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 kœŋ^{ɣ} ŋ^{ɣ} ʊn^{ɣ}s] SAMPA d i:+ k 9 n-m @- n-+ v-m -MA i:6-+ U n s+
IPA [dɪ kœŋ^{ɣ} ŋ^{ɣ} ʊn^{ɣ}s] 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'œ̃n̰n]**

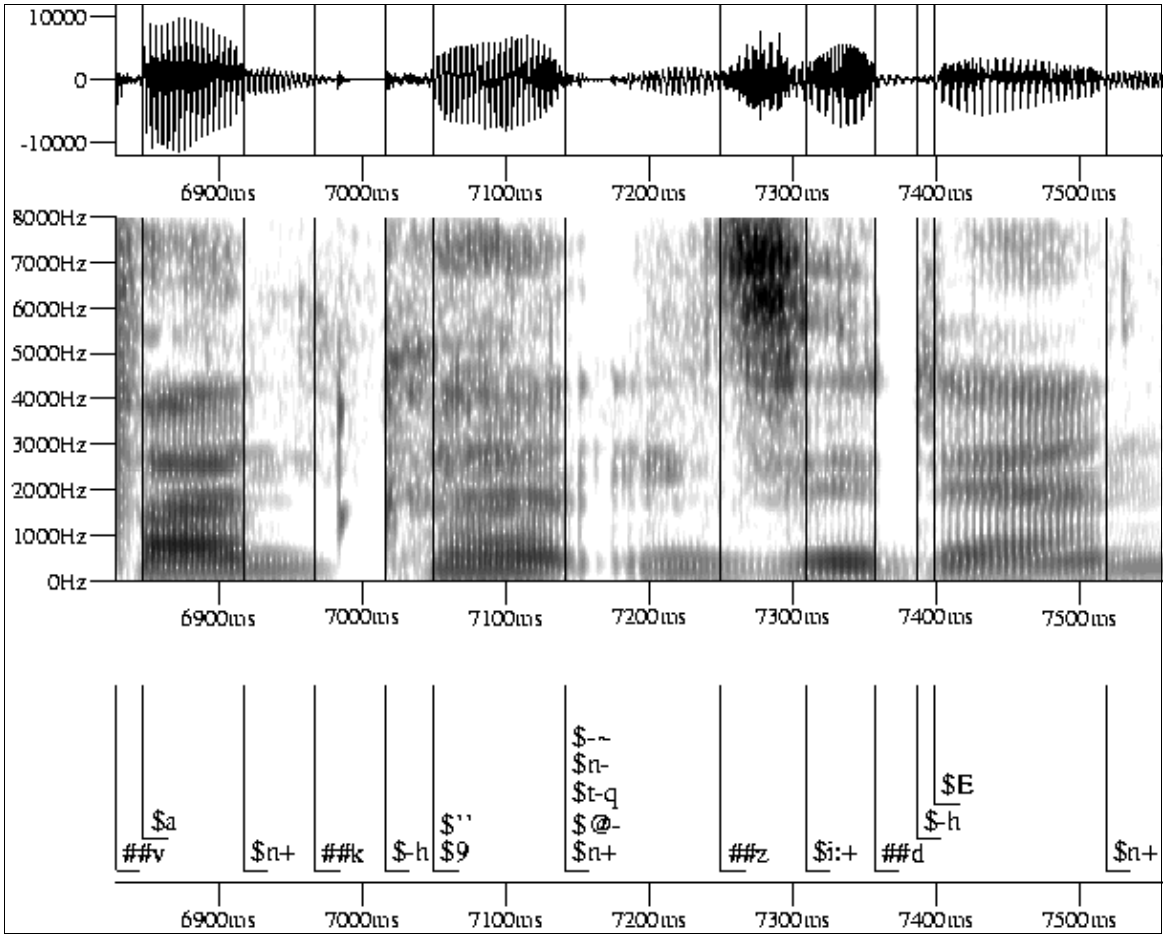

Figure 7. Speech wave, spectrogram and label sequence of *"Wann könnten Sie denn?";* spontaneous speech corpus KAEg197a011.

- 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 **[vˈɛn̰n].**
- 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 **[tsɐt]**, 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:
[nˈɔɪntseːnhˌʊndɐt fˈiːʁʊntnˌɔɪntsɪç]
[nˈɔɪntsənɦˌʊndɐt fˈiːɐnnˌɔɪntsɪç]
[nˈɔɪntsɒɦˌʊnnɐt fˈiːɐnnˌɔɪntsɪç]
[nˈɔɪntsɒˌʊnnɐt fˈiːɐnnˌɔɪntsɪç]
[nˈɔɪntsɒənɐt fˈiːɐnnˌɔɪntsɪç]
[nˈɔɪntsnənɐt fˈiːɐnnˌɔɪntsɪç]
[nˈɔɪntsnnɐt fˈiːɐnnˌɔɪntsɪç]
[nˈɔɪntsnɐt fˈiːɐnnˌɔɪntsɪç]
[nˈɔɪntsɐt fˈiːɐnnˌɔɪntsɪç]
[nˈɔɪnsɐ̯t fˈiːɐnnˌɔɪnsɪ̯ç]
[nˈɔ̃ĩsɐ̯t fˈiːɐnnˌɔ̃ĩsɪ̯ç]

