TRAVAUX

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CERCLE LINGUISTIQUE

DE COPENHAGUE

VOL. XXXI

Nina Grønnum and Jørgen Rischel (eds.)

TO HONOUR ELI FISCHER-JØRGENSEN

C.A. REITZEL
COPENHAGEN 2001

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TO HONOUR ELI FISCHER-JØRGENSEN

Festschrift on the occasion of her 90th birthday
February 11th, 2001

edited by Nina Grønnum and Jørgen Rischel

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Portrait of
Eli Fischer-Jorgensen
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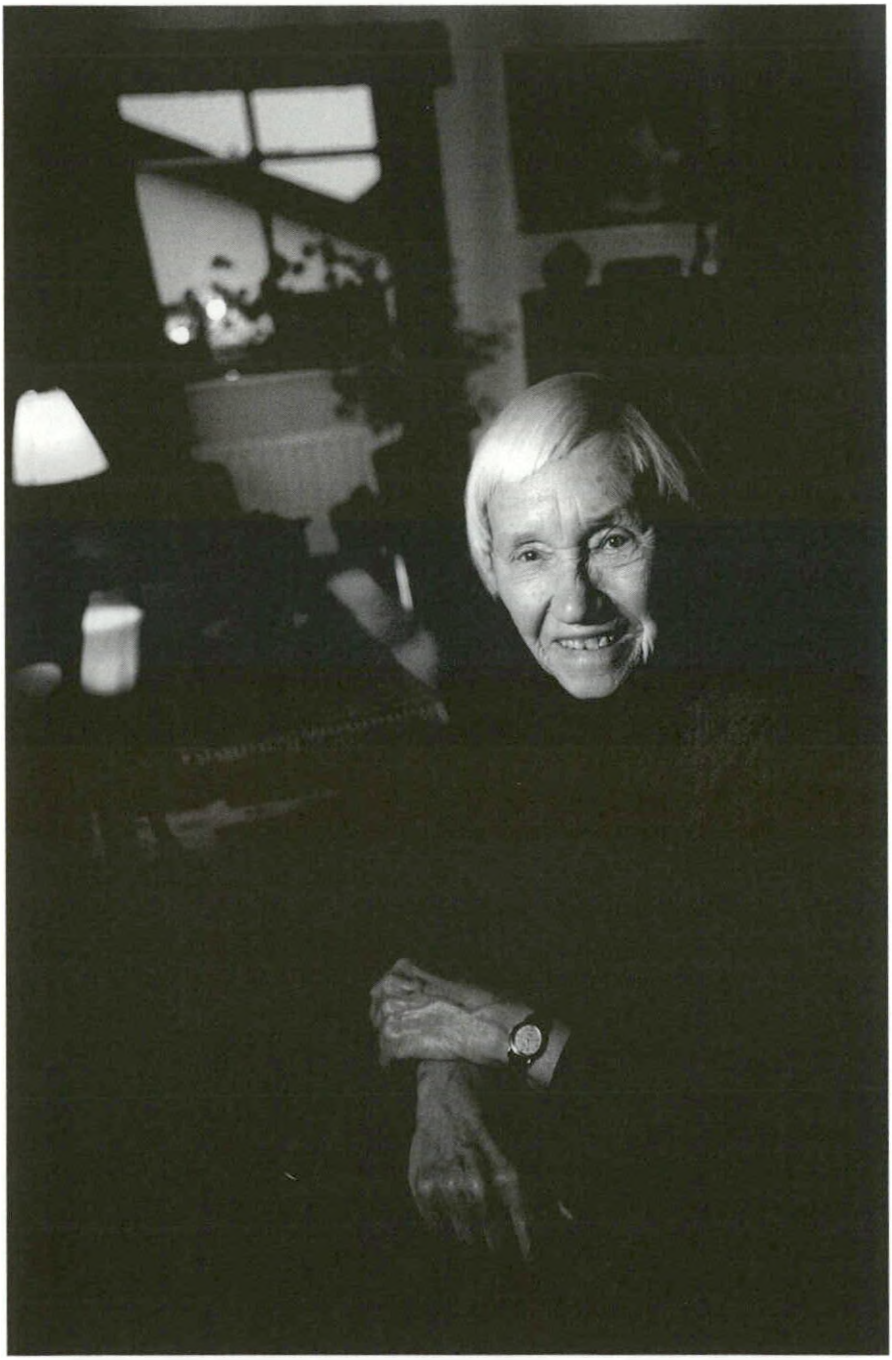

Preface

It is not often that a scholar's ninetieth anniversary becomes the proper occasion for paying tribute to a life of scholarly achievements in a Festschrift. The Grand Old Lady of general phonetics and phonology, Eli Fischer-Jørgensen, has not only lived a long life but an extremely active one, and it is most remarkable that the greater part of her work was completed during the second half of those nine decades. Indeed, whereas one of her two magna opera: the classic textbook *Trends in Phonological Theory* appeared when she was in her sixties, she completed the second: a philological and phonetic treatise on the history of Danish word stress, only last year, i.e. when she was eighty-nine. Thus it is singularly appropriate to use this very occasion to pay tribute to *Eli*, as she is called among scholars and friends world wide.

