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PHONETICS:

AN OVERVIEW

INTRODUCTION

Phonetics is traditionally concerned with the ways in which the sounds of speech are produced, but the resulting descriptions normally mix auditory factors with articulatory ones, thus depending ultimately upon percepts of the phonetician. This would be true even in a laboratory report using such terms as 'high back vowel' that do not themselves stem from instrumental analysis. At the very least, then, we must include the hearing of speech sounds in the definition of phonetics to the extent of allowing for the behavior of the field phonetician who uses his ears to match spans of speech with points or zones of the reference grid he has learned. This grid consists of auditory images correlated with places and manners of articulation. That is, the practical phonetician uses auditory phonetics as a research technique in achieving the goals of articulatory phonetics.

In recent decades, with the waxing importance of psychology in phonetic research, there is no question but that auditory perception has become a central topic of phonetics. In addition, the rise of experimental phonetics with its rapidly improving instrumental techniques (Fant 1958; Cooper 1965) has made it possible to look at the speech signal itself, thus adding acoustic phonetics to the scope of the field. In the light of these developments, phonetics may now be defined as the study of the speech signal and its production and perception.¹ A broad view of the interweaving of practical phonetics, the study of the production of speech, analysis of the acoustic signal, and experiments on perception is presented within an historical framework by Dennis B. Fry in his article in this volume.

The collaboration of phoneticians,² acousticians, electrical engineers, experimental psychologists, and physiologists has enabled phonetics to surge forward in recent decades, but at the same time it tends to hamper the linguist in applying the findings of phonetic research to his own phonological preoccupations. Even if mild pro-

¹ I believe that nowadays it is pointless to insist on a sharp distinction between experimental, or instrumental, phonetics and articulatory-auditory, or 'practical', phonetics.

² The term here includes scholars who traditionally function in academic departments of linguistics and modern languages as well as those who function, sometimes under the label of 'speech scientists', in departments of speech and hearing.

professional indignation prompts one to rebuke the linguist whose phonological abstractions seem to be unsupported by the facts of speech production and perception (Abramson and Lisker 1970; Fry in this volume), it certainly behooves us phoneticians to present our material from time to time in a form that our linguist colleagues will find readable.³ It is hard to think of a textbook in phonetics published in the last decade that fills this gap. Some (e.g. Abercrombie 1967) provide a general theoretical and factual matrix within which to give a course. Others (e.g. Gimson 1962; Malmberg 1963; Schubiger 1970) try to do some justice to the union of linguistic phonetics, acoustics, physiology, and psychology already mentioned. There are also a few textbooks that gently introduce their readers to rather technical material (e.g. Ladefoged 1962; Denes and Pinson 1963; Hadding-Koch and Petersson 1965; Zemlin 1968; Lindner 1969); others with this orientation might be considered textbooks, but only by those with some sophistication in mathematics and electronics (e.g. Fant 1960; Flanagan 1965). Certain monographs specifically addressed to linguists have been readable enough to be vulnerable to scholarly criticism as well as appreciated for their possible impact on points of linguistic analysis and theory (e.g. Abramson 1962; Ladefoged 1964; Delattre 1966; Lieberman 1967; Gårding 1967; Lehiste 1970).

Even the well-motivated linguist, then, cannot have found it convenient to keep abreast of new developments in phonetics over the last several years. Scanning the *Proceedings* of the various international congresses, such as the International Congress of Phonetic Sciences, is a haphazard way of doing this. In the absence of comprehensive textbooks, a satisfactory way of presenting material on the state of the art and science of phonetics is to invite a group of specialists to contribute chapters to a book. Although one such collection has appeared recently, the new edition of the *Manual of phonetics* (Malmberg 1968), it was felt that it would be appropriate and useful for a volume of *Current Trends in Linguistics* to include another collection of papers with a considerable change in the selection of major topics as well as a largely different list of authors. Two of the authors, J. C. Catford and D. B. Fry, reappear but their versatility has permitted us to ask them to contribute chapters on new topics.

