

# The Future of Phonetics

Klaus J. Kohler

*Institut für Phonetik und digitale Sprachverarbeitung  
University of Kiel, Germany*

**Lecture on the Occasion of Professor Jørgen Rischel's Retirement from his Chair at Copenhagen University  
6th February 1998**

## **0 Introduction**

Before I begin to develop my ideas on the future of phonetics I would like to express my deep gratitude to the organisers of this Symposium for asking me to present this talk. I feel honoured to be included in the programme, which pays tribute to a scholar of great distinction in our subject, at a university that has been in the vanguard of phonetic studies for a very long time. I shall start off by looking back to the formation of the bases of present-day, modern phonetics, because I firmly believe that an understanding of the history and the tradition of a scientific discipline is a prerequisite to successful innovation in the future. I am going to centre on three strands which may be called 'speech signal analysis', 'historical linguistics and sound change', and 'descriptive phonetics of the languages of the world'. They developed separately, but they are in the process of integration into one coherent science.

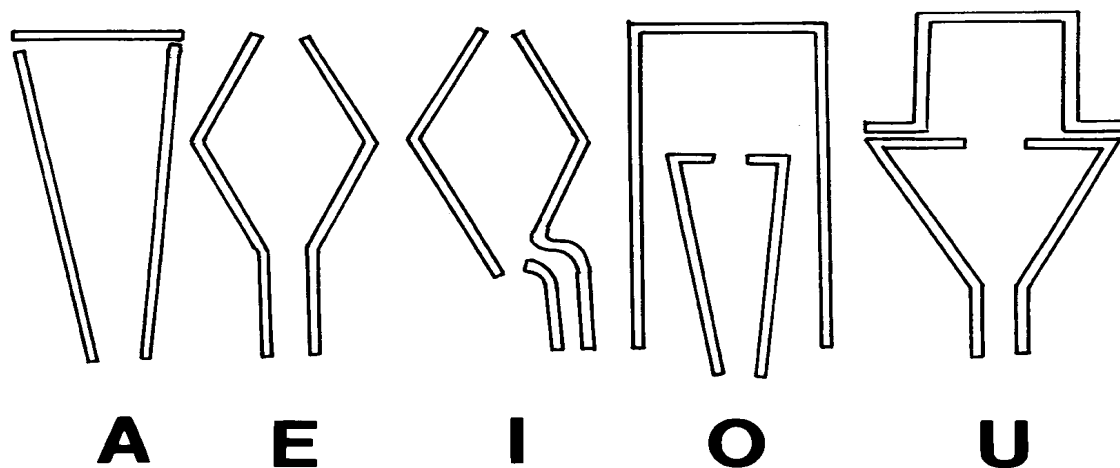
## **1 Historical notes on three strands in phonetic studies**

### **1.1 Strand I: analysis of the acoustic speech signal and its production**

For the year 1780 the Imperial Academy of Sciences at St Petersburg proposed a public prize competition on the nature of the five vowels of the alphabet and on their instrumental simulation. The text of the prize question ran as follows:

- 1) *Qualis sit natura et character sonorum litterarum vocalium a, e, i, o, u tam insigniter inter se diversorum.*
  - 2) *Annon construi queant instrumenta ordini tuborum organicorum, sub termino vocis humanae noto, similia, quae litterarum vocalium a, e, i, o, u, sonos expriment.*
- 
- 1) *What is the nature and character of the sounds of the vowel letters a, e, i, o, u, which are so clearly different from each other.*
  - 2) *Whether it would not be possible to build instruments, which are, from the point of view of the human voice, similar to organic tubes and capable of sounding the vowel letters a, e, i, o, u.*

The dissertation submitted by the physiologist and professor of physics at Copenhagen University, Christian Theophil Kratzenstein, was selected as the winner, and it received international recognition so quickly that the *Journal de Physique* published it, as early as 1782, in a French translation: *Sur la naissance de la formation des voyelles* [42]. The treatise marks the



**Figure 1.** Kratzenstein's models for the five vowels a,e,i,o,u.

beginning of professional speech signal analysis by an acoustic model of the underlying articulation. Kratzenstein shaped tubes in such a way that, when excited by a vibrating reed, they emitted the sounds of the five vowels. His models for vowel synthesis were to simulate the acoustic characteristics of the vocal tract configurations in human vowel production, with the reed replacing the vocal fold sound generator of the larynx. The scientific analysis and synthesis of acoustic speech signals thus had its origin at this University just over two centuries ago. Kratzenstein's ideas were subsequently elaborated by physicists, communication engineers and phoneticians from Willis, Wheatstone, Helmholtz, Hermann in the 19th to Stumpf, Dudley, Chiba and Kajiyama, Ungeheuer in the 20th century, culminating in Gunnar Fant's *Acoustic Theory of Speech Production* of 1960 [4]. The acoustics of speech is today an integral part of the study of speech sounds, i.e. of the academic discipline of phonetics. So Phonetics at Copenhagen can look back to a long and distinguished tradition in the development of the field.

Whereas Kratzenstein and all his successors in speech signal analysis and synthesis I have mentioned were professional scientists, the man who is cited far more readily as the originator of a speaking machine was not: Wolfgang von Kempelen, "k. k. wirklicher Hofrath" in Vienna, was an interested and dedicated amateur. In 1791, eleven years after Kratzenstein's treatise, he published his *Mechanismus der menschlichen Sprache nebst der Beschreibung seiner sprechenden Maschine* [20], and presented his talking device, which was reconstructed by Wheatstone in the 19th century.

This machine was not only the realization of a dream mankind had cherished since antiquity, but it also put into practice a research programme that was formulated a century earlier. In Kiel, in the Dukedom of Schleswig-Holstein-Gottorf in the southern part of the Danish Kingdom, Duke Christian Albrecht founded a university in 1665, and in the year of its foundation a certain Samuel Reyher was appointed to the chair of mathematics. He may be regarded as an early applied physicist, who had a broad interest in natural phenomena. For example - upon the suggestion by the philosopher Leibniz - he set up a weather station and collected daily records of air temperature, pressure and humidity over a period of several years. In 1670 he published his *Dissertatio de Aere* [55], which contains a chapter *De Sono, Organis pneumaticis, Statuis etc. loquentibus*. It gives the following ideas for the construction of a speaking machine:

*Si autem quis similem componere vellet statuum, quae non tantum membra instar vivi hominis movere, sed etiam verba proferre deberet, summo studio conformationes musculorum corporis humani imitandae essent....Ad loquelam quod attinet, primo simplices formandi sunt vocales, cum aliquibus consonantibus, qui tactis pinnis solitariis & admissio spiritu sonum desideratum edant. Postea facile quoque aliquibus pinnis simul motis mixtura & compositio aequae facilis erit, ac compositio Musicorum vulgaris. Sed haec initio tempus & sumtus haud mediocres requirunt, unica autem machina disposita quilibet brevi tempore parvisque impensis illud imitari poterit.*

*If, however, someone wanted to build a statue that should not only be capable of moving its limbs like a living human being, but also of uttering words, it would be necessary to simulate the muscular coordination of the human body with greatest exactness....As regards speech, simple vowels must first be formed, together with any consonants, which emit the desired sound by pressing single keys and adding breath. Subsequently, several keys can also easily be moved simultaneously, and a mixture and composition becomes as easy as an ordinary musical composition. But initially this requires no small amount of time and costs. However, once a single machine is available anyone can reproduce this sound in a short time and with little expense.*

This description recalls the figures from von Kempelen's *Mechanismus*.

Wolfgang von Kempelen  
 k. k. wirklichen Hofraths

# Mechanismus

der

## menschlichen Sprache

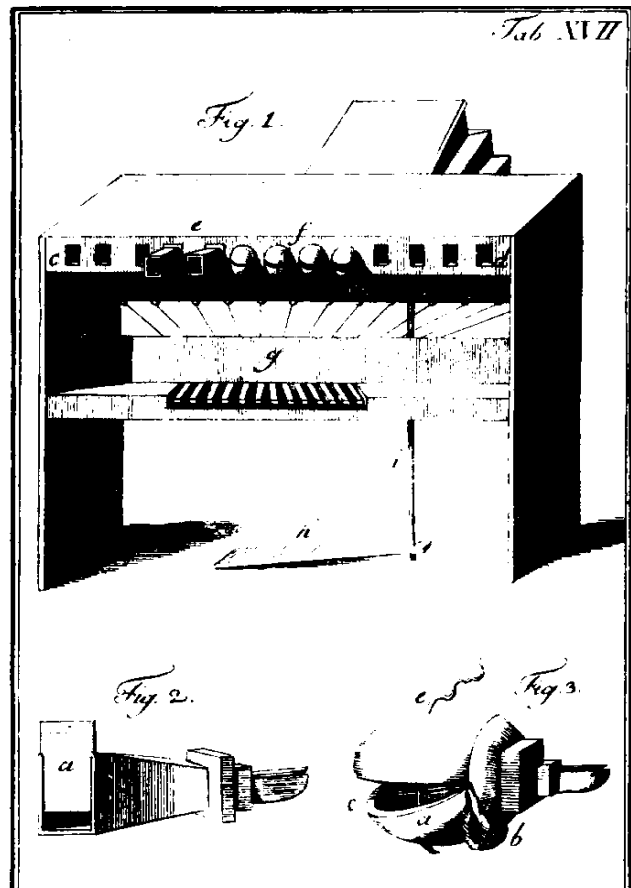
nebst der Beschreibung  
 seiner Sprechenden  
 Maschine.

Mit XXVII Kupfertafeln.

*Haec igitur penitus voces cum corpore nostro  
 Exprimimus, rectoque foras emittimus ore,  
 Mobilis articulatur verborum daedala lingua,  
 Formaturaque labrorum pro parte figurat.*  
 Lucret. lib. IV. v. 558.

W i e n,  
 bei J. B. Degen, 1791.

**Figure 2.** Title page of Wolfgang von Kempelen's *Mechanismus der menschlichen Sprache nebst Beschreibung seiner Sprechenden Maschine*.