Eli started out as a Germanic philologist. Interestingly, both her first published work (on the importance of dialect geography for the understanding of sound change) and her latest are historically oriented. Most of the intervening work, however, has been devoted to theoretical and descriptive linguistics and phonetics. Eli soon became one of the most active members of the Linguistic Circle of Copenhagen and played an important role as the sparring partner of Hjelmslev, the most perpetuated theme of their friendly struggle being the relation of phonetic substance to abstract expression form. More or less as an offshoot of this, she wrote a series of remarkable papers on phonology around the middle of the twentieth century which gained her an international reputation in the field. Rather mistakenly, however, her involvement in the glossematic debate, coupled with her expert knowledge of its theoretical foundation, made many linguists outside of Denmark think of her as a glossematician.

Throughout most of her career, however, experimental phonetics has been her preferred field of research. Although she has always remained a linguist in that she approached general phonetic issues by studying language-specific data with a view to their linguistic function, an equally distinctive feature of her approach is her pioneering spirit as an experimenter and her use of advanced technical equipment soon after it had been developed (often for a different purpose, as with the electrical manometer which Eli used already in the fifties to study air pressure in speech). At the same time, with a frankness typical of Eli, she has often emphasized that she herself lacks the mathematical and engineering background which some of her contemporaries could utilize when addressing issues in speech production or perception very technically. This, however, did not in the least deter Eli from embarking on basic research in all major areas of general phonetics, nor did it prevent her from being in the forefront both through her own research and her painstaking and insightful criticism of the work of her colleagues from other fields such as engineering or psychology.

A dual emphasis on phonological theory and instrumental phonetics is characteristic also of the way in which Eli institutionalized the study of general phonetics at the University of Copenhagen in the fifties and sixties. A further characteristic of Copenhagen phonetics is a strong emphasis on what British phoneticians used to call „practical phonetics," reflected in a very thorough training in the perception, transcription and oral reproduction of a wide variety of sound types occurring in the World's languages. Much of the taped material for this training Eli had recorded herself when she was invited as guest professor to India in 1957.

In giving general phonetic research this trilateral profile of impressionistic, phonological, and instrumental data-processing Eli has had an influence on the way in which practical and theoretical-phonetic issues are approached in Denmark equalled only by Otto Jespersen's influence half a century earlier.

A major event in Eli's (and her colleagues') life was the preparation and running of the International Congress of Phonetic Sciences which took place in Copenhagen in 1979. Eli of course presided over the congress, devoting to it the energy and planning skills which she possesses in rich measure, and received enthusiastic and unanimous praise from participants world-wide.

We have attempted to mirror some characteristics of Eli's personality as a scholar in the present volume. The list of contributors and the titles of their papers reflect the breadth of her interests and the range of her influence, from theoretical issues in general linguistics to acoustically or physiologically based studies of speech. The volume comprises a series of original papers written by long-term colleagues of Eli's and by some of her former students. We think it is in line with her own preferences that the majority of papers deal with phonetics proper.

Nina Grønnum
Jørgen Rischel

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A bridge over the Sound

Dialogue between Eva Gårding and Gösta Bruce
dedicated to Eli Fischer-Jørgensen

GB: When did you first meet Eli?

EG: At the international congress of linguists in Oslo in 1957. It was my first congress and I was very much impressed. Linguistics included as a matter of course phonetics. Plenary talks were given by Eli Fischer-Jørgensen, Roman Jakobson, Kenneth Pike and others. Privately Claes Christian Elert and I nominated Eli as the queen of the congress and Roman Jakobson as the king.

The title of Eli's talk was: What can the new techniques of acoustic phonetics contribute to linguistics.

GB: I read this paper when I started my phonetics studies in the late sixties. It was for many years part of the phonetics syllabus in Lund. What made it so long-lived?

EG: Now that I reread the paper I notice that it has all the typical features of Eli's works. It is sharp and clear and easy to understand, the theoretical as well as the technical part. She is positive about new trends, but does not refrain from criticism. She has an eye on the future.

As in many later works she emphasizes her belief that phonetics cannot be separated from phonology and vice versa. I quote from her paper: »Linguistics is primarily concerned with language as a system but this system can only be found through the study of speech... The chief objective of linguistics is the functional system ('form' in the glossematic terminology), but the units of this abstract system can only be identified if the 'substance' (the physical side) is taken into account.«

GB: This seems rather obvious for somebody raised in the Malmberg tradition but what is obvious in Lund is perhaps not so obvious in Copenhagen. What Eli says here and often in later works is maybe directed against Hjelmslev. According to him, as we all know, language has an autonomous structure which is properly described only when it is separated from the substance. On the whole Eli is very interested in substance and in particular in its interplay with form.