The foregoing considerations should not lead the reader to believe the collection of papers on phonetics in the present volume can in fact serve as an introductory textbook in phonetics. In accepting a topic, each author committed himself to a critical exposition of the research in areas in which he himself is active. In deciding on a list of ten topics and ten authors to handle them, I tried to think of themes that would cut broad swaths through the field of phonetics in an interesting and useful fashion. Some, of course, are more narrowly specialized than others and consequently more demanding of the reader. The authors, by the way, were not passive partners in the selection of topics; some of them negotiated for deviations from the original agreement. For the linguist dipping into this section then, the

³ Naturally this point applies equally to the grammarians.

kind of background he would need for intelligent reading is available in the books cited earlier. Internally there is considerable cohesion among the ten articles presented here. They might all best be read against the background of the article by D. B. Fry and perhaps some of the thoughts expressed in this "Overview". The authors were aware of each other's presence in the projected volume, some of them even being in the fortunate position of being able to see a few of their fellow contributors' rough drafts, and they provide cross references where needed. In what follows, I will try to furnish more systematic interconnections.

1. DIRECTIONS

Modern phonetics has moved in a number of directions simultaneously, aiming to achieve a greater understanding of the phenomena of the production and perception of speech, making contributions to phonological and psychological theory, and yielding practical advances of use to language teachers and communication engineers. A lucid and well-balanced perspective on these directions and goals is to be found in D. B. Fry's article.

1.1. *Production and Perception*

It is obvious that one can attend separately to mechanisms of production of speech (Harris, Sawashima) and perception of speech (Studdert-Kennedy), but in any broad view of the speech process, it is becoming increasingly difficult to keep the two apart. The study of the correlations between these two aspects of the speech event, with particular concentration on the acoustic signal as the link that binds them, has been called acoustic phonetics. The article contributed by J. Heinz was intended as a statement of what we know today about speech acoustics. In fact, treating the topic under the three divisions of sources of sound, sound modification, and acoustic characteristics of speech sounds, it goes much further. By shuttling between aspects of physiological control and acoustic output, the author provides the basis for a combined articulatory-acoustic phonetics that, taken together with the study of speech perception, I believe to be the kind of phonetics that all students of linguistics should have as part of their training. The reader with such objectives in mind will find it useful to go directly from Heinz to Studdert-Kennedy. Of course, I should add that concern with the relations between production and perception is found throughout this section of the book, with some authors stressing one side or the other.

1.2. *Phonology*

Phonology, whether it be considered an autonomous domain of language structure or a component of the grammar intimately integrated with other components (Postal

1968), is likely to be fairly abstract. The linguist may need broad phonetic symbols to represent phonemes or matrices of distinctive features, for use in transcribing sentences of a language in a distinctive fashion or spelling lexical entries. But no matter how abstract the level of phonology — a phonemic transcription devoid of all redundancy or sets of binary classificatory features for characterizing underlying forms — the phonologist's strategy must include instructions for going from his particular kind of abstraction to a phonetic output that is consistent with observational data on both production and perception. In seeking to determine the physical bases of phonological distinctions, the phonetician provides information on physiological mechanisms and acoustic features implied by the phonologist's instructions. To what extent the linguist is willing to check his phonological statements against the data supplied by the phonetician (Lisker et al. 1962) may depend in part upon the depth of his conviction as to the validity of his theory and in part upon his level of sophistication in matters of speech production and perception; the two may not be unrelated. Students of language vary considerably in their willingness to let observation and experiment alternate with speculation and theorizing; this is the constant theme that runs through D. B. Fry's article.

