to therapy with all his clients. In fact, he will be aware that there are as yet too few answers, only more and better questions. His speech science training will permit him to be discovered by way of valid questions. And 'good' questions can only be formulated with a firm knowledge of the mechanism and process under study.

Obviously this is a brief overview of the potential applications of the knowledge from the speech and hearing sciences. And, of course, the speech and hearing scientist has only barely begun to uncover the myriad of detail associated with speech, language, and hearing. But habilitation and rehabilitation will improve only as new facts and information become available.

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