But what were the new techniques that she talked about?

EG: Eli had plenty of material for the technical part of her talk. At the time of the Oslo congress phonetics was teeming with new methods and instruments. Even the tape recorder could be considered as a new instrument and then there were the sonagraph, the vocoder, the pattern playback to name the most important ones. All this technical equipment brought about a revolution in phonetics research: the possibility of refining the acoustic analysis of speech, of making synthetic speech and of conducting perceptual experiments.

GB: I remember another great congress, when the International Congress of Phonetic Sciences was held in Copenhagen in 1979 and Eli was the head organizer. I remember it as The Congress; it was such a brilliant and happy meeting, organized with the special Danish smile.

EG: I quite agree even if I have always been sceptical about the Danish smile.

But let us go back to the opening topic. When did you yourself first meet Eli?

GB: It was in the very early seventies. There was then an exchange of phonetics seminars between Lund and Copenhagen. The seminars and post-seminars occurred fairly regularly alternating between the two universities. Eli was the natural center of those meetings. At that time we were very intrigued and some of us even convinced by the crusades of generative phonology. Eli was accepting up to a point. With her background and experience she was able to put things in their right perspective, when the discussions became too abstract and off the phonetic trail.

EG: We also had vivid discussions about prosody, in particular the role of sentence accent. From our own experience we took sentence accent for granted even for Danish but we encountered a fair degree of resistance from the native speakers.

GB: I remember the Danish phrase 'Per så Lis' repeated with even stresses by the Danes as a support for the non-existence of sentence accent. They eventually succeeded in persuading us that the story about compulsory sentence accent is the 'East side story' and something that does not necessarily occur, at least not on the west side of the Sound.

EG: Yes that was at the time a happy ending. But I think we should now talk about a couple of Eli's most important works. One natural choice will be Trends in phonological theory from 1975. Her goal was to characterize by ideas and theoretical concepts different branches in modern phonology and show their connections with classical works. In this task she could combine personal experience from the thirties onwards with a natural talent for clear exposition.

GB: Can't you say something about the contents?

EG: Her book treats 'forerunners' in ancient India and Greece as well as the Icelandic 'first grammatical treatise' from the 12th century. The main body of the text is devoted to the many new directions of the twentieth century. Structuralism is represented by the general ideas of de Saussure, Prague phonology by Trubetzkoy, Jakobson and Martinet. There is an overview of the then leading American linguists: Bloomfield, Hockett, Sapir and others. British linguistics is exemplified by Daniel Jones and Firth, glossematics by Hjelmslev and Uldall and the then recent generative linguistics by Chomsky and Halle.

GB: But there are Swedes as well?

EG: Oh yes, there are appreciative summaries of the contributions of Adolf Noreen and Axel Koch and many references to Malmberg.

GB: What strikes me is that Eli has so many well chosen enlightening quotations. In general she hails developments that cause a widening of perspectives but she does not conceal the fact that many of the ideas that are exposed in the book contradict each other. It is implicitly clear that she has little sympathy for the most radical and abstract schemes of the time.

EG: At the end of a talk 'Phonetics and Phonology' (1994), given on a festive occasion when she became an honorary doctor at Copenhagen university, Eli finds an opportunity to state her own views more explicitly. She describes how in the thirties she encountered the theories of Prague phonology with enthusiasm but she was critical of many too general claims. She criticised for instance the definition of distinctive feature and the strict use of binary oppositions. She strongly advocates the simultaneous use of articulatory, acoustic and perceptual means to obtain reliable descriptive phonological units.

GB: Now you have said a lot about Trends in Phonological Theory but isn't the dust-cover also worth mentioning? It has eight drawings of great linguists, made by Eli.

EG: Yes, Eli is a real artist. She once told me that she had actually wanted to become an architect. In her 1994 talk she described her way to phonetics as departing from a prize-winning essay in syntax on the definition of the sentence going via Prague-phonology to her interest in substance and experimental procedures.

GB: Her work with substance is really extensive: acoustic analyses of vowels and consonants, including phenomena like aspiration and voicing, the opposition tense-lax and a special study of the murmured vowels of Gujarati.

EG: One impressive contribution where she combines old and new methods is her book on the Danish stød: A phonetic study of the stød in standard Danish from 1989. As one can see from the table of contents she uses videofilm of larynx position and movement, electromyography of laryngeal muscles, fiber optical analysis of the vocal folds, airflow and measurements of pressure below and above the glottis, analysis of articulatory force, as well as inverse filtering and acoustic analysis of several prosodic parameters.

GB: Yes, Eli has thought of virtually everything. It is hard to think of a more complete and thorough phonetic investigation. It is a substantial and substantive table she has prepared for us.

EG: Actually it is a summary of a lot of research that had been going on at the institute over the years. She concludes that respiration is not directly involved in the production of the stød. Like Svend Smith she studies two consecutive parts of the segments connected with the stød. The high level of pitch in the first part is explained by cricothyroid activity and the low pitch in the second part by glottis constriction.