**Figure 3.** von Kempelen's concept of a speaking machine.

Nine years after *De Aere*, Reyher published *Mathesis Mosaica, sive Loca Pentateuchi Mathematica Mathematice Explicata* [56], an attempt to explain the five Books of Moses scientifically in an encompassing excursion into a wide variety of subjects, typical for dealing with knowledge in the late 17th century. On p. 432, §§ 41 - 45 we find a discussion on the differences between vowel sounds. Reyher says that they do not only differ by the shape of the mouth and tongue but also by a tone which may be heard when the voice is suppressed and the vowels are only produced by breath, i.e. whispered. He illustrates his findings by a musical scale notation for German vowels and diphthongs, differentiating not only the five vowels of the Latin alphabet but also the front rounded vowels and different degrees of open “e” as well as different types of “a”. He actually discovered what we would today classify as the second formant, and his descriptions are astonishingly accurate. We can relate them to frequency values via an interpretation of the



**Figure 4.** Samuel Reyher’s musical notation of the characteristic vowel tones in whispering

musical symbolization. So Reyher provided more detailed acoustic information on vowel articulation than Kratzenstein, although - unlike the latter - he did not proceed by physical experimentation but by impressionistic auditory observation and description. However, the 19th century physicists and physiologists knew about Reyher’s discovery and valued it by referring to it. So Hermann Helmholtz mentions it in his *Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* of 1862 [9], and so does the professor of medicine in the University of Leipzig Carl Ludwig Merkel in his *Physiologie der menschlichen Sprache* of 1866 [47]. Even the 20th century authors Chiba and Kajiyama [3] pay tribute to Reyher.

## 1.2 Strand II: descriptive and experimental phonetics in historical linguistics and sound change

The impressionistic method of phonetic observation and description just referred to has been the dominant paradigm in the study of the spoken medium of language for centuries, exploiting all sensory channels, especially through visual and tactile inspection of articulation and through auditory assessment of acoustic events. Methods have been developed repeatedly to reduce languages to writing, and thus to make fleeting sensory impressions durable and transportable in space and time, through systematic sound classification. The invention of any alphabetic writing system presupposed such analytic procedures. Moreover, grammarians have, at various times in history

and for many different languages, produced phonetic descriptions of words and letters, some more reliable than others. Among the most accurate are the ones by the Sanskrit grammarians.

These alphabetic records and descriptive phonetic accounts in historical texts made the comparative historical method in linguistics possible. It established itself in the 19th century and became the prevalent research paradigm well into the 20th century. It culminated in the *Neogrammarian* tenet that historical sound change is lawful and exceptionless. This dictum heavily depended on phonetic insight, so it is logical that historical linguistics took great interest in general phonetics.

In 1875 the Copenhagen linguist Karl Verner, building on the formulation, in 1818, of a Germanic consonant shift by another Danish scholar, Rasmus Rask [52], published his famous article *Eine Ausnahme der ersten Lautverschiebung* (*An Exception to the First Consonant Shift*) [73]. He related the difference between German “*Bruder*”-“*Vater*” or Gothic “*brōþar*”-“*faðar*” versus Latin “*frāter*”- “*pater*” and Sanskrit “*bhrātā*” - “*pitā*” to an original difference between pre- vs. postconsonantal stress position, as maintained in Sanskrit. He thus assumed that the change of the dental plosive [t] to the dental fricative [θ] was general in the Germanic consonant shift, but that voicing occurred when the immediately preceding syllable was not stressed. The difference between Gothic *þ* - *d* and German *d* - *t* is then due to the second consonant shift in High German. The morphophonemic alternation between English “*was*” and “*were*” are similarly to be explained as [s] vs. [z] → [r]. What looked like an exception to a sound law at first sight was thus resolved with reference to different phonetic conditions.

We may quote examples from other languages where voicing of fricatives in unstressed syllables intervenes in a far narrower historical span or even synchronically, e.g. in English “*exhibit*” [gz] vs. “*exhibition*” [ks] or German “*Hannoveraner*” [v] vs. “*Hannover*” [f]. In experiments carried out at IPDS Kiel in the early seventies with German utterances of the type “*das muß ich doch nicht*”, “*das schaff ich doch nicht*”, “*das mach ich doch nicht*”, where stress was either placed on the verb or on “*doch*”, Andy Butcher [2] found the same phenomenon: the fricatives tended to be voiced, when the verbs were unstressed. This time the observation was not just impressionistic, but was confirmed by instrumental measurement. Verner, through his descriptive phonetic insight, had hit upon a generalizable sound pattern in human language.

Thus phonetic studies became essential for historical linguistics and the investigation of sound change, and again this University played a decisive role in their development. The Neogrammarians gave phonetics a prominent place in two ways:

- In 1876 Eduard Sievers, a contemporary of Verner at Leipzig University, published his *Grundzüge der Lautphysiologie* (changed to *Grundzüge der Phonetik* in subsequent editions) as the first volume in a newly planned series of Indo-European grammars (*Bibliothek Indogermanischer Grammatiken*) [70]. It was to lay the foundations for exact phonetic descriptions in a positivist fashion as a basis for all further studies to be included in the series.
- In the same positivist spirit, these descriptive accounts were supplemented by instrumental analyses of speech waves within the developing field of experimental phonetics in order to assist the study of sound change by recording minute details of pronunciation. L'abbé Rousselot used this method to investigate the sound changes in the dialect of a family (*Les modifications phonétiques du langage, étudiées dans le patois d'une famille de Cellefrouin (Charente)*, 1892 [68]), and between 1897 and 1901 he published a comprehensive experimental phonetics manual: *Principes de phonétique expérimentale* [69].

### 1.3 Strand III: descriptive phonetics of the languages of the world

So, to the Neogrammarians, the study of living idioms became an essential source of information for their historical and comparative research, but there was, at the same time, a growing interest in synchronic descriptions of languages and dialects in their own right. This resulted in large-scale dialect surveys in, e.g., Sweden, Germany and France, as well as detailed phonetic accounts of individual languages and handbooks of general phonetics. Paul Passy, Henry Sweet, Wilhelm Viëtor produced a number of excellent textbooks on the pronunciation of French, English and German, and Otto Jespersen, another distinguished phonetician of this University, in the years 1897 to 1899 published a comprehensive compendium on phonetics, *Fonetik, en systematisk fremstilling af læren om sproglyd* [16], which, besides the fundamentals of general descriptive and experimental phonetics, also contains a wealth of observations on his native language Danish. He had this book translated into German and published in two volumes: *Lehrbuch der Phonetik*, 1904, <sup>2</sup>1913 [17], and *Grundfragen der Phonetik*, 1904 [18].

All four phoneticians were among the first members of the *The Phonetic Teachers' Association*, founded in 1886 and renamed in 1897 as *L'Association Phonétique Internationale* or *The International Phonetic Association*, respectively. They all took a consuming interest in phonetic transcription and in the development of the International Phonetic Alphabet. Otto Jespersen's contribution to the symbolization of pronunciation is particularly noteworthy in two ways:

- He produced a systematic alphabetic notation on the basis of articulatory parameters and their synchronization: *The articulations of speech sounds represented by means of alphabetic symbols*, 1889 [15].
- He organized a conference in Copenhagen in 1925 to arrive at an international standardization of the many different transcription systems used for various scientific goals, in dialectology, African studies, language teaching etc.; some of the suggestions voted on by the participants at the meeting [6] found their way into the International Phonetic Alphabet.

In the course of a century this International Phonetic Alphabet has established itself as the most widely used standard of phonetic transcription, and in 1989 received its modern revision at another conference, down the road from Copenhagen, at Kiel.

Through the International Phonetic Association phonetics stepped outside the boundaries of an academic discipline into practical application in foreign language teaching. And here again Jespersen was a very active figure. On October 14 -15, 1895, the teachers' association of Danish grammar schools held its annual meeting in Copenhagen, at which Jespersen gave a paper on the value of phonetics in the teaching of the mother tongue and of foreign languages. The main points of his talk were that anyone teaching any language, beginning with instruction in the mother tongue at nursery school level, has to be familiar with the most important points of phonetic theory and practice. The teacher must know the articulations and acoustic features of sounds and be able to produce them as well as to recognise his pupils' mistakes by ear and to relate these to their articulatory causes.

Jespersen's paper was translated into German, together with the discussion, and published with annotations as a programme in the journal *Englische Studien* in 1898 (*Der Werth der Phonetik für den Unterricht in der Muttersprache und den Fremdsprachen* [22]). The author was Hermann Klinghardt, a school teacher in Rendsburg, just outside Kiel. As a step towards the realization of Jespersen's views he issued a practical manual of articulation and ear training exercises *Artikulations- und Hörübungen* two years after the Copenhagen meeting.

He is even better known for his practical books on intonation:

*Französische Intonationsübungen. Für Lehrer und Studierende.* (with M. de Fourmestraux, 1911) [23],

*Übungen im englischen Tonfall. Für Lehrer und Studierende.* (with G. Klemm, 1920) [24],

*Übungen in deutschem Tonfall. Für Lehrer und Studierende, auch für Ausländer* (1927) [25].

#### 1.4 The relationship between the three strands: integration or separation?

Strand I had its roots in acoustics, anatomy and physiology, whereas the origins of Strands II and III are linked to diachronic and synchronic linguistics. But the positivist Neogrammarian conception of the study of speech and language not only linked Strands II and III, but also introduced Strand I, in the form of experimental and instrumental analysis, into an integrated framework of phonetics. Thus Sievers called the first edition of his compendium *Grundzüge der Lautphysiologie*, and even after changing the title to the more linguistic wording of *Grundzüge der Phonetik*, from the second edition (1881) onwards, he stressed the need for an exposition of a unitary discipline. He demanded of linguists that they should first of all become familiar with the indispensable foundations for the further development of phonetics as laid down by the science approach, and that they should build linguistic phonetic studies on these general scientific laws derived from observable speech data. Sievers admitted, however, that this goal was still a long way off because linguistics had learned, or wanted to learn, too little from natural science, and vice versa, and where a mutual exchange of knowledge had taken place it was often accompanied by misunderstanding at the receiving end.