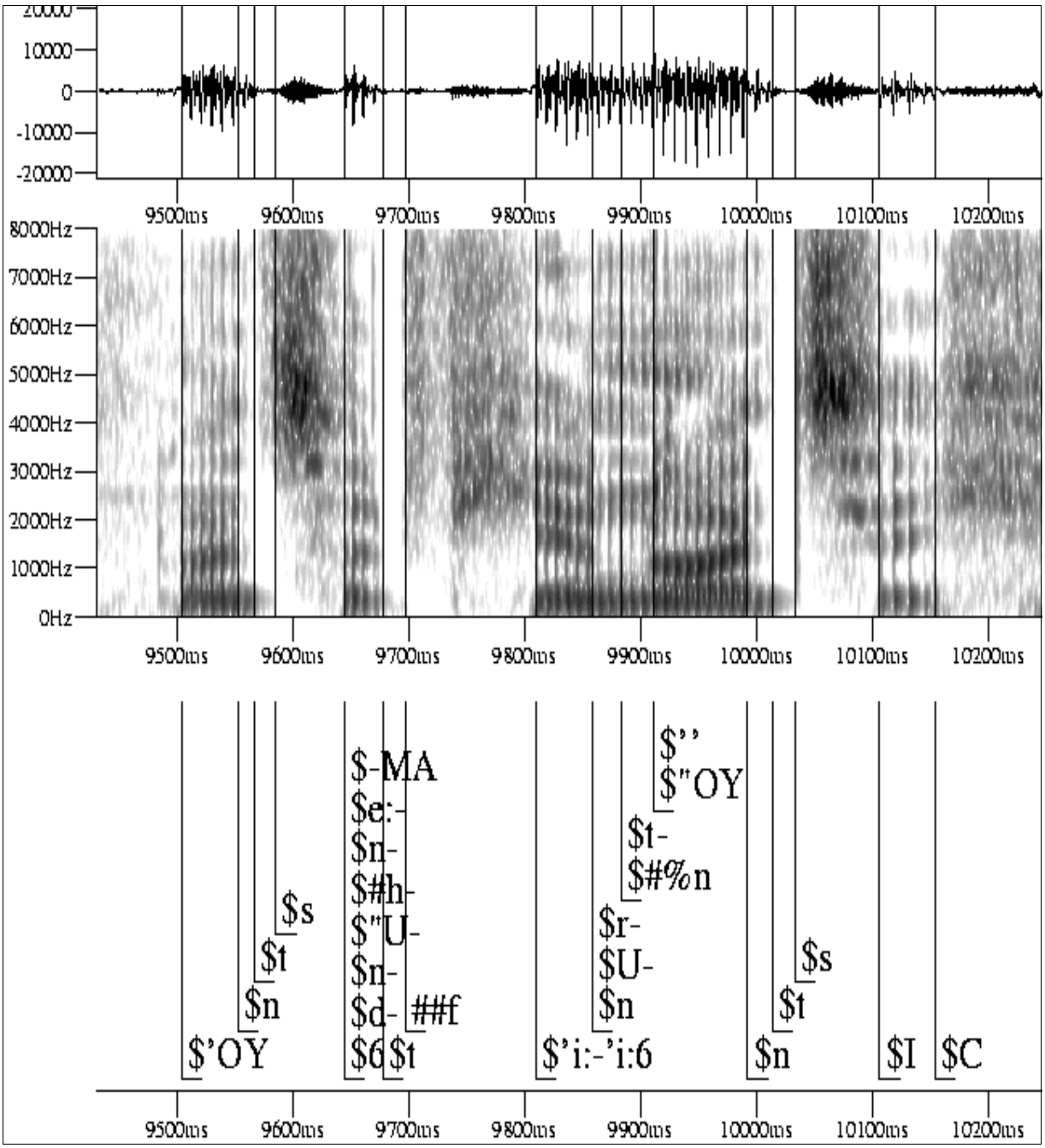

Figure 8. Speech wave, spectrogram and label sequence of *"neunzehnhundert vierundneunzig"*; spontaneous speech corpus BACg142a005.

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 intersonorant 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):

[mˈɛːənɡptəhˈɔɪ]?[nˈeː].[mˈɛːkdəmˌɛːənhˈɔɪ],[ˈɡptəbˈeːtn].

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 or 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 Bloothooft. 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."

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