GB: Yes, it is clearly demonstrated that the dynamic properties are primary, particularly the sudden death in intensity between the two consecutive phases of the stød; but it is not a glottal stop, it is not just creaky voice, and the pitch characteristics are somehow secondary.

There is one section that deals with phonological and historical aspects. A generally accepted view is that the stød / non-stød opposition in Danish and the two tonal word accents in Swedish and Norwegian are historically related. They certainly are phonetically different but they have lots of common distribution rules. It was also assumed that they had a common origin and there was an ongoing discussion about which came first, the stød or the tones. Although in most accounts the tonal nature of the word accent has been considered original, this view has been challenged. As usual, Eli had a very balanced and wise position. She suggested that the original accentual mark may have had features of both. Today's stød and tonal accents may have developed from an earlier distinction with both dynamic and tonal properties.

EG: Talking about dynamic and tonal I am tempted to conclude that our contacts with Eli over the years have both dynamic and tonal properties. Dynamic through her sharp wit, common sense and sense of humor and tonal by her friendly and unassuming nature. We have really profited from these contacts both in personal and seminar discussions and by reading her excellent expositions. Her work and her friendship have spanned a bridge over the Sound beneficial to all of us here in Lund.

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Honoris causa. Tribute to Eli

Frans Gregersen and Una Canger

Eli Fischer-Jørgensen's intimate connection with the Linguistic Circle of Copenhagen for almost seventy years has made it natural to publish this volume in the *Travaux* series. The introductory tribute will show how Eli's life and that of the Circle have been interwoven.

Eli's birth and early years

Eli Fischer-Jørgensen (hereafter Eli) was born on February 11, 1911, in Nakskov, a town in the south of Denmark, where she lived for the first seven years until the family moved to Fåborg where they stayed for the rest of her childhood. Fåborg is a beautiful town on Fyn (Funen), one of the larger Danish islands.

Eli's parents have been of considerable importance to her, particularly her mother who was gifted and creative and who brought up her children virtually on her own, the father being too busy with his work as a local judge (*dommerfuldmægtig*).

> One of Eli's most remarkable characteristics is her antiauthoritarian perspective on science and indeed life. She has always wanted to see and grasp for herself and has repeatedly tested accepted truths. This is part of her ancestral heritage; it is tempting to call her a natural born radical. In addition she is a rationalist to the bone, another heritage from home.
>
> Eli's observation that her father was unable to lie and unable to withhold his opinions is also a very good autoritratto. Eli's mother

loved music and literature and a paternal aunt was a paintress. Eli is a talented watercolor painter. Her many small watercolors over the years vividly convey her gift for noticing and delimiting (i.e. structuring for the canvas) conspicuous natural sights.

Eli's studies and her years at Kvinderegensen

Eli graduated from Danish gymnasium (high school) in 1929 at Svendborg Statsgymnasium and immediately began her studies at the University of Copenhagen. Her major subject was German, her minor French. To preclude misunderstandings it must be noted that at that time phonetics was not offered as a university subject. Though Otto Jespersen is universally acknowledged as a phonetician of the first order, he was a professor of English at the University of Copenhagen (until 1925; he died in 1943).

The professors of German and French were both prominent in the life of the university, and they soon became important for Eli too: Louis L. Hammerich (1892-1975) had written on accentuation, on philological historical subjects and phonetics, while Viggo Brøndal's (1887-1942) doctoral dissertation was on borrowing and substratum theory within Romance Languages. His later works include an important book on *Ordklasserne* (Word Classes 1928) and one on *Morfologi og Syntax* (Morphology and Syntax 1932). Both Brøndal and Hammerich had good international connections and read the contemporary linguistic literature, especially that by the Prague phonologists. Hammerich would regularly pass his personal copies on to Eli.

As a professor Hammerich was the very ideal of informality, always active in staging discussions on whatever topics occupied the students and himself. There is no doubt that his informal manner resonated in Eli.

While not a feminist by later standards, Eli was part and parcel of the first breakthrough for female academics, and she lived in the first all-female college, Kvinderegensen, in its glorious *Gründer* period from January 1933 until the summer of 1936. In years this is not much but they were some of her formative years, and there she formed important bonds with a group of talented friends several of whom were to influence postwar Danish society (e.g. Ester Ammundsen, Else Dalhoff, Johanne Hansen). When, in 1936, she passed her final exam as the first student from Kvinderegensen to be honoured with a *summa cum laude*, her college mates fetched her in a specially hired streetcar and escorted her to Kvinderegensen for a huge celebration, complete with originally composed songs and dinner speeches. In an interview given in 1994, Eli remembers such celebrations as peak moments of her student years (*Weekendavisen*, 15.-20. juli 1994, p. 18).

