THE GOAL OF PHONETICS, ITS UNIFICATION AND APPLICATION

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In trying to propose a formulation of the goals of phonetics I have begun by asking: (i) What are the goals and the methods of any scientific discipline? How does science in general work? secondly, (ii) What is the traditional subject matter of phonetics? and thirdly, (iii) What are some of the potential practical applications of phonetic knowledge?

Theory, explanation and scientific understanding

How do scientists formulate their understanding of the phenomena that they have chosen to investigate? We find generally that in empirical sciences it is in the form of a theory that such understanding is expressed. Consequently much scientific endeavor is directed towards the construction of theories. Accordingly a fundamental goal also of phonetics is theory construction.

Our first diagram (Fig. 1) is an attempt to illustrate in simplified form some of the components likely to be found in all scientific work such as making quantitative observations, deriving numerical predictions from a theory and inventing a theory. Scientists select a certain set of phenomena that they would like to explain. This set is the explananda in the right, empirical part of the diagram. They devise methods of observation whose output is intended to be facts not artefacts.

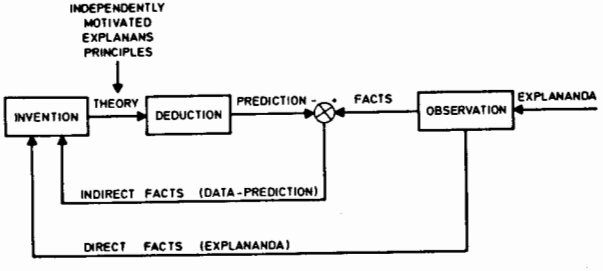

Fig. 1. Some components of scientific investigation.

Moving to the left we find the stage at which facts are compared with predictions or theoretical expectations. This is the point at which the evaluation of a theory begins. Or alternatively, if we have reason to be more confident in our theory than in our methods, it is the point at which we can assess the quality of our measurements. Early in my career as a phonetician I proudly showed Gunnar Fant some spectra that I had produced on the lab spectrograph with what I thought was extreme care so as not to introduce calibration errors etc. Much to my disappointment Gunnar dismissed the data right away and talked about distortion and "spurious formants". Of course he was right. But how could he tell? Later I have realized that the answer is that he looked at the data from the point of his strong theoretical understanding. I find this anecdote instructive since it pinpoints a general problem of research in the several areas of phonetics in which we still lack a powerful theory.

I shall use the term theory to refer to a set of basic laws or principles, on the one hand, and a system of rules on the other. From these basic principles and by means of these rules we deduce mathematically, in a perfectly automatic and formalized way, certain (numerical) consequences representing the predictions of the theory. The job that theories do is to explain. The anatomy of a scientific explanation presents at least the following parts:

1. It presupposes a theory that makes quantitative rather than qualitative statements.
2. It presupposes a theory that is completely formalized and leaves no room for the intelligence and intuition of the person using it.
3. It presupposes a set of explanans principles for which there is ample independent motivation. By independent motivation I mean justification not in terms of the data and the measurements but on external grounds.

In my usage the first two criteria are minimum requirements for an interpretation to qualify a theory. The quality of an explanation appears to be related to two things: the extent to which the theory meets the third condition, that is, has external justification and its scope, i.e., how much data it accomodates.

Summarizing what has been said so far we propose the following tentative definition of scientific understanding: To understand

something scientifically is to be able to recreate one's observations in a quantitative, formalized and explanatory way.

In order to further illustrate these ideas let us move back onto somewhat more familiar ground. Suppose we do an experiment in which listeners are asked to find the best perceptual match between steady-state pairs of synthetic vowels. The reference vowel has four formants. The test vowel has two. The upper formant, the so-called F_2', can be varied by the subject. Carlson, Fant and Granström (1970, 1975) did this type of experiment some time ago.

They were able to describe their results in two ways: (i) by means of an empirical formula making F_2' a function of F_2, F_3 and F_4; (ii) in terms of an auditory model reflecting the frequency analysis of the auditory periphery.

With respect to numerical accuracy the two descriptions gave almost identical and equally good results. However, when we place these accounts in the context of our previous discussion it becomes clear that only one of them offers an explanation, the one based on the auditory model. Why? Because this description is justified on external grounds. It shows us not only how but also why. It says that the matching behavior of the listeners is simply a consequence of a straightforward cognitive strategy and a phonetic universal: the human auditory system.

The empirical formula explains nothing. It captures certain regularities in the data in a compact and formalized way. It shows how the data came out but provides no clues as to why they came out that way.

Theory and explanation are concepts associated with the ultimate goals of research and it is therefore natural that most of the time we use these terms with restraint. We can name almost any area of phonetics: speech physiology, speech perception, speech development or sound change and we will find that in a certain sense it is true that "we are still at a data gathering stage". Note though that it would be a serious mistake to take this remark to mean that we should abandon all attempts at preliminary theoretical interpretation and model making and concentrate our efforts to the right half of Fig. 1. There are two types of data we need to gather: The facts obtained by direct observation, on the one hand, and the indirect facts represented by the discrepancies between the data and the theoretical model on the other.