In spite of this decided view on the unity of phonetics Sievers wrote his compendium for linguists and largely excluded Strand I as well as the experimental-instrumental aspects of Strands II and III in his handbook. Moreover, the early experimental phoneticians did not help to overcome the misunderstandings between the linguistic and science approaches, nor did they develop a methodology for linking speech measurements with linguistic categories, for connecting a huge variability in instrumental data with the symbolic invariants of descriptive phonetics. On the contrary, all known categorizations, such as ‘sound’, ‘syllable’, ‘word’ etc., seemed to disintegrate in the individual curves of instrumental recordings.

It is therefore not surprising that Sievers reworded his goal for the discipline of phonetics and its handbook presentation in the third edition (1889). Now he separated the science areas of physics and physiology of speech from the linguistic domains of historical and comparative phonetics and of phonetic description of living languages, i.e. Strand I from Strands II and III. And he voiced his conviction that a general descriptive system of speech sounds meeting the needs of all three areas equally was quite impossible. He added nevertheless that he was not sure whether he would be able to persuade others of the legitimacy of his restricted, linguistic goal because he considered his opinion more or less unparalleled. So Sievers became an early forerunner of the linguistic ‘separatist’ movement in phonetics, which gained momentum in the 20th century. It eventually culminated in the most serious break within the subject from the 1920s onwards, namely the institution of phonology as a new linguistic subject, an arts discipline, separated from the natural science of experimental and instrumental phonetics, a dichotomy most vigorously proposed by Trubetzkoy in his *Grundzüge der Phonologie* of 1939 [72].

## 2 The State-of-the-Art in Modern Phonetics

### 2.1 The development of a new integrated paradigm

The past sixty years have not only seen the *negative* consolidation of the phonetics-phonology schism within *linguistic* thinking, but also the *positive* development of a new integrated paradigm in *phonetics*. It began to assert itself with Eberhard and Kurt Zwirner's *Grundfragen der Phonetik* of 1936 [74], which, on the one hand, opposed the a-linguistic procedures of early experimental phonetics, and on the other hand, stressed the need for relating linguistic categories with speech signal measurements on the basis of statistical evaluation. Both areas thus became indispensable to each other in the study of the spoken medium of language. This is the framework that was adopted by Eli Fischer-Jørgensen and became the trade mark of phonetics at Copenhagen University. She combined all three strands in her work, and a particularly fine example of this integration in her research, over many years, is her study of the Danish stød, *A phonetic study of the stød in Standard Danish*, of 1989 [5].

The scholar in whose honour we have gathered at this Symposium - Jørgen Rischel - is firmly rooted in this paradigm and has continued the long tradition of phonetic study at this University. He, too, has worked in all three areas of phonetics. By way of illustration:

- In 1966, almost two centuries after Kratzenstein, he wrote a paper on *Instrumentation for vowel synthesis* [57].
- His PhD thesis of 1974 *Topics of West Greenlandic phonology* [58] spans the field from phonetic data collection to (morpho)phonological interpretation, including a historical, comparative perspective. The paper *Devoicing or strengthening of long obstruents in Greenlandic* (1986) [62] elaborates the analysis of fine phonetic detail and its explanatory power for language development. This theme is also taken up from a theoretical and methodological point of view in the paper *A note on diachronic data, universals and research strategies* of 1981 [59].
- His phonetic fieldwork in Thailand provides further instances of phonetic descriptions [61]. It has at the same time stimulated his reflection on the problems and types of *Phonetic transcription in fieldwork* (1987) [63], as well as on the relationship between lab speech and real speech, on descriptive *Fieldwork data as input to instrumental analysis - a dilemma* (1985) [60].

So Sievers' original goal of a unitary phonetics, integrating language and science aspects for an adequate explication of how speech communication works has reasserted itself, and the University of Copenhagen has played an important role in this historical process. The evolution of the subject has even gone beyond Sievers' prospect because this paradigm has become established in the state-of-the-art of modern phonetics: it has gained recognition in a number of phonetics centres around the world. Let us look at two of them.

There is first of all the phonetics lab at Berkeley, with John Ohala, who received an honorary doctorate from this University for his contributions to phonetics. He has been concerned for a long time with the elucidation of general laws of sound change through a consideration of anatomical, physiological, acoustic and auditory constraints on speech signals in communication, and through the analysis of synchronic variation [49, 50]. He has thus picked up the thread of the first experimental phoneticians within Neogrammarian historical linguistics and has woven it into a tapestry of linguistic phonetics, which the former failed to do.



Complementary to this projection of phonological structure onto experimental data in John Ohala's work is his projection of phonetic organization onto phonology, i.e. the derivation of explanatory power from phonetic substance in experimental phonology. Ohala's experimental phonology [48] makes use of laboratory analyses in speech production, acoustics and perception to evaluate phonological categories, whereas laboratory phonology [1] takes pre-established phonological categories into the lab to substantiate them phonetically. John Ohala's reversal of general phonological practice also picks up Sievers' thread that general scientific laws are derived from observable speech data for linguistic explanation, and weaves it into a tapestry of phonetic phonology in its own right. Connected with this conceptualization of phonetics is John Ohala's concern for phonetic universals.

Over and above this paradigm of 'phonetic or experimental phonology' a change in research strategy is gaining recognition in modern phonetics world-wide: a shift of focus from lab to non-lab speech, i.e. to different varieties of connected speech in general and of non-scripted, spontaneous speech in particular. Among other phonetics institutes, IPDS Kiel has concentrated on regularities of articulatory reduction and elaboration at the sentence and utterance levels, in an attempt to supplement word phonology by a phonetic phonology above the word. In the central part of my lecture I shall now present some of the issues and results of this work on utterance phonetics.

## 2.2 A new focus: phonetics and phonology above the word

Supralexical phonetics and phonology have been in focus at IPDS Kiel since the early 1970's [26, 27]. There is now a powerful and flexible data acquisition, processing and analysis platform available for this research focus. It consists of a sufficiently large, phonetically annotated acoustic data base of read and unscripted connected speech, of altogether 70,000 running words, completely transcribed segmentally and in part also with prosodic labels: 'The Kiel Corpus of Read/Spontaneous Speech' on four CD-ROMs so far [10-13, 40]. Together with a data bank environment and appropriate search as well as analysis tools it provides the necessary facilities [14,39,51] for large-scale corpus studies of connected speech processes in German [8,28,30,31,33,34,41,53,54,66,67]. The importance of this modern orientation of phonetic research world-wide was mirrored in a German Research Council funded International Symposium on "Sound Patterns of Connected Speech", organised at Kiel in June 1996 [71].

In the following, I shall give a few illustrations of word variability in utterances of connected and unscripted speech, ranging from complete separation to complete fusion or even disappearance of phonetic words. I shall first of all look at function words as they exhibit reduction phenomena most strongly, and then move on to a discussion of degrees of articulatory adjustment in content words. Finally, the empirical data will be interpreted as an interplay between articulatory effort and perceptual distinctivity.

### 2.2.1 Function words: from separation to integration

In (sequences of) function words German shows frequent interference with phonetic word identity, for example in

*"Hast du einen Moment Zeit?"* [haspm mom'en ts'ait]

*"Hast du den Bericht über die letzte Sitzung endlich geschrieben?"* [haspm b ɪ'ɪçt].

The same phonetic form [m] in the strongly reduced sequence of three function words "*hast du einen/den*" can be uniquely identified with "*einen*" in one context and with "*den*" in another, although the solely remaining nasal (with labial adjustment to the following consonant) can no

longer trigger the phonetic identification of the word. The separation of these words is further hampered when [hasm] is produced, instead of [haspm], with a glottalized nasal, which signals the article and the plosive residual of “du” at the same time.

But the reduction can go further and eliminate all traces of “du” in [hasm mom'en ts'art], with a syllabic nasal, which may in turn follow the general German geminate reduction, especially in unstressed position and fast speaking rate, resulting in [has mom'en ts'art], where the reflex of “einen” has also disappeared in the phonetic manifestation. The verbal paradigm as well as the idiomatic phrasing make the decoding of the intended meaning of the utterance unique, and the listener therefore does not depend on the signal detection of every word.

The disappearance of words in context is not restricted to the loss of all phonetic traces but may also take the form of the appearance of new lexical items through the complete fusion of others. This is particularly common for prepositions + articles, as in French “au”, “du” or German “im”, “ins”, “zum”, “zur”. In today’s usage, German “er geht zur Schule” and “er geht zu der Schule”, “er kommt zum Schluß” und “er kommt zu dem Schluß” have different meanings although both forms are historically related on a scale of articulatory reduction.