While current theorizing on generative phonology is perhaps in many respects more abstract than the kinds of phonology espoused by other schools of thought, it also has the merit of trying to be very explicit about the speech-producing capabilities of the human vocal tract in terms of a 'universal phonetics' (Chomsky and Halle 1968: Chap. 7). Of course the very explicitness of these physical descriptions of phonetic features should and indeed does make at least some of them vulnerable to criticism based on hard data or, in fact, on lack of data (Lisker and Abramson 1971). It should be understood that other phonetic theories have been presented in the recent past (e.g. Peterson and Shoup 1966a, 1966b), but it is especially encouraging occasionally to find an experimental phonetician, well grounded in linguistics, laying the basis of a phonetic theory within a phonological framework (Lieberman 1970). The argument that the phonologist, confronted by the increasingly technical nature of phonetics, can avoid yielding to 'the temptation to do phonology on the basis of phonetic folklore' by focusing his attention on the work of investigators engaged in synthesis of speech by rule, is persuasively presented by I. G. Mattingly. Other articles in this section that would seem to be relevant to particular principles of phonology are those by L. Lisker, P. Lieberman, and J. C. Catford, even though all the contributions should be useful to the linguist in their bearing on general phonetics.

1.3. *Psychology*

It must be stressed that the interdisciplinary character of phonetic research today is not meant merely to provide grist for the linguist's mill. One of the participating

disciplines, psychology, also has a vested interest in phonetics. Speech is such a complex, and yet so highly organized, form of human behavior that it was inevitable that psychologists would raise questions about it and design experiments to answer those questions. Here, of course, we are concerned with those psychologists who have investigated mechanisms involved in the production of the sounds of speech as well as the perceptual processing of those sounds. Two of the authors in the present collection, K. S. Harris and M. Studdert-Kennedy, are psychologists who have devoted the major part of their research efforts for some years to phonetics. Most of the other authors have worked in close collaboration with experimental and physiological psychologists.

I think it is easy to defend the proposition that it was the emergence of the Haskins Laboratories group (Cooper 1950; Cooper et al. 1951) that stimulated lines of research that gradually convinced more and more psychologists that psychologically interesting questions could be answered by experimental phonetic techniques.⁴ One of the members of the group, M. Studdert-Kennedy, leads us carefully and revealingly through what might otherwise be a maze of disconnected roads and byways covering recent thought and research into the perception of speech. His generous bibliography enables the reader to pursue with ease any point raised in his account. It may surprise some readers to learn that much physiological phonetic work going on in our day derives from psychological speculation concerning links between certain aspects of speech perception and the control of articulatory gestures. In her chapter in this volume, K. S. Harris discusses the matter with particular attention to electromyography as a research technique. Finally, it must be said that psychologists have begun to find phonetic research relevant to questions of language acquisition in both children and adults.

2. METHODS AND APPLICATIONS

In the past decade, the rapidly increasing involvement of engineers, physicians, and computer people in speech research has resulted in a great elaboration of methods of conducting phonetic studies. The authors in this section discuss some of these techniques only to the extent that they are needed in support of themes and concepts being presented. The reader who desires a broad but not too technical knowledge of these developments should consult one of the general works mentioned at the beginning of this "Overview". Anyone wishing to avail himself of a new technique or an instrument not commercially available may find what he needs in such technical notes as occasionally appear in the *Journal of the Acoustical Society of America* (e.g. Shipp et al. 1970; Sussman and Smith 1970). Interwoven with references to research methods in the following paragraphs is concern with the more or

⁴ Harvey Fletcher (1929) and George A. Miller (1951) provide surveys of earlier work on speech perception.

less practical application of phonetics to problems of communications engineering, speech and hearing disorders, language description, and language pedagogy.

2.1. *Physiological Research*

Physiological phonetics has furnished us with a rather detailed, if uneven, picture of supraglottal articulations, control of the larynx, management of movements and accumulations of air and — in recent years — muscle contractions involved in all these aspects of the speech event. What with current speculation on 'feature detectors' and data bearing on the probable links between perception and articulation, it is to be hoped that the neurologists will help us probe into speech mechanisms at even higher levels of control in the not too distant future.