Eli was a brilliant student and had much support in her studies from her professors, in particular from her main supervisor, professor L.L. Hammerich. Her MA thesis, *Dialektgeografiens betydning for opfattelsen af lydforandringer* (The importance of dialect geography for the understanding of sound change), was published by the German department as the first in a series designed to forge a link between the university and high school teachers of German, cf. Eli Fischer-Jørgensen's Publications (henceforth Publ.) 1934. The aim was to publish only the best of the MA theses written in the department. Although her essays made her one of the most promising students of her generation, unfortunately neither her prize essay on Weisgerber (Publ. 1932) nor her Gold medal prize essay on John Ries' *Was ist ein Satz* (Publ. 1935a) has ever been published. Along with the published MA thesis they amply documented her research abilities and intentions and thus made it natural for her to continue her career at the University. She did, however, in the spring semester of 1937 take the obligatory course in pedagogical practice (the *pædagogikum*) required to be a licensed high school teacher.

Eli in the early years of the Linguistic Circle (until 1942)

Eli joined the Linguistic Circle in January 1933. The Circle had been established on September 24 1931, by a group of young linguists headed by the true founder Louis Hjelmslev and backed up by the somewhat older and much more influential professor, the very Viggo Brøndal who was one of Eli's professors. In 1933 the Circle sent out a newsletter with the purpose of drawing new members to the Circle, and Hammerich, who had himself joined in the autumn of 1931, suggested that Eli join. In the Circle she met for the first time Paul Diderichsen, MA in Nordic philology, who had also been newly recruited (presumably by Hammerich and Brøndal as well).

Eli's first presentation in the Circle followed on October 5 1933, when she, together with one of the founders Paul Lier, reviewed Grammont's *Traité de phonétique* (*BCLC* '0':2, *Rapport*:25). Brøndal, Hammerich, Hjelmslev and others contributed to the discussion after the review (*BCLC* '0':2).

Eli has given the following lectures and reviews in the Circle. The list is ordered chronologically. The documentation may be found in the various *Bulletins du Cercle Linguistique de Copenhague* (abbreviated *BCLC*):

1933

5.10.: Paul Lier and Eli: Review of M. Grammont: *Traité de phonétique*, 1933.

1934

22.11.: Eli presents her book: *Dialektgeografiens betydning for opfattelsen af lydforandringer*, cf. Publ. 1934.

1937

30.9.: Eli: review of A. Martinet: *La gémination consonantique d'origine expressive dans les langues germaniques*, 1937, cf. Publ. 1939.

1938

30.9.: Eli: review of A.W. de Groot: *Taalkunde*, 1938, cf. Publ. 1940a.

1939

14.12.: Eli: review of N. Trubetzkoy: *Grundzüge der Phonologie*, 1939, cf. Publ. 1941c.

1940

28.11.: Eli: review of N. van Wijk: *Phonologie*, 1939; Eli and A. Bjerrum and V. Brøndal: Review of papers published in *Travaux du Cercle linguistique de Prague*, vol. VIII, 1939.

1941

25.3.: Eli: The Syllable Contact (Loose and close contact). Meeting arranged together with the Society for Nordic Philology, cf. Publ. 1941a, 1946b and later: 1969a and 1969b.

1942

26.2.: Eli: review of Roman Jakobson: *Kindersprache, Aphasie und allgemeine Lautgesetze*, 1941, cf. Publ. 1946d.

1944

18.4.: Paul Diderichsen and Eli introduce a discussion on the present state of the theory of language on the occasion of the appearance in print of Louis Hjelmslev: *Omkring sprogteoriens grundlæggelse*, 1943. Meeting arranged in collaboration with the society for Nordic Philology and the Society for Psychology and Philosophy, cf. Publ. 1943, 1944 and 1970f.

1948

12.2.: Eli: review of K.L. Pike: *The Intonation of American English*, 2nd edition, 1947, cf. Publ. 1949a.

29.4.: Eli: review of K.L. Pike: *Phonetics*, 1943, cf. Publ. 1950a; and *Phonemics*, 2nd edition, 1947.

30.9.: Eli reports on the joint meeting of the sections of Linguistics and Phonetics at the International Congress of the Anthropological and Ethnological Sciences, Bruxelles 1948.

1949

24.2.: Eli: review of K.L. Pike: *Tone Languages*, 1948, cf. Publ. 1950–51b.

1950

26.5.: Eli: The minimal units of the phonemic analysis.

1951

20.2.: Eli: Phonetic classification on an auditory basis.

18.5.: Eli: On the definition of phonemic categories on a distributional basis, cf. Publ. 1952d.

18.12.: Eli presents her paper 'Remarques sur les principes de l'analyse phonémique,' cf. Publ. 1949c.

1952

11.11. Eli reports on: Conference on Speech Analysis at MIT, Cambridge Mass. 1952.

1953

3.3.: Eli reports on the state of acoustic phonetics in the USA and demonstrates synthetic vowels.

1955

15.2.: Eli: review of C.E. Bazell: *The Choice of Criteria in Structural Linguistics.*

19.4.: Eli: Commutation and the commutation test, cf. Publ. 1956a.