Similarly, subject pronouns in enclitic position to function verbs form a scale from separation into two items to fusion into a single new one in “haben wir”, “sind wir”, “hat er”, “habt ihr”:

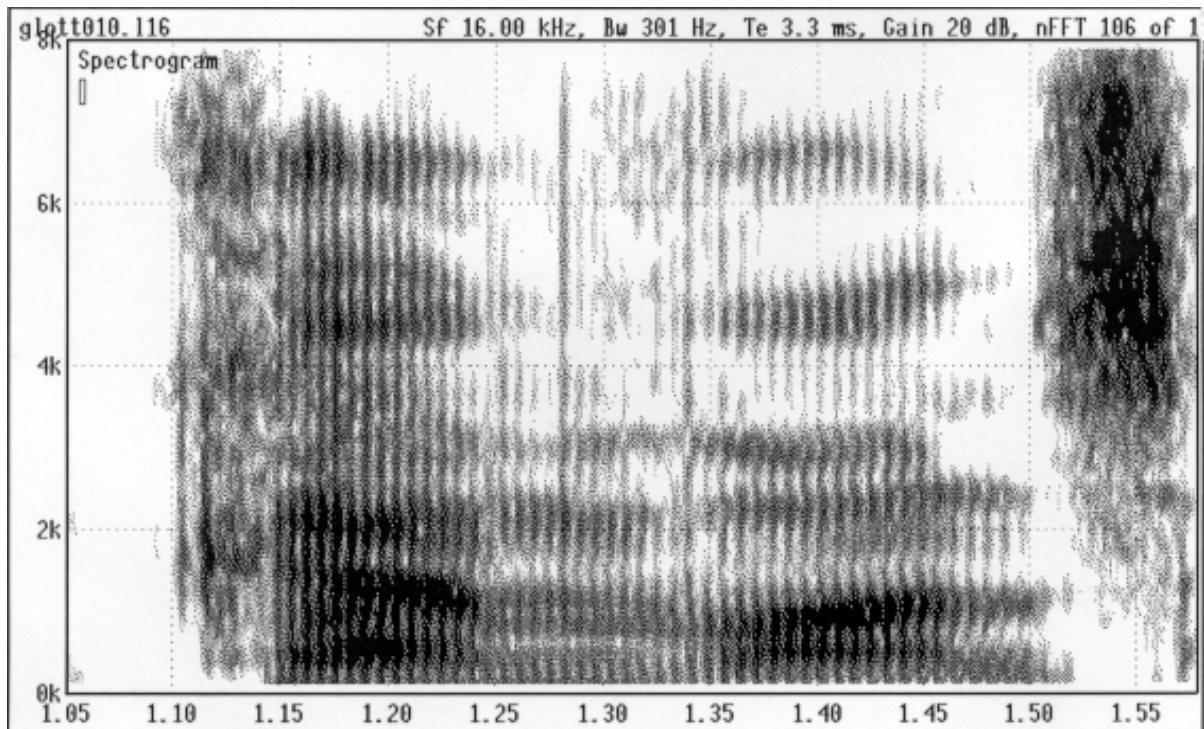
[ha:bən vi:rə] [zɪnt vi:rə] [hat ʔerə] [hapt ʔi:rə]  
 [ha(:)ŋ vɪrə] [zɪŋ(p<sup>v</sup>) vɪrə] [hat (ʔ)ɛrə] [hapt (ʔ)ɪrə]  
 [ha(:)ŋ vɐ] [zɪŋ vɐ] [hat<sup>h</sup> ɐ] [hapt<sup>h</sup> ɐ]  
 [ham ɐ] [zɪŋ ɐ] [hat ɐ] [hapt ɐ]  
 [hamə] [zɪmə] [hadə] [habʔə].

The same subject pronouns in proclitic position and the indirect object “ihr” (in e.g. “er hat ihr geholfen”) reduce less, the possessive pronoun “ihr” (in e.g. “sie hat ihr Kleid gewaschen”) least: in these cases fusion does not occur. So the disappearance of words in context and the appearance of new ones is not only situationally determined but also morphologically and syntactically [26].

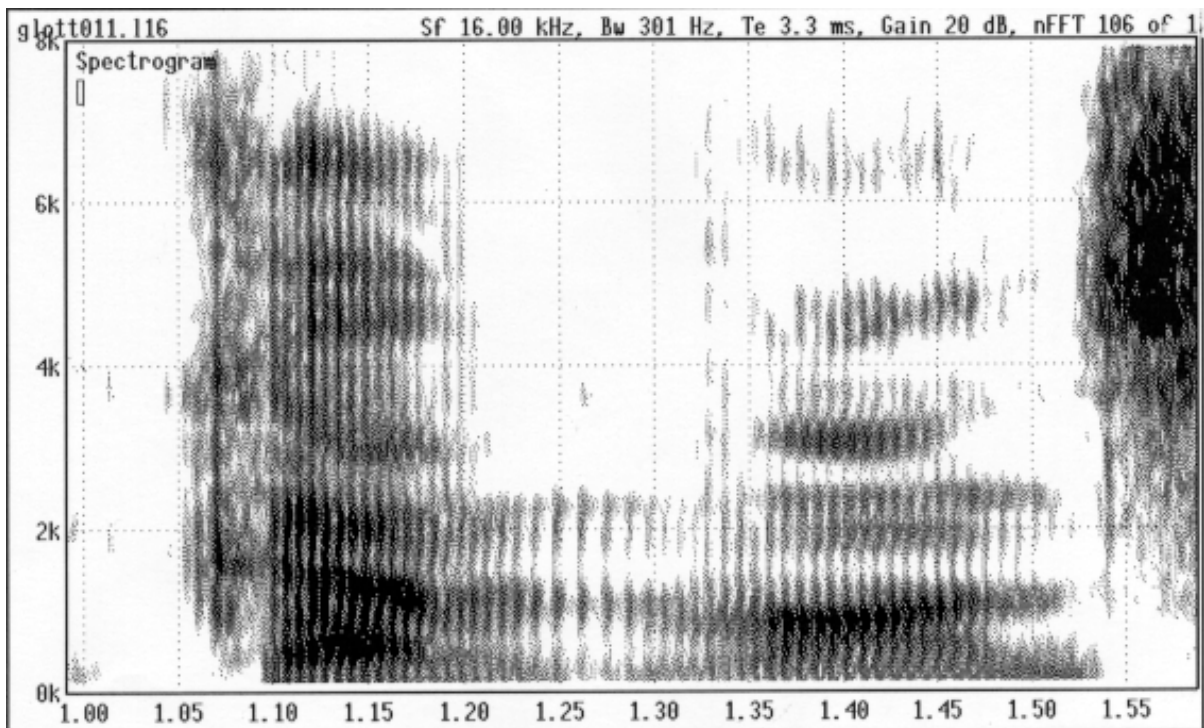
This complete fusion of words to new lexical items is common to other languages too. Examples are Swedish “nas” for “naturligtvis” or English [aɪŋ n] for “I am going to” and [dɪz] for “did you”. Jokes and crossword puzzles in English thrive on this coalescence of word sequences, as, e.g., in “Jamaica? - No, she wanted to.”

A third type of the integration of words is illustrated by some of the reduced phonetic variants in “die können wir uns abholen” and “die könnten wir uns abholen” vs. “die können uns abholen” [dɪ kœŋ<sup>y</sup> ŋ<sup>y</sup> ʊn<sup>y</sup>s] and [dɪ kœŋ<sup>y</sup> ŋ<sup>y</sup> ʊn<sup>y</sup>s] vs. [dɪ kœnn ʊns].

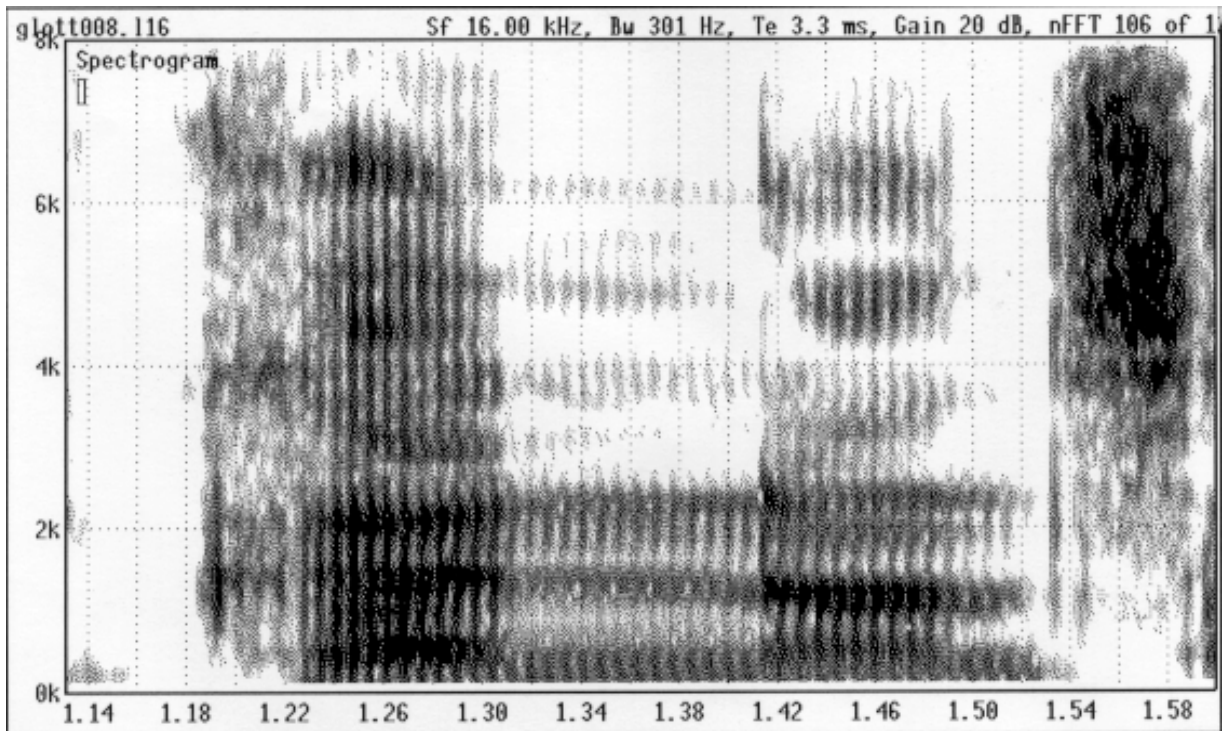
Here words neither disappear without trace nor are they fused to new units: on the one hand, the sequential articulatory movements are greatly reduced, but, on the other hand, phonetic components of velarization, palatalization, glottalization, nasalization etc. are kept as long residual traces of the eliminated elements overlaying the remaining ones. In these instances the tendency towards integration by articulatory fusion is counteracted by the opposite tendency to maintain the phonetic identity of the word through **articulatory prosodies** in a Firthian sense [29].