If the linguist is right in asserting that a phonological entity can appear intact over a wide range of environments, then one important task of the phonetician is to explain physiologically what production mechanisms are common to all these manifestations and, at the same time, which ones are needed to account for contextual variation. Of the latter, some may be under active control of the speaker and others simply automatic consequences of the constraints of the human vocal apparatus. With these questions as a unifying theme, K. S. Harris gives us a critical survey of the major trends in current research on speech physiology. After establishing a theoretical framework along with a helpful digression on electromyography, she presents the organization of the speech musculature. This is divided into the respiratory system, laryngeal mechanisms, and the upper articulators. Linguists and, indeed, phoneticians who have uncritically accepted certain phonetic observations as support for particular phonological hypotheses may find it sobering to read some of the discussion in this part of Harris's contribution. The rest of the review concerns the organization of speech, followed by a concluding discussion of the failure so far to find an invariant physiological representation of the phoneme at the peripheral levels investigated.

K. S. Harris gives considerable attention to laryngeal mechanisms as does P. Lieberman in his review of work on prosodic features. Of course there has been considerable physiological research on the larynx itself, to be found mostly in the medical literature. M. Sawashima, one of those rare laryngologists devoting much of their effort to speech research, has culled this literature to provide background material to help the phonetician understand the mechanisms whose functions he is exploring. Following this, the bulk of Sawashima's report discusses recent progress in observing the larynx during the production of voice and speech. This is not an article for beginners. To reap all the benefits to be had from it, the reader should at least have the depth of knowledge of the anatomy of the larynx and of the myo-elastic-aerodynamic theory of phonation as described by Sonesson (1968) or Zemlin (1968). P. Lieberman presents physiological data and arguments dealing with the

interplay of variations in tensions of the intrinsic muscles of the larynx and changes in subglottal air pressure in the control of prosodic features.

2.2. *Acoustic Analysis*

The availability of the sound spectrograph at the end of World War II (Joos 1948) gave a great impetus to the research effort that culminated in the present-day acoustic theory of speech production so succinctly outlined by J. Heinz in his report on seminal studies of the last couple of decades. Here, too, we have an article that requires some background on the part of the reader. It would be advisable to have control of such elementary acoustic concepts and basic acoustic phonetics as presented in Denes and Pinson (1963) before reading Heinz to learn about current trends and findings in acoustic phonetic research. The articles by L. Lisker on temporal aspects of speech and A. Malécot on studies in comparative phonetics lean heavily on acoustic data. Of course, most of the other articles make frequent allusions to acoustics too.

2.3. *Speech Synthesis*

Gone are the days when speech synthesizers were available only to the privileged few at scattered points in Europe and North America. Experimental phoneticians now have access to synthesizers at many universities and research institutes. Nearly all of them are terminal analog devices which, when properly programmed, simulate the acoustic output of the human vocal tract. At the same time, there has been work on synthesizers that are analogs of the vocal tract itself. The synthesizer can be used as a very flexible linguistic 'informant', capable of separately controlling individual phonetic parameters in a way no human speaker can do. I. G. Mattingly gives a helpful historical and conceptual background on speech synthesizers before launching into the question of their relevance for phonetic and phonological models. Here, too, it must be said that we are talking of a method of phonetic research that looms large in most of the articles in this section.

2.4. *Experiments in Speech Perception*

Manipulating real or synthetic speech has been a powerful research technique with two major objectives: (1) finding the information-bearing elements of the speech signal and (2) testing hypotheses on the nature of speech perception. For the first goal, the experimenter examines acoustic displays of utterances, usually spectrograms, to pinpoint features that seem to be correlated with the phonological distinction of interest. Nowadays, as compared with the pioneer days of this enterprise, he would approach the task armed with an acoustic theory of speech production