1957

13.9.: Eli: Impressions from a Linguistic Summer School in India.

1958

18.12.: Eli and Louis Hjelmslev report on the Eighth International Congress of Linguists in Oslo 1957.

1965

14.12.: Eli: Form and Substance in Glossematics, cf. Publ. 1966k.

1966

3.3.: Eli introduces a discussion on Form and Substance in Glossematics in continuance of the preceding meeting.

1967

9.5.: Eli: Phonetic Analysis of Breathy ("Murmured") Vowels in Gujarati, cf. Publ. 1967c, 1968d and 1970b.

In the period when Eli was president of the committee (1968-72, cf. below), she apparently did not want to give any presentations. The exception to prove the rule was:

1972

12.12.: Eli: Problems and Methods in Recent Auditory Phonetics, cf. Publ. 1978a.

In september 1973 Eli left the committee and the last paper she has given which can be documented from the published sources is:

1973

18.12.: Eli: Phonological Theories in the Soviet Union (identical with a chapter in *Trends in Phonological Theory*, cf. Publ. 1975b).

Volume XVI of *Acta Linguistica Hafniensia* (1978) is the last volume with *Bulletins* (viz. those for the years 1972-73 and 1973-74). Eli has certainly given lectures in the Circle since 1974, but they cannot be documented with reference to printed *Bulletins*.

It was Hjelmslev's great idea that the Linguistic Circle was to be a collective working group (in the word of the first newsletter an *Arbejdssammenslutning*). The model for this conception was clearly the Prague Linguistic Circle: Hjelmslev had met the Praguians at the first International Congress of Linguists in 1928 when Jakobson, Karcevsky and Trubetzkoy participated precisely as representatives of the Circle. An essential ingredient in Hjelmslev's program for the circle was the continuous monitoring of the international linguistic scene. He did not want the circle to develop into a 'society' (of which there were several at the time). By closely following and critically assessing what was written by contemporaries who shared the goals of creating a structural linguistics, the Circle members sharpened their understanding of their own views and acquired a common frame of reference. Hence the frequent reviews and presentations of books written by leading linguists of the time. Eli was particularly active in this respect, giving 12 reviews in the first 20 years of the Circle (*Rapport*:22).

The collective spirit in the Circle had other consequences: The interaction between the members shifted between teaching and learning. One member would, with his or her lecture on his/her current research, teach the other members while (s)he would learn from their comments and criticism. This interaction inevitably led to changes in the final printed version. In sum, it was a collective endeavor, a joint venture by active, working linguists. Add to this that Eli's archives are replete with all kinds of notes and letters that she wrote to the protagonists of this era, notably Louis Hjelmslev and Paul Diderichsen, asking questions, commenting on papers read, and challenging beliefs held, and you will conclude: this was a family of kindred spirits who, by the grace of God, a stroke of luck, and - last but not least - by hard work wanted to change the fate of linguistics.

Even a cursory inspection of the themes taken up by Eli in the Circle reveal the predominance of expression analysis. The first reviews to be given were all on phonological works, and some very central ones at that (Trubetzkoy and Jakobson). Among Eli's contributions there are numerous reviews. There are two explanations for this. One is the one given above, namely that it was part of Hjelmslev's (very successful) strategy for the Circle to keep up with the best and most important contemporary work outside the Circle. Another is a personal one: Eli caught a severe illness during her final exams and was ill for several years with chronic sinusitis and a common accompanying symptom that - in her own words - makes one unable to produce new and original thoughts but on the other hand allows the critical assessment of those of others'. Hence the reviews.

Since the *Bulletin du Cercle Linguistique de Copenhague* (*BCLC*) in general notes not only the members who gave presentations at the meetings, but also those who offered observations, we have studied the first eight volumes of *BCLC*, including the mimeographed first volume from 1934, in order to ascertain the specific role Eli had in the Circle. In her first years in the Circle Eli commented on Einar Cordes' presentation of theories of the syllable (March 15 1934), on Alan S.C. Ross's presentation of his *A Theory of Language* (September 27 1934), and on Kaj Barr's review of Trubetzkoy's *Principles of Morphonology* (October 25 1934). At the meeting on the 22nd of November 1934 when Eli presented her MA thesis on *Sound Change and Dialect Geography* (cf. Publ. 1934), Viggo Brondal gave a lecture on *the concept of a dialect and the methods of dialect description* which Eli, along with several others, commented on.

In the following years (1935-37) Eli did not participate in the discussions. Judging from the bibliography, she was busy preparing her final exams and writing her prize essay. *BCLC II* (1935) and *BCLC III* (1936-37) note no comments by Eli, and after her presentation of Martinet's work on *Consonant gemination* at the meeting on September 30 1937, there is no trace of her in *BCLC IV* - for the simple reason that she had gone abroad.