Although the predictions may disagree with reality they should nevertheless be regarded as facts, facts about the model. Both the direct and the indirect facts are important sources of information in the creation of models. A good way to learn is to make mistakes in some systematic fashion.

The study of speech sounds: past and present

Phonetics has been traditionally defined as the study of speech sounds. If a deceased colleague of ours active around the turn of the century suddenly rose from the dead and could peep over the shoulders of his modern colleagues he would be unlikely to feel at home in our technologically sophisticated laboratories. However attending conferences and seminars he would no doubt conclude that the major problems to be solved and the questions asked had changed very little. It is instructive to contrast how classical phonetics dealt with the still current fundamental problem of devising a universal phonetic framework for spoken language. This task is essentially two-fold:

First of all, Find a way of describing phonetically an arbitrary utterance of an arbitrary language!

Secondly, Try to represent it in such a way that the description can be reproduced in audible form and with the linguistically relevant features preserved! Here the expression "linguistically relevant features" means the original native accent.

The first problem we can call the analysis or representation problem. The second is that of synthesis.

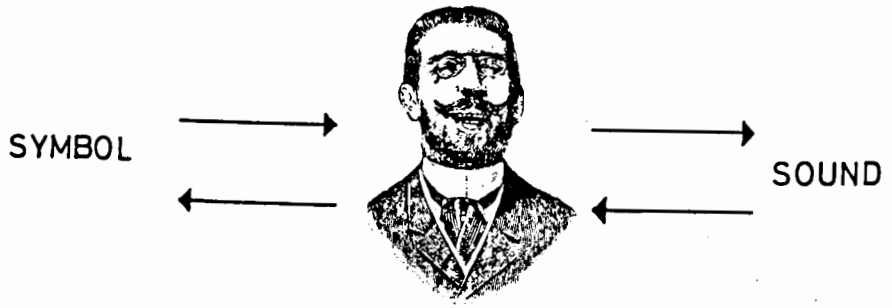

Fig. 2. The solution of classical auditory phonetics to the problem of speech sound specification: the skilled phonetician serving as a human tape-recorder in the "recording" and "playback" of acoustic facts.

The solution of classical phonetics was the concept of the universal phonetic alphabet and the use of highly skilled phoneticians serving as extremely sophisticated tape-recorders in the "recording" and "playback" of acoustic facts. Consider a certain utterance in a given language. Moving to the right in Fig. 2 corresponds to obtaining an answer to the question: What does this utterance, or rather the transcription of it, sound like? Moving to the left: The utterance just spoken by the informant, what is its representation in terms of phonetic symbols?

As we all know this solution of the problem of speech sound specification fails. Its inadequacies cannot be remedied by invoking the important insights contributed later by functional phonemic analysis and distinctive feature frameworks which achieved quantization of the infinite variety of sound and helped define the terms "alphabet" and "universal" more precisely. Nor would it matter if the quest for the ultimate phonetic framework could be brought to a successful close and if suddenly utopian phoneticians emerged capable of using transcription techniques of this type ideally. Why? If science aims at the construction of theories that explain the phenomena under investigation and if contemporary phonetics has the ambition to come of age as a science then it is quite clear why we reject the solution of classical auditory phonetics. This is so because the scientific description of speech sounds must necessarily aim at characterizing explicitly and quantitatively the acoustic events as well as the psychological and physiological processes that speakers and listeners use in generating and interpreting utterances. With the aid of the nimble tongue of the phonetic acrobat classical phonetics succeeds at best in skilfully merely imitating the speech processes of native speakers.

Clearly we must reject the method of impressionistic phonetics because it does not work in practice. Even if it did, it explains nothing: it does not reveal the processes underlying the production and perception of speech sounds. It does not represent a theory in the established sense of this term.

Phoneticians accordingly construe their task of speech sound specification as that of modeling the entire chain of speech behavior in a physiologically, physical and psychologically realistic manner. We thus arrive at the following conclusions: The

traditional subject matter of phonetics is the study of speech sounds; The general goal of scientific disciplines is theory construction and explanation; Consequently the goal of phonetics is to construct a theory of speech sounds; In order to make this theory meet established criteria of explanatory adequacy speech sounds cannot be studied as isolated acoustic events. Speech sounds can only be understood scientifically in terms of the psychological, physiological and physical processes responsible for their generation, on the one hand and with reference to their teleology, that is to their perceptual and communicative purpose on the other. Accordingly the phonetician whose inquiry began at the acoustic level in the domain of speech sounds is today forced to look upstream towards the mind and brain of the speaker and downstream towards the destination of the utterance in the brain and mind of the listener.