that takes articulation into account. Having formed an hypothesis as to what is carrying the information, in the simplest case a single acoustic feature, he will synthesize a set of utterances varying only along this single dimension, record them many times each on magnetic tape and then play them in random order to native speakers of the language for identification as words or syllables of the language. For example, let us suppose that our investigator wishes to determine what acoustic cues distinguish /s/ from /ʃ/. Examining such pairs of English words as *sin* / *shin*, *so* / *show*, etc., where he believes on linguistic grounds the same phonological contrast to prevail over all the environments, he observes certain frequency differences in the spectral distribution of the turbulent noise of the fricatives.⁵ He will then set the parameters of the synthesizer so that appropriate formants and nasal resonances are combined to give the auditory impression of [ɪn] with a time span reserved at the beginning for the frication variants. In the initial slot, he uses the noise generator of the synthesizer to produce variants in small steps over the full range of spectral differences observed and perhaps somewhat beyond to be sure to bracket the two phonemes. The rest of the procedure is as I have outlined it for the general case. Having found that differences in spectral distribution of noise energy are indeed relevant for this syllable type (Harris 1956), the phonetician might well check it across a sampling of other vocalic environments. For some kinds of acoustic cues it is possible to avoid synthesis and simply manipulate natural speech, as in filtering experiments (Gay 1970) or tape cutting and splicing (Hadding-Koch and Abramson 1964).

For the second goal, the testing of hypotheses on the nature of speech perception, a favorite technique through the years has been discrimination testing. One constant theme has been the comparison of the acuity of discrimination of variants along a physical dimension relevant to a phonological distinction with the findings of the classical psycho-acoustic experiments on the discrimination of pitch, loudness, etc. In more recent years, with questions of lateralization of speech processing in the brain coming to the fore, a prominent technique has been that of the dichotic experiment in which competing signals are presented to the two ears. These topics in their proper setting are presented at considerable length by M. Studdert-Kennedy.

2.5. *Engineering Applications*

Much of the impetus for phonetic research during the twentieth century has come from outside linguistics. Communications engineers concerned with more efficient transmission of speech signals and automatic recognition of speech have contributed much to our understanding of phonetic phenomena (Cherry 1957; Flanagan 1965). The early efforts of the telephone engineers concentrated on the problem of getting

⁵ Of course he may detect other differences as well, some of which may ultimately turn out to have perceptual relevance too. Normal practice would be to creep up on these one by one, testing the sufficiency of each one, and only later to assess the combined effect of all of them.

a sufficiently broad frequency range out of their equipment to cover enough of the voice range for minimum loss of message intelligibility (Fletcher 1929). Gradually the orientation of these engineers shifted to the analysis of the speech signal into its information-bearing components and the question of what kind of channel was needed to transmit only the features relevant for message intelligibility (Cherry 1957). One of the fond hopes of our engineering colleagues has been to succeed so well in determining the acoustic cues of speech that it would be possible to design various devices that could 'recognize' speech automatically (Flanagan 1965:158-164). One could then give dictation to 'phonetic' typewriters, sort packages in the post office by naming the destination aloud, run machinery by voice command while having the hands free to cope with other aspects of the work, and in general 'converse' with computers. Despite much frustration among workers in this field, perhaps largely because of naivete with regard to the syntactic and semantic aspects of speech communication, the work on automatic recognition has helped in our general research effort. D. B. Fry devotes a section of his article to phonetics and engineering.

2.6. *Handicaps in Communication*

Speech therapists and audiologists are ready consumers of phonetic data (Halpern 1971). It is easy to see that the therapist seeking to help his patient compensate for organic deficiencies or adjust to a post-operative state should be well grounded in phonetics. The same reasoning applies of course to the speech correctionist working with normally endowed people whose articulatory habits are for one reason or another abnormal. Many a linguist, however, may not be aware of the applications of phonetic research to the handling of hearing impairments (Whetnall and Fry 1964; Huntington et al. 1968). Taking a patient's hearing loss into account, the problem, broadly speaking, is to make sufficient acoustic cues available to such residual hearing as he has. Such considerations are important for the design of sensory aids such as conventional hearing aids or more sophisticated devices that may be available in the future. Reading machines for the blind form another class of sensory aids depending very heavily on phonetic research (Cooper et al. 1969). The goal here is to have a machine that will scan the printed page and, using speech synthesis by rule (Mattingly in this volume), convert the printed material into a phonetic output that is not only intelligible but also esthetically quite tolerable to the blind. Much of the acoustic phonetic research conducted at Haskins Laboratories over the years has been applied to this problem.