In order to place this activity in the proper perspective one should remember firstly that the central members of the

Linguistic Circle, Viggo Brøndal, L.L. Hammerich and first and foremost Louis Hjelmslev, were not only the true giants of Danish linguistic structuralism but also among the giants of the international scene in general, and secondly, that when Eli joined the Circle, she was not yet 22 and still a student, albeit a very promising and already noted one.

In 1935-36 while Eli was preparing for her final exams, she fell ill and was away from Copenhagen until January 1937 when she started on her six months course of teacher training at the Metropolitan High School (still suffering from sinusitis). This explains the unusual and very uncharacteristic silence. It could be added that she was not the only member silent in that period. Hjelmslev himself was in Aarhus and unable to attend many of the meetings of the Circle between 1934 and 1937.

The *Bulletins* from a certain period, viz. *BCLC V-VII* (1939-40) and (1940-41), bring not only the minutes of the meetings making it possible to construct lists of presentations and comments such as the ones above, but also a list of the members present. This enables us to reconstruct for this crucial period at what meetings Eli was present and when she took the floor for comments.

Eli was present at all the meetings during the seasons 1939-40 (starting September 1939) and 1940-41 (finishing May 29 1941). She commented on the presentations at four of the eight meetings during the season of 1939-40 and at two of the nine meetings of the season of 1940-41. In addition she presented two reviews at one of the meetings and was herself the only lecturer at a third (joint meeting with the Society for Nordic Philology), the net result being that in this period Eli on the average had the floor at every second meeting. In summary, during the first period of the existence of the Linguistic Circle (1931-1942) Eli was very active in the beginning and still more active in the end.

Eli's career

In the summer of 1936 Eli received her MA degree. Immediately after, she was hospitalized for almost two months following which she stayed at her parents' home in Fåborg until January 1937. The first part of 1937 was reserved for teacher's training, while Eli spent the Winter semester 1937-38 at Marburg University having landed a Humboldt scholarship for studies in Germany. She had planned to write a phonological description of German, including the dialects, but there was no one in Marburg to guide her. She wrote to Trubetzkoy who agreed to receive her as his student in Vienna. However, he died shortly after, in 1938. Instead, Eli went to Paris to study phonology with Martinet and experimental phonetics with Fouché and Marguerite Durand. In the spring semester of 1939 she went to Berlin to study with Zwirner (cf. Publ. 1987b). Zwirner was (wrongly) accused of being a pacifist and had been dismissed from office, and his lab had been closed down, but his measurements were still accessible, and they gave Eli material for two short papers (Publ. 1940b and 1940-41c). Eli returned to Copenhagen in August 1939 immediately before the Second World War broke out.

Back in Copenhagen after her first *grand tour* Eli was hired by Hammerich as a teaching assistant in German in the fall of 1939, but the salary was so low that she had no money for books or transportation; her sinusitis became chronic. In 1943 she became a reader (*lektor*) in phonetics (the first one ever at the University of Copenhagen), and in 1947 in addition she was appointed *amanuensis*, a title for those who academically assisted professors by teaching some of their courses. Hjelmslev had made plans for a professorship of phonetics for Hans Jørgen Uldall, but his plan was unexpectedly rejected by the Faculty in 1939. This opened the possibility of Eli's being appointed, but in order to convince the Faculty of her qualifications she had to write a doctoral dissertation.

Eli's original plans for obtaining the required qualifications by writing on German phonology were abandoned during the '40s because she had developed an interest in stress in the Germanic languages. As the war dragged on, however, most of her time was taken by illegal work as an assistant to professor Carsten Høeg, the head of the Resistance Movement's central intelligence bureau which collected and critically assessed evidence about Nazi cooperation by Danish citizens. In this climate she could not write on German.

Her next scheme was to take up the historical development of stress in Danish compounds following up on a book by Hammerich entitled *Zur deutschen Akzentuation* (1921). Since Hjelmslev had more or less given up his original idea that Uldall should teach phonetics at the University of Copenhagen, he thought that Eli needed proper phonetic training in order to be up to date in all respects. As soon as the war was over he approached Daniel Jones in London. In 1946-47 Eli held a travel grant from the Association of Female Academics and studied with Daniel Jones at University College. On the same trip she collected material in Holland for her planned book on stress in compounds, the idea being that the Danish development had to be viewed as closely integrated into the general continental Germanic one. Hjelmslev, however, did not like the idea of a doctoral dissertation on such a rather philological topic, it was not sufficiently linguistic. He probably also thought that it was not quite phonetic or phonological enough to point directly to a post in phonetics. (This, incidentally, is the work which Eli has now finished more than half a century later, cf. Publ. forthcoming). Since Hjelmslev and Hammerich hated each other cordially, and since they would have been the obvious opponents at the defense, this idea was shelved as well.