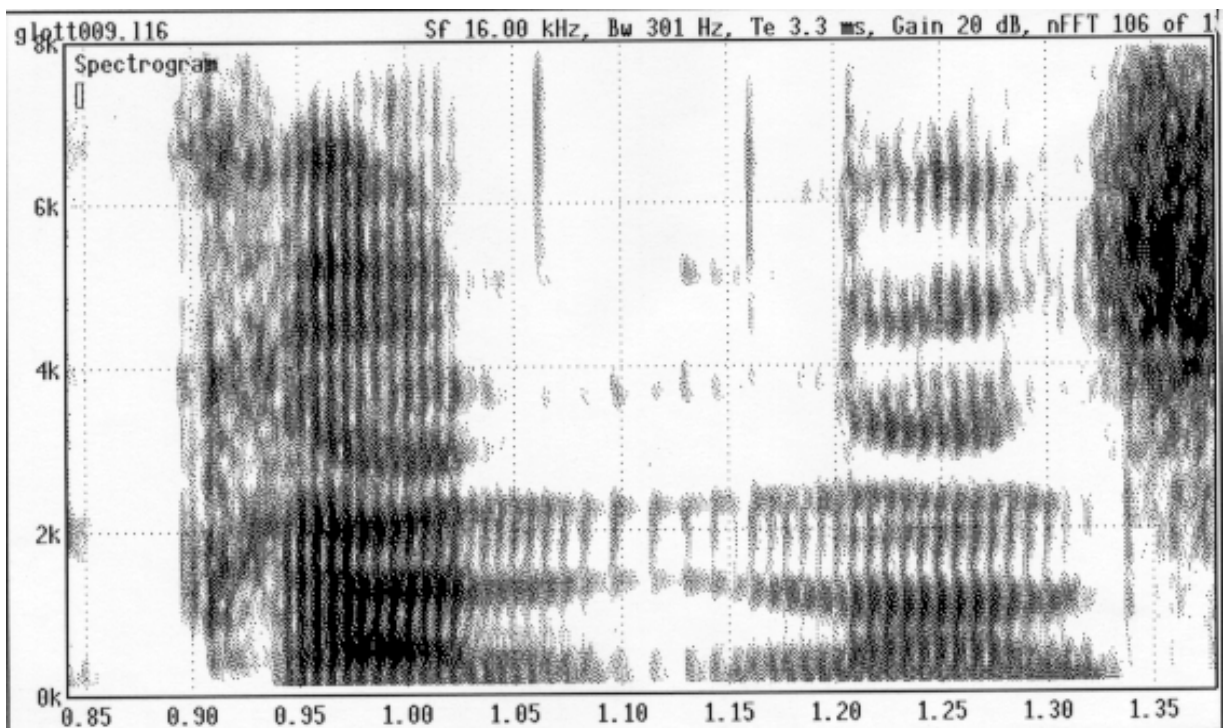
**Figure 5a.** Spectrogram of "*(Die) können wir uns (abholen).*"; read speech, speaker KJK.



**Figure 5b.** Spectrogram of "*(Die) könnten wir uns (abholen).*"; read speech, speaker KJK.



**Figure 6a.** Spectrogram of "*(Die) können uns (ab)holen.*"; read speech, speaker KJK.



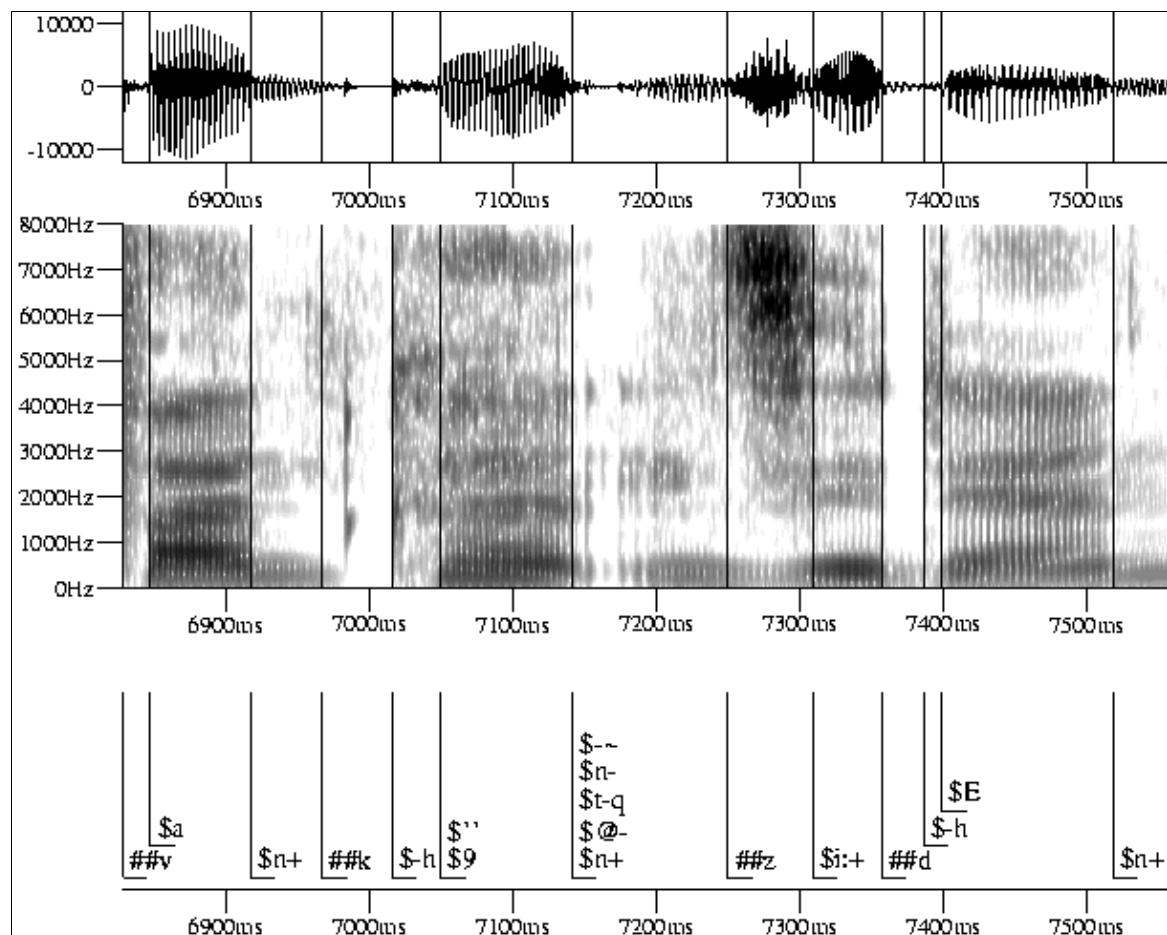
**Figure 6b.** Spectrogram of "*(Die) könnten uns (ab)holen.*"; read speech, speaker KJK.

These componential features have to be represented in a phonetic transcription, even if it is basically segmental, because they mark phonological contrasts at the level above the word. In our labelling system in the Kiel Corpus, we have adopted the symbol **-MA** as a general, unspecified marker, as well as **-q** for glottalization and **--** for nasalization, inserted into the canonical transcription before symbolically deleted segments [40]. In the above examples, velarization and glottalization are labelled in SAMPA transcription of variants as follows:

IPA [dɪ kœmʲ mʲ ʊnʲs] SAMPA d i:+ k 9 n-m @- n-+ v-m -MA i:6-+ U n s+  
 IPA [dɪ kœmʲ mʲ ʊnʲs] SAMPA d i:+ k 9 n-m t-q @- n-+ v-m -MA i:6- U n s+

**-MA** refers to labiodentalization and velarization, in connection with the deletion of the segmental symbols **i:6-**, and **-q** to the replacement of **t** by glottalization. In both cases the componential markers are allocated a point in time in the segmentation, but they have no duration. The following example illustrates the use of **-q** and **--** for glottalized and nasalized componential residues, respectively, from spontaneous speech.

**KAE g197a011** *könnten*  
 canonical SAMPA k 9 n t @ n+  
 variant SAMPA k -h ' '9 -- n- t-q @- n+  
 IPA [k'œ̃ñn]



**Figure 7.** Speech wave, spectrogram and label sequence of “Wann könnten Sie denn?”; spontaneous speech corpus KAEg197a011.

- The first nasal consonant is deleted as a sequential element, but a residue of nasalization is still manifest in the preceding vowel as a componential feature.
- The plosive **t** is realized as glottalization somewhere in the sonorant context (vowel, nasal consonant), without a precise temporal and segmental alignment. The result is comparable to the frequent phonetic realization of the Danish stød, e.g. when German *wenden* and Danish *venden* appear as [v'ɛŋn].
- Both cases of articulatory (nasal or glottal) residues require a non-linear symbolization, i.e. markers that do not receive durations:
  - -- refers to **nasalization**, **t-q** to **glottalization**;
  - both are aligned to the same time as the following, non-deleted segment **n**,
  - indexing phonetic parameters in the segmentally labelled environment (further details in [40]).

### 2.2.2 Content words: degrees of articulatory adjustment

The three types of interference with the phonetic unit of a word are not limited to function words. For example, in German numerals “-zehn” may be realized as [tsn], and, over and above that, “-zehnhundert” (as in “neunzehnhundert vierundneunzig”) may even be pronounced [tset], as long as the word refers to a year and “hundert” is not stressed. In the Kiel Corpus, for instance, we find the following variant (in SAMPA notation) for “neunzehnhundert vierundneunzig” (BACg142a005):

n 'OY n t s e:- n- #h- "U- n- d- 6 t f 'i:-'i:6 r- U- n t- #%n "OY n t s I C .

It is, on the one hand, a strongly reduced variant, linked to the citation form pronunciation n'OYntse:n#h"Und6t f'i:rUnt#n'OYntsIC ,

on the other hand, it does not represent the end of the reduction scale because there may be further articulatory simplification, namely

- voiceless vowels in the voiceless obstruent environments
- **t** deletion before **s**
- deletion of nasal consonants and nasalization of the preceding vowels,

resulting in the variant

n 'OY -- n- t- s e:- n- #h- "U- n- d- -MA 6- t f 'i:-'i:6 r- U- n t- #%n "OY -- n- t- s -MA I- C.