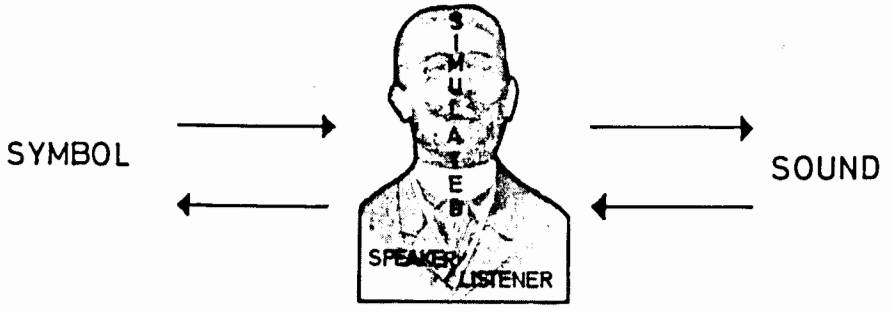

Fig. 3. A goal for modern experimental phonetics: a theory modeling the processes of speaking and listening in an acoustically, physiologically and psychologically realistic manner.

Let us at this point introduce Fig. 3, a slightly modified version of Fig. 2 and recall the phrase we used to summarize our initial discussion of scientific method: To understand something scientifically is to be able to recreate one's observations in a quantitative, formalized and explanatory way.

We can apply this thinking to a larger field of inquiry such as speech production, speech perception or speech development. Or we can apply it to a very restricted set of measurements made in a specific experiment. One very useful measure of our explicit rather than intuitive understanding of the phenomena investigated

is going to be our ability to recreate or simulate them. Needless to say we are in many cases not likely to come close to this goal in the foreseeable future. Nevertheless it provides us with the set of criteria we need to judge the relevance of our short-term efforts.

As we contrast past and present in the historical development of phonetics we see a discipline in the process of transforming from more or less a practical skill or an art into some sort of natural science. This development has yet to be completed but it is undoubtedly an inevitable consequence of: (i) the very nature of the subject matter that we have happened to have chosen; (ii) the natural ambition of any discipline to attain scientific maturity.

We should mention a third factor that has reinforced the present trend namely the prospect of using phonetics for practical purposes. Let me mention a few:

- educational methods and technical aids for the deaf, the hard of hearing, the handicapped and for second-language learners;
- the diagnosis and treatment of patients with phonetic symptoms including for instance delayed speech development, functional and organic voice disorders, aphasia, hypernasality, dysarthria and stuttering

as well as

- the automatic analysis and synthesis of speech for various technological purposes.

Békésy's mosaic model of scientific progress

In the introductory chapter of his book Experiments in Hearing, von Békésy describes his own research in relation to two research strategies: I quote "One, which may be called the theoretical approach, is to formulate the problem in relation to what is already known, to make predictions or extensions on the basis of accepted principles, and then to proceed to test these hypotheses experimentally. Another, which may be called the mosaic approach, takes each problem for itself with little reference to the field in which it lies, and seeks to discover relations and principles that hold within the circumscribed area." Further along in the text: "When in the field of science a great deal of progress has been made and most of the pertinent variables are known, a new problem may most readily be handled by trying to fit it into the

existing framework. When, however, the framework is uncertain and the number of variables is large the mosaic approach is much the easier. Many of the experiments to be described in this book employed the mosaic approach, but when considered in connection with other experiments carried out subsequently by the author and by many other workers in this field they take on a broader meaning and perhaps now may be woven into a more general structure."

Perhaps phonetics is a good example of a field growing like a mosaic. We have profited immensely from technological progress in the form of spectrographs, synthesizers and computers. Clearly such progress has not occurred as a result of premeditated planning on the part of phoneticians but as spin-off effects from adjacent fields with slightly different goals. Recruiting researchers trained in communication engineering, psychology, physiology, mathematics, physics etc. has demonstrably had an extremely vitalizing influence. According to the mosaic model of scientific progress the contents of a field is determined by the questions asked. Eventually a large number of questions will be asked and methods will be developed to answer them. Results will emerge that can be "woven into a more general structure". The lesson taught by the mosaic model thus seems to be: Leave your science alone! Stop worrying about where linguistics and phonetics are going and whether theoretical work is at a standstill or progresses sufficiently fast in response to practical needs etc. I would very much like to accept this advice. But unfortunately the examples that I am going to present to you will lead us in a different direction.

Form-based phonetics

When under laboratory conditions Swedish listeners hear the following stimulus:

Tape presentation of left spectrogram of Fig. 4 (next page).

Most of them say that they hear the Swedish word hallon beginning with an /h/ and meaning raspberry. What they hear and what you just listened to is in fact the following word simply played backwards[1]:

Tape presentation of right spectrogram of Fig. 4 (next page).