2.7. *Practical Phonetics*

Linguists, language teachers, and speech therapists are often called upon to apply auditory-articulatory techniques to the description of speech signals. The linguist

does it as part of his code-cracking operation in doing fieldwork with an unknown language. The language teacher does it to assess the errors of his students. The speech therapist does it in the clinic or classroom to describe deviations from normal speech. How well and consistently can a practical phonetician describe a vowel phone using, say, the IPA Cardinal Vowel reference system? What significance do we attach to such descriptions as 'a slightly backed [y]' as compared with 'a slightly fronted [ɥ]'? Although it is true that for some linguistic purposes a 'phonetic' transcription is desired that reflects the intuitions of the native speaker (Chomsky and Halle 1968:14), it is also important as part of our account of speech behavior to have narrow transcriptions of utterances as uninfluenced as possible by linguistic bias. For those of us who accept the latter argument, it is at the same time necessary to be sensitive to the problem of calibrating the practical phonetician's ability to take his own percepts of stretches of speech, segment them into phones, and describe these speech sounds usefully in terms of their production and auditory quality (Ladefoged 1960; Witting 1962; Laver 1965). A comprehensive discussion of these matters is provided by J. C. Catford. Some relevant thoughts are also expressed by D. B. Fry in the section of his article that deals with linguistic phonetics. The reader should also consult L. Lisker's contribution, particularly for problems of segmentation and length.

2.8. *Language Teaching*

For the language teacher the typical phonological account is much too superficial. I put it this way purposely even though it may disturb the linguist to think of a good phonetic description as reflecting anything more than a rather superficial stratum. For the teacher wrestling with the problem of making his students overcome the phonic interference of their native language and master the articulatory patterns of a foreign language, a somewhat better phonetic description is required than is generally found in the linguistic literature. By now many contrastive studies of groups of languages aimed at such a goal are available. The phonetic rules incorporated in their phonological analyses normally derive from articulatory-auditory techniques (e.g. Moulton 1962). Obviously there is much room for application of instrumental phonetics to these pedagogical problems. It is perhaps not surprising that the impact of this kind of speech research on language teaching does not as yet appear to have been very great. For example, in the early 1960s F. S. Cooper and I, in collaboration with various linguists, produced a set of X-ray motion pictures in slow motion with stretched speech. These films of supraglottal articulations in English, Hungarian, Mandarin Chinese, Russian, and Syrian Arabic were sponsored by the United States Office of Education not for use in the language classroom itself but in the training of language teachers in the phonetics of these several languages. Although individual specialists in these languages have used the films for their own

research purposes, it is not evident to me that departments of language teaching in schools of education have been eager to make much use of them.⁶ In recent years a few experimental phoneticians have devoted more of their time and energy to questions of comparative phonetic analysis yielding data that should be useful in language teaching. Since some of these people are accepted on other grounds as members of the confraternity of language teaching methodologists, their work may have a greater impact. The report by A. Malécot surveys most of what has been done in this field and serves as a guide to the relevant literature.

3. CONCLUSION

The choice of authors and topics, as well as the organization of this "Overview", reflects my own outlook and that of close colleagues. This should not be taken to mean that nothing else of interest has been done or should be done in phonetic research or in the application of such research to other areas. For example, some scholars may wish to examine poetry (Fónagy 1961) and other types of literature with phonetic features in mind. Others have shown how the methods of experimental phonetics can be applied to research on children's acquisition of speech (Eimas et al. 1971). Among linguists, the historical phonologist might be well advised in positing formulaic representations of protolanguages to be more concerned with phonetic plausibility than he often is.

It is to be hoped that the ten reports on the state of the art and science of phonetics presented in this volume will stimulate much interest on the part of linguists. I readily admit that the list of these distinguished workers in the field could easily have been extended to include a number of others, but this is always so in such a collection.

ARTHUR S. ABRAMSON

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⁶ I prefer to believe that this is through disinclination rather than dissatisfaction with the quality of the films.

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