Filling in possible further variants between the canonical form, the corpus example and the most integrated pronunciation we get the following set of IPA-transcribed word sequences from most separated to most fused:

[n'ɔ̃ntse:nh,ʊndət f'i:ʁʊntn,ɔ̃ntsɪç]

[n'ɔ̃ntsən̄h,ʊndət f'i:ɛnn,ɔ̃ntsɪç]

[n'ɔ̃ntsp̄h,ʊnnət f'i:ɛnn,ɔ̃ntsɪç]

[n'ɔ̃ntsp̄,ʊnnət f'i:ɛnn,ɔ̃ntsɪç]

[n'ɔ̃ntsp̄ənət f'i:ɛnn,ɔ̃ntsɪç]

[n'ɔ̃ntsn̄ənət f'i:ɛnn,ɔ̃ntsɪç]

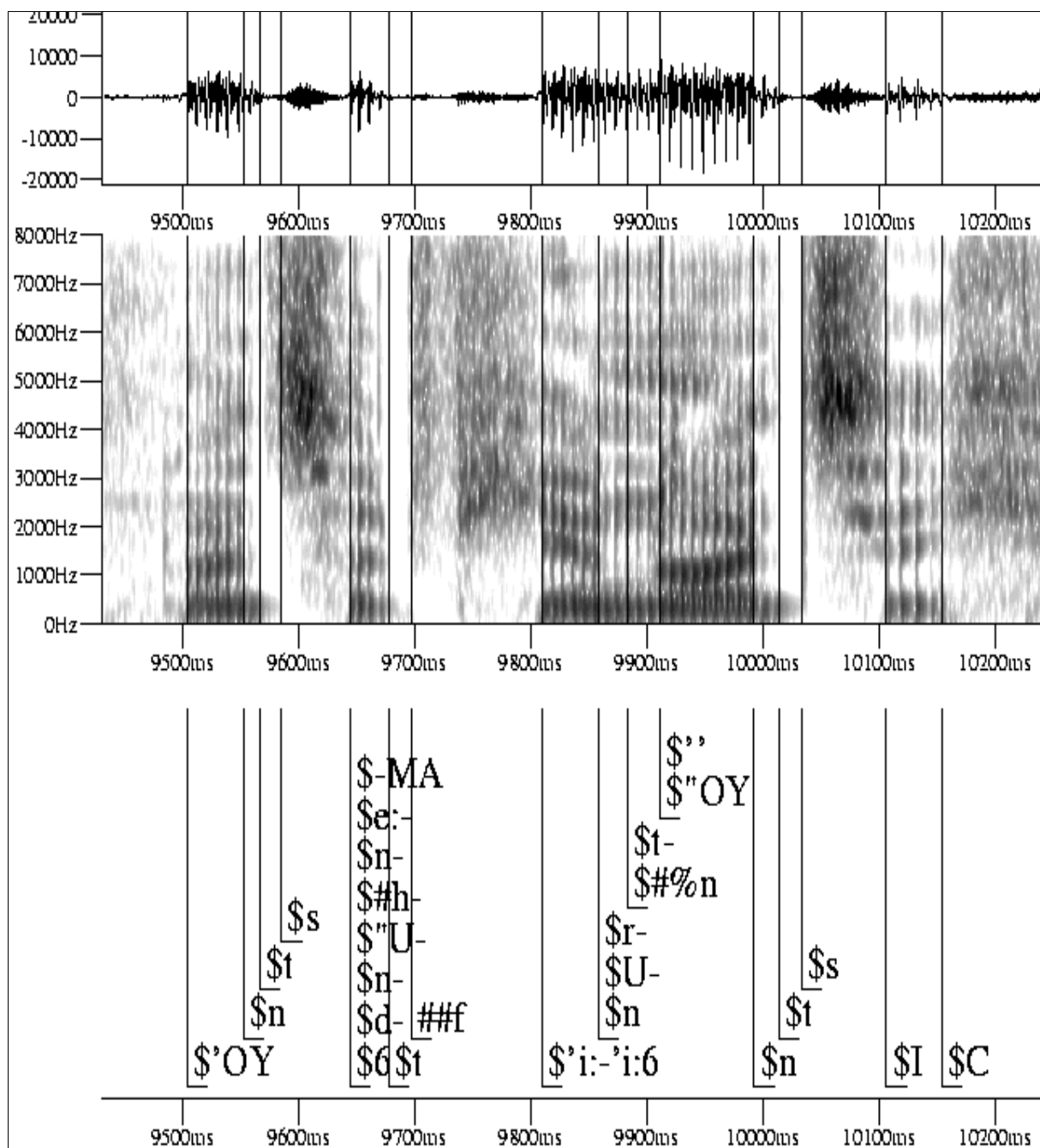
[n'ɔ̃ntsn̄nət f'i:ɛnn,ɔ̃ntsɪç]

[n'ɔ̃ntsn̄ət f'i:ɛnn,ɔ̃ntsɪç]

[n'ɔ̃ntset f'i:ɛnn,ɔ̃ntsɪç]

[n'ɔ̃ms̄ət f'i:ɛnn,ɔ̃ms̄ɪç]

[n'ɔ̃ɪs̄ət f'i:ɛnn,ɔ̃ɪs̄ɪç]



**Figure 8.** Speech wave, spectrogram and label sequence of “*neunzehnhundert vierundneunzig*”; spontaneous speech corpus BACg142a005.

### 2.3 Balance between articulatory economy and auditory distinctivity as a function of the communicative situation

The examples presented in the preceding sections suggest that word production is a compromise between articulatory economy for the speaker and acoustic distinctivity for the listener. Economy of effort in speech production is governed by a number of anatomical, physiological and temporal constraints in the speech producing apparatus that introduce directionality into reductions, such that they are not chaotic. Not just any changes, but only certain types are possible, which occur over and over again in the languages of the world and in historical sound change. For instance the development of nasal vowels is tied to the position before nasal consonants, which are in turn deleted. Stops may become fricatives and approximants, and the latter may even disappear in inter-sonorant position, but the reversal of this chain is not possible.

These physically constrained tendencies to reduce effort are in their turn controlled by linguistic structures at all levels, from phonology to syntax and semantics, and therefore have different manifestations and distributions in different languages, although basic types can be generalized. Furthermore the degree of articulatory effort is governed by the precision listeners need in order to understand, and this need is different in different speaking environments, for acoustic reasons as well as for reasons of redundancy in form and content. This redundancy is determined by the common core of linguistic context and context of situation in the widest sense between speaker and hearer, ranging from world knowledge through culture and society to the individual discourse setting.

The balance between articulatory effort and perceptual distinctivity is thus solved differently in various communication situations (cf. Lindblom's H&H theory [45]). In the lab speech situation the effect of the principle of articulatory economy is small and consequently the preservation of word identity is much greater than in read texts and even greater than in spontaneous speech taking place within delimited scenarios. This means that the study of different speaking styles [30] may be expected to yield different frequencies and different degrees of articulatory reductions or reinforcements, and are consequently a research area of great potential for gaining insight into human communication, an area that has been too much neglected for too long to the detriment of linguistic science. Modern phonetics has the theoretical and methodological tools to get on with the task and to put spoken language performance into its proper perspective vis-à-vis the linguistic imperialism of written language competence.

Because of this balance between production effort and perception ease it is also an important and interesting question how listeners manage - or why they do not manage - to decode various forms of spoken language, which may, in the case of casual spontaneous dialogue, be extremely "distorted" from the point of view of canonical word forms. The examples quoted in this paper can all be understood immediately by native speakers of German in the contexts in which they are uttered; even the strongly reduced version of "*die könnten wir uns abholen*", spoken by itself is quite intelligible. So listeners do not need complete phonetic signals for all the words that make up an utterance.

On the other hand, utterances that do contain all the phonetic word information may not be comprehensible because they lack the necessary (non-phonetic) context of situation cues. An example is the following German sentence (in IPA transcription without word divisions and with punctuation marks to indicate sentence prosodies):



[m'ɛ:ən ɛptəh'ɔɪ]?[n'ɛ:].[m'ɛ:kdəm,ɛ:ən h'ɔɪ],[ɛptəb'ɛ:tn].

German listeners are usually not able to decode it at all - or at least not without repetition - as the pronunciation corresponding to the spelling

*“Mähen Äbte Heu? Nee. Mägde mähen Heu, Äbte beten.”*

*“Do abbots cut hay? No. Maids cut hay, abbots pray.”*

The hearer thus gets along with a lot less phonetic word signalling, but also needs a lot more contextual cues; how much less of the one and how much more of the other in what phonetic, linguistic and situational contexts is a question to be answered by future research. **Word phonology** has outlived itself. We have to look much more closely at the regularities of production and perception processes at the **utterance level** in actual speech communication, and this goal goes beyond the word as a phonetic unit and beyond the collection of phonetic variants lexica, because we should not just deal with the question of how the words of a language are pronounced, we also need to give answers why the pronunciations are the way they are under the constraints of the utterance in communicative context. This scientific perspective also demands a thorough integration of the symbolic domain of phonological structures with the signal domain of phonetic speech dynamics. At IPDS Kiel we have been working very intensively on the question of utterance phonology and phonetics overlapping, and interfering with, word phonology and phonetics. A research grant from the German Research Council that we have recently been allocated for this type of investigation will allow us to continue this work within a framework of fundamental research to gain deeper scientific insight into how speech works. The focus is on German but we are ultimately aiming at a comparative treatment of European languages [7,36,37,64,65].

### 3 The Future of Phonetics

After having looked at phonetics past and present I shall now turn to its future and discuss some tasks which seem to me to be deducible from the present state-of-the-art and from the insight into its historical development. The phonetic paradigm which I have presented with reference to the research at Copenhagen, Berkeley and Kiel lies outside the scopes of linguistics, engineering or computer science in their dealings with language and speech. Neither the signal-to-symbol relation in a phonetic phonology nor the handling of phonetics and phonology above the word find parallels in these disciplines. So modern phonetics presents itself as a subject in its own right. Its practitioners require sufficient theoretical and methodological competence in both signal processing and language categorization to establish the fundamental signal-to-symbol relation for their work. Phonetics should thus not be considered a juxtaposition of the subjects mentioned, and of many others that may deal with the spoken medium, but as one science.