This word means zero. It has the so-called grave accent with an approximately symmetrical rising-falling F_0 contour. The spectrogram to the right thus shows the original recording and to the

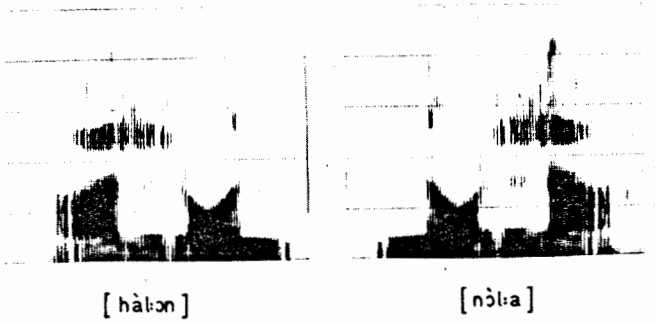

Fig. 4. A perceptual paradox: the "nolla-hallon" effect. Left: the Swedish word "nolla" played backwards. Right: the identical word played forwards. Transcriptions indicate perceptual asymmetry.

left we see the backward version. I think you can see that there is a weak expiratory [h]-like noise at the end of [nɔ̀l:a]. Why do our listeners perceive this segment as /h/ when we play the tape backwards but not forwards? One possible interpretation is that this perceptual asymmetry is due to the operation of top-down processes. In other words, you hear in terms of the structure of your native language. Like in many other languages the glottal fricative [h] does not occur in word-final or syllable-final position in Swedish. It does occur in initial position, however. Listeners do not have a sequence *allon, that is a sequence without the [h] in their lexicon. These facts evidently influence the perception of the acoustic signal in a drastic fashion for the effect is surprisingly strong to native Swedish ears.

The result of this simple tape reversal experiment appears to point to a fundamental principle of linguistic sound analysis: It is language structure and the human ear that determine what is linguistically relevant in the speech wave. The facts of physical phonetics cannot do so no matter how fine-grained we make the analysis. Although initially we rejected the method of classical auditory phonetics we are now paradoxically forced to admit that acoustic-instrumental facts about the behavior we are interested in must be accorded a secondary role in relation to the results of an auditory-functional analysis of sound substance. After all this is very elementary and not very new at all. Think of the notions of segmentation or invariance. Consider for instance the

distinctive feature, the phoneme, the syllable and so forth. All these are linguistic notions in the first place. They have an abstract theoretical status. We bring them with us into our laboratories (and normally we lose them in there before we get out).

Let us consider a statement by Malmberg (1968, 15). In the introduction of A Manual of Phonetics he formulates the role of experimental phonetics in a long-term perspective as follows: "...a combination of a strictly structural approach on the form level with an auditorily based description on the substance level will be the best basis for a scientific analysis of the expression when manifested as sounds. This description has to start by the fundamental analysis, then it must establish in auditory terms the distinctions used for separating phonemic units, and finally, by means of appropriate instruments, find out which acoustic and physiological events correspond to these different units. The interplay between the different sets of phenomena will probably for a long time remain a basic problem in phonetic research." Or take the following statement by Bolinger (1968, 13): "The science of phonetics, whose domain is the sounds of speech, is to linguistics what numismatics is to finance: it makes no difference to a financial transaction what alloys are used in a coin, and it makes no difference to the brain what bits of substance are used as triggers for language."

Substance-based phonology

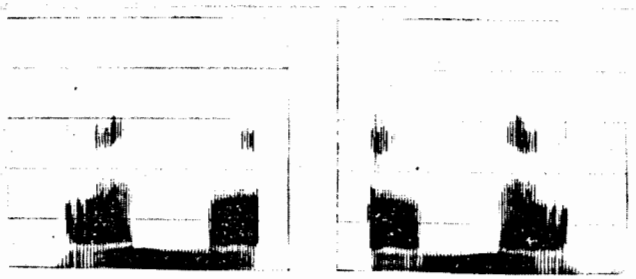

Fig. 5. Left: "Anna" (backwards). Right: the same word (forwards).

Investigating the case of syllable-final [h] further a colleague of mine at Stockholm University Eva Holmberg finds that this stimulus:

Tape presentation of left spectrogram of Fig. 5

is heard most often as Hanna. What you just heard was the following word played backwards:

Tape presentation of right spectrogram of Fig. 5.

Thus subjects clearly hear Hanna rather than Anna[2] in spite of the fact that both are names and should therefore be in the lexicon of our subjects. Clearly this throws some doubt on our previous interpretation attributing the perceptual asymmetry to language-specific top-down processing. A preliminary look at a large number of languages indicates that the /h/ phoneme tends to be either absent or realized as an [x]-laut or supraglottal fricative in syllable final position. These findings make us favor another hypothesis namely: The parallel between the perceptual asymmetry and the phonological asymmetry is not due to chance. It is due to universal properties of the human speech perception mechanism.[3]

The two cultures

The point that I would like to discuss is not whether this hypothesis is correct or not. Rather I have used the case of syllable-final /h/ to demonstrate that this hypothesis cannot be investigated within what Kuhn calls the current "paradigm" of linguistic theory. Given the role that phonetics has played so far in the construction of a theory of language there is no room for a hypothesis of this sort.

What is wrong? Although as linguists we are much concerned with the explanatory adequacy of our descriptions we nevertheless appear to make mistakes of a very elementary nature. In the beginning of our presentation we found that the concept of explanatory theory presupposes that reference is made to principles that are independent of the domain of the observations themselves and that have justification that goes beyond the patterning of the data (cf. vertical arrow at top left of Fig. 1). In common sense terms linguistic behavior presumably arises, both ontogenetically and phylogenetically, as the result of an interplay between

a) the functions that language is to subserve;
b) biological prerequisites such as brain, nervous system, speech organs, ear, memory mechanisms etc. and
c) environmental factors.

Languages thus evolve the way they do because of the body, the mind and the environment. They are the way they are on account of the functions they serve and owing to the properties of both innate and acquired mechanisms of learning, production and perception.

A scientific inquiry conducted along such lines would move our search for basic explanatory principles into the physics and physiology of the brain, nervous system and speech organs, the psychology of the mind and the social dimensions of language use. In other words it would take us right into areas that lie outside linguistics proper and the domains of our primary training and competence.

It might seem as if the strategy that I have been advocating is a reductionist approach to both phonetics and phonology. In other words, adopting this strategy would we then be headed ultimately for "molecular biology" rather than for insights of more primary interest to students of language? My response to this is that there are a host of phenomena for which we do not yet have a very good theoretical understanding. Just to mention a few consider the notions of distinctive feature, segmentation and the syllable and so forth. As long as we cannot treat for instance distinctive features as explananda, as things to be explained, rather than as empirically given primitives - as long as we cannot derive the distinctive features, that is the dimensions of possible phonological contrast, as consequences of constraints on speech communication the reductionist argument has very little force.

The history of phonetics and phonology is the story of two cultures that have always resisted unification. Trubetzkoy (Fischer-Jørgensen 1975, 22) classed phonetics among the natural sciences and assigned phonology to the humanities. The current paradigm of linguistics is aptly termed autonomous linguistics by Derwing (in press). In its context phonetics is a field worth annexing - but for completeness rather than for theoretical relevance.

One cannot help but suspect that autonomous linguistics and the role it assigns to phonetics has developed under the strong influence of educational and administrative constraints and that the program formulated by de Saussure and more recently by Chomsky is a brilliant rationalization of those constraints. If this suspicion is correct - and I truly believe it is - we have reason to examine how we train our linguistics and phonetics students and how without knowing it we become victims of the irrelevant and conservative influence of how universities are organized in terms of natural sciences, humanities and social sciences and so forth. In that kind of situation leaving one's science alone becomes impossible. However, educational programs can be changed.

Summary

We find that the long-term task of phonetics is to contribute towards the construction of a theory of language and language use. This goal is an ambitious undertaking calling for a multiplicity of experimental approaches as well as for theoretical unification.

The question of unification arises in all areas of our field but with particular force as we examine the traditional relationship between phonetics and phonology. We are forced to ask whether phonetics is currently embedded in an intellectual context that is ideally suited for approaching the long-term objectives. Generalizing from the results of a simple but I think instructive perceptual experiment I argue that the answer must be no. The trouble is that the stuff that theories and explanations are made of take us outside the domain of the primary training and competence of phoneticians and linguists. What can be done about this situation? Should we change the goals of phonetics? No, I don't think we can. We are trapped by our choice of subject matter, by scientific method as well as by our obligation to produce knowledge to fields of applied phonetics.

However, phoneticians are not alone in their dissatisfaction with the current paradigm of linguistics. Functionalism has always been alive. We see signs of linguistic research broadening its scope and intensifying research efforts in areas such as sociolinguistics, neurolinguistics, psycholinguistics, language acquisition, sound change, sign language, animal communication and so forth. I think this conference appears to demonstrate a number of such developments which inspire hopes for a new paradigm, a paradigm that views language in a biological perspective and makes it natural and respectable to ask teleological questions - questions that often successfully serve as guidelines for theoretical analysis in other areas of biology (Jacob 1970, Granit 1977) and that in the case of language patterns can be formulated as follows: For what biological and communicative purpose?[4)]

It seems to me that this is the paradigm that phonetic needs.

This is the paradigm in which phonetics will be most effective in contributing towards a better understanding of spoken language. That is a goal worth working for.

Conclusion

von Békésy found a close analogy to his research strategies in the field of art. To illustrate the mosaic approach he used a medieval Persian painting with persons and objects represented individually "with little perspective or relation to one another". For the theoretical approach he used a Renaissance woodcut constituting an early attempt to introduce perspective into representation.

Fig. 6. "The Gardener", painting by G. Arcimboldo (1527/30-1593), Skokloster Palace, Sweden.

I was inspired by Békésy to express my final point with the aid of a painting (Fig. 6). I would like to conclude by referring to a portrait by Arcimboldo (1527/30-1593). Let this painting be a symbol of three things: It symbolizes firstly the broad-based, multiple-approach experimental program that we should cultivate, secondly the need for theoretical unification and thirdly the hope that a biological perspective on speech and language will make such unification possible replacing the old paradigms of taxonomy and autonomous anti-functionalism.