What we need to achieve in the future is a broad recognition of the successful integration we have accomplished between linguistic phonetics and speech signal processing, i.e. we must try to overcome the hegemonic thinking of linguistics and phonology. But at the same time we do not want to return to the a-linguistic philosophy of the early experimental phoneticians either. The danger of history repeating itself in this respect is great, because an ever increasing number of engineers and computer scientists without the essential understanding for language structures treat speech as mere statistical signals. Their a-linguistic signal approach tends to dominate applied research in speech technology, where the money for phonetic research lies nowadays.

Phonetics has a lot to offer in the way of answers to applicational problems in automatic speech synthesis and speech recognition, but it must make its voice heard more forcefully. We have to

convince funding organizations and university administrators that more basic research into speech production and perception is needed for successful solutions to practical questions in information technology in the long run, and that better funding is a prerequisite for it. In Björn Lindblom's words: "Favoured by sponsors, gambling on shortcuts will no doubt continue to attract people and cost a lot of money, although it appears singularly untempting to the informed phonetician. Supporting, and doing, fundamental research seems like a much safer strategy in making phonetics useful." [46] The first step is entering scientific competition as a unified science with a binding paradigm and a single voice triggered by this paradigm, instead of operating as a multitude of 'phonetic sciences'.

This view is diametrically opposed to the one Peter Ladefoged expressed in his opening address at the 1987 ICPHS in Tallinn, when, referring to communication engineering, physical acoustics, psychology, anatomy, physiology, linguistics, applied linguistics, computer science and poetry as parts of our lives as phoneticians, he remarked: "...we are phoneticians, we, the people who come to phonetics congresses, and know something about some of these diverse disciplines. None of us can know enough about all of them, which is why being a complete phonetician is an impossible task. But every four years we can get together and pool our knowledge. This is phonetics." [43]

This kind of statement is not only unscientific since it replaces theoretical questions, motivated by, and converging on, one principled research paradigm, with an encyclopedic collection of diverging research activities. It also gives a wrong picture of phonetic reality because phoneticians need not and should not be jacks of all trades, but they should be masters of one, namely phonetics, by providing accounts and explanations of how speech is produced, perceived and acquired, and how the world's sound patterns are related to the on-line phenomena of speaking, listening and learning [46], and they should achieve this through the application of mutually related symbolic phonetic and signal processing techniques. This is phonetics, and this is how responsible and competent phoneticians actually go about their daily work. They know enough about the fields their questions touch upon, and they establish interdisciplinary connections with other fields when the type of question suggests it as profitable, but this does not turn the latter into phonetic sciences. All other serious sciences proceed along these lines, defining their own basic paradigm and establishing interdisciplinary relations from it.

But Ladefoged's view is not only at odds with the needs and the facts of modern phonetics, it is also harmful, because people will then ask the obvious question how phonetics differs from the individual areas that make up the sum, and this leads to the inevitable and fatal conclusion that phonetics has no independent status and therefore need not receive financial support as a subject in times of economic recession. It will not do either to say, as Ladefoged did [44], with reference to the International Phonetic Association, the main professional society of phonetics, that "[it behaves] somewhat like the Church of England - a body whose doctrine is so diffuse that one can hold almost any kind of religious belief and still claim to be a member of it." If this were the case - fortunately it is only an Englishman's idiosyncratic opinion - phonetics could no longer be taken seriously as an academic discipline.

In order to do full justice to its scientific profile, potential and affiliations phonetics should not be subordinated unilaterally to either linguistics or engineering or computer science or psychology or any other of the subjects listed by Ladefoged, but should be able to establish equal links with all these disciplines. This means that from the point of view of academic administration it should be our policy for the future to get phonetics organised in independent departments or at least in independent divisions with their own budgets and research programmes. There is more than one

example of independent phonetics departments having their staff, funds, research and teaching activities severely curtailed after forced amalgamation with linguistics.

Following on from these programmatic views of the future of phonetics as a scientific discipline and of its organization I should now like to mention some of the topics that, I think, are going to dominate future phonetic research. In a previous publication [32] I listed

- acoustic/articulatory data bases and phonetic labelling
- articulatory reduction and elaboration in speech
- accentuation, intonation and speech timing
- spontaneous speech

as areas of investigation in the languages of the world. The vastness of this programme becomes apparent when we realise that even well-described languages like Danish, English, German, Swedish have large blanks in their analyses, particularly in the area of spontaneous speech, and for the majority of the world's languages we have no more than basic word-level phonetics and phonology.

These topics fit into the following wider theoretical and methodological questions:

- the development of a research paradigm for sound patterns of connected speech in the languages of the world [40]; this also comprises the development of methods for integrating analyses of 'real' speech, i.e. fieldwork and spontaneous data, with lab speech, i.e. experimental articulatory, acoustic and perceptual data
- the comparative analysis and phonetic typology of speaking styles, including different varieties of unscripted and spontaneous speech for individual languages
- phonetics and phonology above the word for individual languages
- universals and typologies of sentence and utterance phonetics and phonology
- universals of sound change
- the intelligibility of reduced speech
- speech development.

Applications of phonetics in foreign language learning, forensic speaker recognition, speech pathology and automatic speech synthesis/recognition supplement this catalogue of basic research.

We must also invest a good deal of time and effort into the development of generally recognised teaching curricula that transmit the theoretical, methodological and empirical foundations of the subject to students in under- and post-graduate programmes and thus train future generations of phoneticians for practical job applications as well as for basic research world-wide. Another facet of teaching will have to be the reinstating of expert phonetic service teaching in language subjects and speech therapy.

The type of phonetics curriculum envisaged here represents an entirely different scientific standard from what is being pursued at the European level under the direction of Gerrit Bloothoof. The European initiative did not take the definition of a paradigm of phonetics as its point of departure, as would have been absolutely essential, but produced an encyclopedic compilation in the spirit of Peter Ladefoged's definitions of a phonetician and of the IPA. Curricula set up on such premises are worthless for the training of the phoneticians we need in the future, and the phonetics community should fight any attempts to introduce them in Europe. Of course, we need to increase our scientific cooperation in research and teaching at the European and world levels, but I am convinced it will be realised more efficiently outside this official European bureaucratic dilettantism by strengthening already existing ties between individual institutes. There is a thought in this connection which Olle Engstrand has put forth and which I find very attractive. Round the Baltic Sea there is a linguistically very diverse area with the highest density of phonetics institutes in the

world, about a dozen, including Norway . Why not get them closer together, organise a colloquium and form a working group of Baltic phonetics for cooperation and meetings? Others might think about this too.

So a huge number of tasks lie ahead of us with regard to general policy, research and teaching, but when we compare today's state-of-the-art with the phonetics in Kratzenstein's days or even within the last half-century we can be quite pleased and a little proud too of what we have achieved. But mixed into this joy is also some sadness at seeing the person go who has done so much for phonetics in general and in Copenhagen in particular. Jørgen, we all know that this is only your official retirement and that you will most likely be as active as before; but your department is losing you as the pilot in rough seas, and that may fill you with sadness too when you think of its future. To console you let me finish with the words Alexander Graham Bell, the inventor of the telephone, used in an address to graduates in Boston in 1917 at the age of 70:

*“What a glorious thing it is to be young and have a future before you: it is also glorious to be old and look back upon the progress of the world during one's own lifetime. I myself am not so very old yet, but I can still remember the days when there were no telephones.”*

#### 4 References

(AIPUK = Arbeitsberichte d. Instituts f. Phonetik u. digitale Sprachverarb. d.Univ. Kiel

ARIPUK = Annual Report of the Institute of Phonetics, University of Copenhagen)

- [1] Browman, C.P., and Goldstein, L.: Articulatory phonology: an overview. *Phonetica* 49, 155-180 (1992)
- [2] Butcher, A.: Coarticulation in intervocalic voiceless plosives and fricatives in connected speech. *AIPUK* 8, 154-213 (1977)
- [3] Chiba, T. , Kajiyama, M.: *The Vowel, its Nature and Structure*. Tokyo (1941)
- [4] Fant, G.: *Acoustic Theory of Speech Production*. s'Gravenhage: Mouton (1960)
- [5] Fischer-Jørgensen, E.: *A phonetic study of the stød in Standard Danish*. *ARIPUC* 21, 56-265 (1987), also as a monograph University of Turku Phonetics (1989)
- [6] Heepe, M.: *Lautzeichen und ihre Anwendung in verschiedenen Sprachgebieten*. Berlin: Reichsdruckerei (1928)
- [7] Helgason, P.: Lenition in German and Icelandic. *AIPUK* 31, 219-226 (1996)
- [8] Helgason, P., Kohler, K. J.: Vowel deletion in the Kiel Corpus of Spontaneous Speech. *AIPUK* 30, 115-157 (1996)
- [9] Helmholtz, H.: *Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik*. Braunschweig (1862)
- [10] IPDS: CD-ROM#1: *The Kiel Corpus of Read Speech, vol. I*. Kiel: IPDS (1994)
- [11] IPDS: CD-ROM#2: *The Kiel Corpus of Spontaneous Speech, vol. I*. Kiel: IPDS (1995)