Acknowledgments

The picture of the Arcimboldo painting was kindly made available to me by Svenska Porträttarkivet, Nationalmuseum, Stockholm.

Footnotes

1) The "nolla-hallon" effect was discovered about ten years ago by Ulf Ståhlhammar of RIT, Stockholm. I am grateful to him for bringing it to my attention at that time.
2) In working on the manuscript of this article I was pleased to hear from G. Heike that the "Anna-Hanna" asymmetry is valid also for German listeners.
3) The "nolla-hallon" effect resembles a phenomenon in psychoacoustics known as echo suppression. The sound of a hammer hitting a brick exhibits a certain decay waveform. Comparing backward and forward presentations of this noise one notes a striking asymmetry in that the decay appears much more prominent in the backward playback (Harvard Psychophysics Laboratory: Auditory Demonstration Tapes). There is some recent work on the forward and backward masking of speech-like noise stimuli caused by stationary vowels (Resnick, Weiss and Heinz 1979). This work shows forward masking to be more pronounced than backward masking. It is tempting to assume that the perceptual (and phonotactic?) asymmetry discussed here could be due to asymmetries of temporal masking among other things. However, the literature is somewhat ambiguous as to the direction and magnitude of these masking effects (Holmberg and Gibson 1979).
4) Note that I am not advocating some "divine foresight" responsible for order in nature. My model of "purpose" has two components: a "source" generating variation and a "filter" selecting those forms that happen to be compatible with certain "survival" criteria. In language communication the conditions of survival are social and biological in complex interaction.

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DISCUSSION

Victoria Fromkin, Hans Günther Tillmann, and Harry Hollien opened the discussion.

Victoria Fromkin: The question of the boundaries of phonetics and linguistics, or whether such boundaries should be drawn, is an important one. At the Linguistic Society Meeting in Salzburg last week, Charles Fillmore spoke on the question of boundaries, external and internal, in linguistics. The main point was that the goals we have are very often determined by which particular boundaries we set, and where we set them. And what is to one person phonetics may be to someone else garbage. It seems to me that we have to be able and willing to widen our boundaries.

When I first came into the field I was interested in electromyographic registrations of linguistic units, and there were people who said: "That is not linguistics", and I said: "But linguistics is whatever tells us more about the nature of human language and how language is realized in speech and in perception". - More recently I am interested in the human brain, and I am interested also in mental grammars, and I am even interested in what might go on in one part of the brain as opposed to another, - and people say to me: "That is not linguistics".

I have recently witnessed an experiment with a split-brain patient, whose left hemisphere, and subsequently right hemisphere were anaesthetized. When confronted with pictures of e.g. a mat and a bat, he could not tell them apart, - in fact, he could hardly speak at all, when his left hemisphere was anaesthetized. With the right hemisphere anaesthetized he did very well. Whether one has any quantitative results, whether there is one patient, ten patients, twenty patients, we know that there is something different going on in relation to when a person can tell the difference between mat and bat, and pig and big, and we do not even need to have more than five patients to know that there truly is something qualitatively different in the processing of the linguistic material from the non-linguistic, because when the left side of his brain was anaesthetized, this patient was still able to recognize and sing a song - so there is something special about the linguistic processing going on. Now, of course, we all know that, and what professor Lindblom did reveal is that to understand and to find explanations for this, we must go beyond our perhaps narrow interest and goals, and learn from the physicists, the neurophysiol-

ogists, the neurologists, the psychologists, and gain information wherever we can to try to understand both the nature of language as well as the way we use it in speaking and understanding. It is possible, and I think probable, that there will be certain aspects of human language which we will not find by just these kinds of research. And we will also learn that linguistic systems themselves will give us certain information, in fact raise certain questions as to what some of the rest of us in the laboratory have to seek answers to.

So where I agree with professor Lindblom is that we must go out of our own limited area, seeking help, information, explanations from various disciplines. But at the same time, I think that we should recognize that the autonomous linguists have some very important questions to raise for us to go and do our research on. I think that together we will begin to find out a little bit more about the intricate and complex nature of human language and about those of us who are users of it, the speakers, the hearers, and also the signers and perceivers of sign language, who are deaf.

Hans-Günther Tillmann: Professor Lindblom has drawn our attention to such fundamental and important problems as what it means to say that phoneticians try to develop theories which describe the phonetic facts of speech and language. To further clarify this issue, it could be helpful to turn to two somewhat simpler questions which, on this general metatheoretical level, are somewhat easier to answer: (1) What kinds of facts are given to the phonetician, and (2) what kinds of theories, according to the nature of these facts, can be developed by phoneticians?