- [12] IPDS: CD-ROM#3: *The Kiel Corpus of Spontaneous Speech, vol. II*. Kiel: IPDS (1996)
- [13] IPDS: CD-ROM#4: *The Kiel Corpus of Spontaneous Speech, vol. III*. Kiel: IPDS (1997a)
- [14] IPDS: *xassp* (Advanced Speech Signal Processor under the X Window System) - User's Manual. Version 1.2.15. *AIPUK* 32, 31-115(1997b)
- [15] Jespersen, O.: *The articulations of speech sounds represented by means of alphabetic symbols*. Marburg (1889)
- [16] Jespersen, O.: *Fonetik, en systematisk fremstilling af læren om sproglyd*. København (1897-1899)
- [17] Jespersen, O.: *Lehrbuch der Phonetik*. Leipzig: B.G. Teubner (1904, <sup>2</sup>1913)
- [18] Jespersen, O.: *Grundfragen der Phonetik*. Leipzig: B.G. Teubner (1904)
- [19] Jones, D.: *English Pronouncing Dictionary*. 15th ed. (P. Roach, J. Hartman, eds.). Cambridge: Cambridge University Press (1997)
- [20] Kempelen, W. von : *Mechanismus der menschlichen Sprache nebst der Beschreibung seiner sprechenden Maschine*. Wien (1791)
- [21] Klinghardt, H.: *Artikulations- und Hörübungen. Praktisches Hilfsbuch der Phonetik für Studierende und Lehrer*. Cöthen: Otto Schulze (1897)
- [22] Klinghardt, H.: Der Werth der Phonetik für den Unterricht in der Muttersprache und den Fremdsprachen. *Englische Studien* 24, 239-264; 25, 162-194 (1898)
- [23] Klinghardt, H., und Fourmestraux, M. de: *Französische Intonationsübungen. Für Lehrer und Studierende*. Cöthen: Otto Schulze (1911)
- [24] Klinghardt, H., und Klemm, G.: *Übungen im englischen Tonfall. Für Lehrer und Studierende*. Cöthen: Otto Schulze (1920)
- [25] Klinghardt, H.: *Übungen in deutschem Tonfall. Für Lehrer und Studierende, auch für Ausländer*. Leipzig: Quelle & Meyer (1927)
- [26] Kohler, K.: Kommunikative Aspekte satzphonetischer Prozesse im Deutschen. In: H. Vater (ed.), *Phonologische Probleme des Deutschen*, 13 - 39. Tübingen: G. Narr (1979)
- [27] Kohler, K.: Segmental reduction in connected speech in German: phonological facts and phonetic explanations. In: W.J. Hardcastle, A. Marchal (eds.) *Speech Production and Speech Modelling*, 69 - 92. Dordrecht, Boston, London: Kluwer Academic Publishers (1990)
- [28] Kohler, K. J.: Glottal stops and glottalization in German. Data and theory of connected speech processes. *Phonetica* 51, 38-51 (1994)
- [29] Kohler, K.J.: Complementary phonology: a theoretical frame for labelling an acoustic data

- base of dialogues. *Proc. ICSLP94*, vol. 1, 427-430, Yokohama (1994)
- [30] Kohler, K.J.: Articulatory reduction in different speaking styles. *Proc. XIIIth ICPPhS*, vol. 2, 12-19, Stockholm (1995)
- [31] Kohler, K.J.: The realization of plosives in nasal/lateral environments in spontaneous speech in German. *Proc. XIIIth ICPPhS*, vol. 2, 210-213, Stockholm (1995)
- [32] Kohler, K.J.: Phonetics and Speech Communication: Past Development and Future Perspectives. In: G. Bloothoof, V. Hazan, D. Huber, J. Llisterra (eds.), *European Studies in Phonetics and Speech Communication*, 18-22. Utrecht: OTS Publications (1995)
- [33] Kohler, K.J.: Phonetic realization of German / /-syllables. *AIPUK* 30, 159-194 (1996)
- [34] Kohler, K.J.: Phonetic realization of / /-syllables in German. *AIPUK* 31, 11-14 (1996)
- [35] Kohler, K. J.: Articulatory reduction in German spontaneous speech. *Proc. 1st ESCA Tutorial and Research Workshop on Speech Production Modeling: from control strategies to acoustics*, 1-4, Aufrans (1996)
- [36] Kohler, K. J.: Glottal stop and glottalization - A prosody in European languages. *AIPUK* 30, 207-216 (1996)
- [37] Kohler, K.J.: Glottalization across languages. *AIPUK* 31, 207-210 (1996)
- [38] Kohler, K.J.: Developing a research paradigm for sound patterns of connected speech in the languages of the world. *AIPUK* 31, 227-233 (1996)
- [39] Kohler, K. J.: Labelled data bank of spoken standard German - The Kiel Corpus of Spontaneous Speech. *Proc. ICSLP 96*, vol. 3, 1938-1941, Philadelphia (1996)
- [40] Kohler, K., Pätzold, M., Simpson, A. P.: *From scenario to segment - The controlled elicitation, transcription, segmentation and labelling of spontaneous speech*. *AIPUK* 29 (1995)
- [41] Kohler, K.J., and Rehor, C.: Glottalization across word and syllable boundaries. *AIPUK* 30, 195-206 (1996)
- [42] Kratzenstein, C.T.: Sur la naissance de la formation des voyelles. *Journal de Physique* 21, 358-380 (1782)
- [43] Ladefoged, P.: A view of phonetics. *UCLA Working Papers in Phonetics* 70, 41 (1988)
- [44] Ladefoged, P.: Some reflections on the IPA. *Journal of Phonetics* 18, 335-346 (1990)
- [45] Lindblom, B.: Explaining phonetic variation: a sketch of the H & H theory. In W.J. Hardcastle and A. Marchal (eds.), *Speech Production and Speech Modelling*, 403-439. Dordrecht: Kluwer Academic Publishers (1990)

- [46] Lindblom, B.: A view of the future of phonetics. In: G. Bloothoof, V. Hazan, D. Huber, J. Llisteri (eds.), *European Studies in Phonetics and Speech Communication*, 22-30. Utrecht: OTS Publications (1995)
- [47] Merkel, C.L.: *Physiologie der menschlichen Sprache*. Leipzig (1866)
- [48] Ohala, J., and Jaeger, J.J.: *Experimental Phonology*. London: Academic Press (1986)
- [49] Ohala, J.: The phonetics of phonology. In: G. Bloothoof, V. Hazan, D. Huber, J. Llisteri (eds.), *European Studies in Phonetics and Speech Communication*, 85 - 89. Utrecht: OTS Publications (1995)
- [50] Ohala, J.: The phonetics of sound change. In: C. Jones (ed.), *Historical Linguistics: Problems and Perspectives*, 237-278. London: Longman (1995)
- [51] Pätzold, M.: *KielDat* - Data bank utilities for the *Kiel Corpus*. *AIPUK* 32, 117-126 (1997)
- [52] Rask, R.: *Undersøgelse om det gamle Nordiske eller Islandske Sprogs Oprindelse*. København (1818)
- [53] Rehor, C.: Phonetische Realisierung von Funktionswörtern im Deutschen. *AIPUK* 30, 1-113 (1996)
- [54] Rehor, C., and Pätzold, M.: The phonetic realization of function words in German spontaneous speech. *AIPUK* 31, 5-10 (1996)
- [55] Reyher, S.: *Dissertatio de Aere*. Kiel (1670)
- [56] Reyher, S.: *Mathesis Mosaica, sive Loca Pentateuchi Mathematica Mathematice Explicata*. (1679)
- [57] Rischel, J.: Instrumentation for vowel synthesis. *ARIPUC* 1, 15-21 (1966/7)
- [58] Rischel, J.: *Topics in West Greenlandic Phonology*. København: Akademisk forlag (1974)
- [59] Rischel, J.: A note on diachronic data, universals and research strategies. In: W.U. Dressler, O.E. Pfeiffer, J.R. Rennison (eds.), *Phonologica 1980*, 365-371. Innsbruck: Institut für Sprachwissenschaft (1981)
- [60] Rischel, J.: Fieldwork data as input to instrumental analysis - a dilemma. In: U. Pieper, G. Stickel (eds.), *Studia linguistica diachronica et synchronica*, 709-722. Berlin: Mouton de Gruyter (1985)
- [61] Rischel, J.: An appraisal of research in the phonetics and phonology of Thai. *ARIPUC* 19, 43-93 (1985)
- [62] Rischel, J.: Devoicing or strengthening of long obstruents in Greenlandic. *ARIPUC* 20, 67-78 (1986)
- [63] Rischel, J.: Phonetic transcription in fieldwork. In: A. Almeida, A. Braun (eds.), *Probleme*

*der Transkription*, 57-77. Stuttgart: F. Steiner (1987)

- [64] Rodgers, J.: Vowel deletion/devoicing. *AIPUK* 31, 211-218 (1996)
- [65] Rodgers, J.: Vowel devoicing/deletion in English and German. *AIPUK* 32, 177-195 (1997)
- [66] Rodgers, J.: A comparison of vowel devoicing/deletion phenomena in English laboratory speech and German spontaneous speech. *AIPUK* 32, 197-214 (1997)
- [67] Rodgers, J., Helgason, P., Kohler, K. J.: Segment deletion in the Kiel Corpus of Spontaneous Speech. *AIPUK* 32, 127-176 (1997)
- [68] Rousselot, L'abbé: *Les modifications phonétiques du langage, étudiées dans le patois d'une famille de Cellefrouin (Charente)*. Paris: H. Welter (1892)
- [69] Rousselot, L'abbé: *Principes de phonétique expérimentale*. 2 vols. Paris: H. Welter (1897-1901)
- [70] Sievers, E.: *Grundzüge der Lautphysiologie*. Leipzig: Breitkopf & Härtel (1876)  
2nd ed. *Grundzüge der Phonetik zur Einführung in das Studium der Lautlehre der indogermanischen Sprachen*. (1881); (<sup>3</sup>1889), (<sup>4</sup>1893), (<sup>5</sup>1901)
- [71] Simpson, A. P., and Pätzold, M. (eds.): *Sound Patterns of Connected Speech - Description, Models and Explanation*. *AIPUK* 31 (1996)
- [72] Trubetzkoy, N.S.: *Grundzüge der Phonologie*. 1939. Göttingen: Vandenhoeck & Ruprecht (<sup>3</sup>1966)
- [73] Verner, K.: Eine Ausnahme der ersten Lautverschiebung. (*Kuhns*) *Zs. f. vgl. Sprachforsch.* 23, 97-130 (1875)
- [74] Zwirner, E. und K.: *Grundfragen der Phonometrie*. (1936); Basel: Karger (<sup>2</sup>1966)