(1) It is quite clear that all the facts that phoneticians are concerned with are given by concrete utterances produced by the speakers of a language. It is also quite clear that there are two different types of data to be found in these utterances. In natural circumstances, any such utterance can be perceived by a listener, say a trained phonetician, and hence it can be described symbolically. In this case, the phonetician's data are symbols, and he uses these symbols to refer to certain perceived (or perceivable) facts. Professor Lindblom gave us the two transcriptions [ana] and [hana], and everybody in the audience has learnt under which circumstances each of these transcriptions becomes

true or false - tertium non datur. Quite another type of fact comes into play as soon as we measure co-occurring variations in the physical world. These facts are transphenomenal to ordinary perception, at least in the case of phonetic variations co-occurring with perceivable utterances. If we measure these variations in different areas in and between the brains of the speaker and the listener ('signalphonetisches Band'), we obtain data in the form of time-functions, which in turn can be represented by digital signals. I would like to call special attention to the fact that these two different types of data, i.e. symbols and signals, constitute two different empirical domains for the phonetician - or, as I would like to call it if I could do so in English, two different 'empiries' - which exist separately and logically independently of each other. Perceivable utterances and measurable time-functions co-occur only empirically, yet in an experimentally reproduceable (i.e. verifiable) manner.

(2) Given these two different types of data - symbols, representing the category of perceivable events, and signals, representing measurable facts in the physical world - three different types of phonetic theories can be conceived of:

- A phonetic theory can be restricted to symbolic data - we find theories of this kind in phonology - or
- a phonetic theory can be more or less restricted to signals - the causal relations between different time-functions at different points of the physical continuum from the speaker to the listener can be analyzed in order to model the process of transmission of phonetic information from cortex to cortex - or
- a phonetic theory can explicitly try to connect the different facts given by symbols and signals - in this case, the form of a phonetic theory can simply be characterized by saying that the explicanda are primarily given in the first empirical domain of symbols, whereas independent explication can be looked for in the second empirical domain of time-functions.

Phoneticians and linguists are free to formulate and/or invent their explicanda, and they are also free to find theoretical explicata. In this situation, however, I would like to propose that phoneticians (and linguists) should make a virtue of necessity

and let practical applications determine what is to be translated into explicable explicanda. In this case, the solution of practical problems will be the best test to decide whether phoneticians have succeeded in finding a useful explicatum or not.

Harry Hollien: The first question that we have to ask ourselves seriously is: "Are we a discipline? Or are we simply a part of a more important discipline, whether it is linguistics or engineering or speech pathology, or some areas such as these?" - If we do decide that phonetics is a discipline, the second question we have to ask ourselves is: "Can we define it? Can we define its goals, its boundaries, its nature, in such a way that we can articulate this to other disciplines, and is there a cohesion within our field?" And since we represent different nationalities, different philosophies, different backgrounds, different orientations, different fractionalizations, we also have to deal with the third question: "How do we deal with each other, and develop mechanisms, procedures, processes by which to solve fundamentally the disagreements which we have within our field?"

Björn Lindblom: I think professor Hollien is doing it backwards. One begins by raising questions - that is how fields develop, that is how they grow. And: if phonetics is a discipline? I do not think it matters. We are interested in studying speech processes, interested in studying language, and that is where it all begins. And what you are talking about are some administrative, political problems that should be secondary.

I find myself in agreement with professor Fromkin and professor Tillmann. I wish that professor Fromkin would be a little more impatient with the autonomous linguistics paradigm, because it has such a radical influence on what we are doing.

Antti Sovijärvi gave examples of Finnish words which, when played backwards, are perceived by Finnish listeners in accordance with the syllable structure of Finnish.

Gunnar Fant pointed to the fact that there is a physiological explanation for the post-vocalic aspiration in open syllables, i.e. the glottis opens gradually, just like in an h-sound.

Henrik Birnbaum: In Björn Lindblom's initial chart (fig. 1) I was slightly disturbed by the terminology. He used the term 'indirect facts' for data prediction. But I do not think we can talk about fact in any sense here. We can talk, at best, about

hypotheses. I therefore do not think that there is any parallelism between the facts that we are asked to explain and the data predictions that we make, based on partial knowledge. - I think models are supposed to replicate something that we put into the abstract, and I think that what we have as 'indirect facts' in Björn Lindblom's chart, the data predictions, are part of a model, and models are never facts until they are proven beyond doubt correct, - so I would prefer the term hypotheses or partial hypotheses.

If 'autonomous' is understood in a broader way, and not in the narrow sense in which it was used in standard TG grammar, then of course autonomous linguistics, and within that autonomous phonetics, is a discipline. It does not mean that we should cut out all the neighbouring disciplines, however. I also would like to remind you that not only de Saussure and Chomsky would use this term, but Louis Hjelmslev spoke specifically about language as a structure sui generis. Language is a structure sui generis and not a replica of something else. We restructure reality in terms of the system we use.

Fred Peng: I want to ask professor Lindblom if he means that all people, regardless of linguistic or cultural background, hear more or less the same h initially, not heard at the end of the word. - Perceptual asymmetry is not limited to the auditory channel, it is also found in the visual and tactile modes, and I think that the environment, or context, has something to do with what you hear or do not hear, and the brain has sufficient plasticity to enable us to ignore what is not relevant to our background.

Björn Lindblom: We do not deny that listeners of different language background might have different perceptions, depending on their differences in top-down processing, conditioned by their native languages, but we do find parallels in the responses of our Swedish listeners and in the distribution of /h/-phonemes across the languages of the world. And thus we wonder if final /h/'s are not disfavoured because of some kind of auditory asymmetry that we all share. We are not denying that you can make use of this phoneme in final position, but it is disfavoured. It is a near universal absence.

Lise Menn: We need adequate descriptions from autonomous linguistics. It may well be that explanations cannot come from

within linguistics, but descriptions must. Early work in both child language and aphasia is, from a modern perspective, a great mess, - a lot of it, because of a lack of an adequate linguistic theory to relate the data to.

Another point: one level of investigation defines and sharpens the questions asked by another level. When you have gathered data for your theory, then you rephrase your questions - and it is a constant interaction between theory and data that is absolutely necessary. It is very easy to get a plethora of data: the problem is to relate it to theory. What you have is junk unless you know what its linguistic significance is.

Eric Keller pointed out the need for more theoretical papers in phonetics, the lack of which he tied up with the problem of educational background, which needs to be very wide if one is to do adequate work in phonetics. Students should be encouraged to acquire also mathematics, neurophysiology, physiology, psychology.

André Rigault suggested that we stick to de Saussure's distinction between substance and form: phonetics analyzes substance, phonology deals with form. He criticized the use of the term 'experimental phonetics' for something which is, properly speaking, 'instrumental phonetics', because doing an experiment involves having control of the phenomena investigated, to modify them at will. But he also felt that proper experimental phonetics ought to have a prominent place in our work, allowing us to verify theoretical models.

Further, phonetics should benefit from the contributions from psychology, linguistics, engineering, etc., but we should avoid the hyper-rationalization which has taken place in medicine, which produces people with a phenomenal education in mathematics, but no practicians to cure you of your illnesses.

Suzanne Romaine: I would like to object to the attitude which seems to be implied in professor Lindblom's last remark to the effect that a biological emphasis and perspective is what is needed to unify phonetics and to replace the old paradigms of taxonomy and autonomy, because it reflects a tacit acceptance of a Kuhnian notion of so-called normal science and of science as consisting of a succession of so-called paradigms. I think that unity is the last concept that should be applied to any discipline. We can agree about goals without having to agree on how we are

going to pursue them, and I would like to emphasize my agreement with what Victoria Fromkin said, that there are both quantitative and qualitative aspects to our profession. We do not want to be replacing old paradigms so much as to be increasing competition among paradigms. I think that is the only way for science to grow.

Pierre Divenyi: I would like to expand on the role of biology, from the point of view of perceptual phonetics, and say that maybe we should start learning from what our physiologist colleagues do: at the Cambridge meeting of the Acoustical Society of America in June, physiologists reported on experiments where they have measured the response to speech stimuli of various parts of the auditory system, and I think that now that we know at least how certain levels of this system respond, we should maybe cease considering as a stimulus to the phonetic system the string of phones, for instance, or even the acoustic stimulus itself. Maybe we should consider our proximal stimulus, to demonstrate what is happening at various parts of the system. I would tentatively suggest that the explanation for the 'Anna/Hanna' phenomenon shown to us by professor Lindblom may be deduced from what happens in the auditory nerve.

Fritz Winckel pointed to the parallel between natural sciences, linguistics, and art, all being trial and error processes.

Osamu Fujimura: The point I would like to raise is a general matter of how can we choose the correct criteria for selecting one model among several. And particularly, if there are two models at hand which both of them explain the facts equally well. We should probably be very careful about applying a particular set of criteria, because there are many cases where one experiment or situation does not reveal the entire picture of the subject-matter, and I think that for example in the case of the F2' experiments that professor Lindblom mentioned, isolated utterances, vowels, may not be revealing enough for us to be able to conclude in favour of one model over another.

Jørgen Rischel: It is obvious, to me at least, that we need autonomous linguistic research, at least a research which poses linguistic questions and which does not start out from, say, a biological foundation, and at the same time, of course, we need phonetic research. One of the problems today is that people specializing in different fields do not always grasp the implica-

tions of what people in other fields are doing. For example, it is very important to make clear to what extent a particular distinctive feature framework is motivated linguistically, to what extent it is phonetically motivated by, say, empirical physiological and perceptual research, and so on. There is sometimes a danger of a forth and back reinforcement of one's confidence in model construction: for example some linguistic model may serve as the basis for some phonetic experimentation and confirmation of the possibility of finding a phonetic equivalence, and then this may be used by the linguist as a confirmation of his own research. Therefore, we have to be very careful when we publish our results and make explicit whether we are borrowing assumptions which are not within our own paradigm or research.