Instead, Eli started on an experimental phonetic analysis of Danish stops. She was physically fit in this period (from 1956) having defeated her sinusitis, and in the autumn of 1958 she had leave of absence to write the dissertation. Hjelmslev supported her application stating explicitly that this was going to result in a doctoral dissertation. She lived at Schæffergården, a friendly, quiet and inspiring place close to the wildlife park outside of Copenhagen. Unfortunately, the sight of riders in the nearby park tempted her into trying her hand at a horse which, however, immediately threw her. The result was a bad concussion. This kept her from working for more or less five years, and it was at times utterly debilitating since, apart from having a splitting headache, she was unable to read due to disturbances of eyesight. She managed to revise her textbook on general phonetics (in Danish) during this period (cf. Publ. 1948/1960/1962), but had to record text amendments on tape for her assistant who did the final editing. She also managed to give university lectures "from the bed" by means of tape recordings.

The net result was that she had not written a doctoral dissertation and thus had to wait for a professorship. The explanation for Eli's not writing a doctoral dissertation is thus complex: a combination of external reasons conspired to make it impossible until it had become superfluous as a proof of her abilities as a scholar. Eli received an honorary doctorate at the University of Copenhagen in 1993. She holds honorary doctorates from the universities of Lund (1978) and Aarhus (1978) as well.

After Hjelmslev's death in 1965, Eli's career really took off: in 1966 she was finally appointed *professor extraordinaria* of phonetics - the first of its kind - in Denmark. In 1968 Eli was elected a member of the Royal Danish Academy of Sciences, and she accepted a seat in the Danish Research Council for the Humanities. In both of these capacities she was the first woman to be elected.

In 1965 the Laboratory of Phonetics at the University of Copenhagen was finally established (cf. Publ. 1979b: 412f) and Eli's appointment as professor of phonetics made it possible for her to gather a group of young phoneticians around her. Early on she had had the idea of establishing an obligatory course of general phonetics for all students of languages at the University of Copenhagen, replacing the more or less accidental offers of courses in this discipline. The course in general phonetics was institutionalized in 1944, and she herself taught it for a number of years (cf. Publ. 1948/60/62), but the expansion of humanistic studies at the University of Copenhagen in the late 1950s and in the '60s made it necessary to hire young teachers to take on all the parallel courses since it had by then become a recommended course. By 1960 the students numbered 60-80, but in the beginning of the '70s the maximum was reached with around 700 students taking the 'same' course in general phonetics (cf. Publ. 1979b:412). This proved to be fine grounds for recruiting both researchers and teachers for the Institute of Phonetics, and from being a one woman affair the period from 1966 saw an expansion of the institute to 6 researchers and two engineers plus the best and most modern experimental phonetics equipment, financed by the University and by various foundations. The Annual Report of the Institute (the *ARIPUC*, a mimeographed journal which was regularly exchanged for working papers from other laboratories around the world) detailed what equipment had been acquired during a particular year.

It was fortunate that the research expansion accompanied an expansion of students and funds. The 1970s was the ideal period for the building of empires.

Eli was a very modern head of department. Since her strategy was that recommended today by most everyone who knows anything about such matters, it might be interesting to sketch it.

First, teaching the course in general phonetics was an ideal training ground for young researchers or advanced students. It was sufficiently conventionalized to offer a firm and yet only general outline of the course and suitably broad to make it possible for the teacher to give it his or her personal stamp. Furthermore, it was obviously a great schooling of students for more technical terminology and more strict observations, since phonetics is one of the stricter bodies of knowledge. This made the courses, if not exceptionally popular with all students, then at least extremely popular with the students interested in matters linguistic. Second, Eli had been active as a teacher for so long that she had educated a number of promising students and was now able to hire them as assistant professors (*amanuenser*) at the Institute. Third, the *ARIPUC*, mimeographed, but with serious and much quoted articles that included all the empirical documentation so often left out in the final, published form for lack of space, could serve as a prepublication outlet as well as being the ideal object of exchange with other laboratories, thus keeping the personnel abreast with the international research scene. Fourth, Eli was by now so well acknowledged internationally that a number of foreign students came to her lab to seek her guidance. The Eli period culminated in 1979 with the organization of the huge Ninth International Congress of Phonetic Sciences, superbly managed by the Institute as a collective body.

Two years later Eli was 70 years old and had to retire, and at the same time a long and painful process began for all the humanistic faculties; the expansion was over, recession began.

In a way, Eli put her experiences from the Linguistic Circle into practice. She had participated in small groups working intensely and in larger committees working more steadily, but all inspired by the same common goals and the same theoretical ambitions. She now added that necessary ingredient which had been so fatally lacking in the Circle: A common empirical research program. It fitted the times beautifully that this program was a theoretically based expansion into experimental phonetics. All along she had been arguing that phonetics and phonology had to inspire each other, and that theoretical work had to be bolstered by empirical investigations. Now she grabbed the opportunity to put these ideas into practice and - as far as we are able to judge - with great success. The secret of this success seems to lie in the mixture of explicit leadership and informal cordiality so characteristic of e.g. the legends of Niels Bohr's Institute of Theoretical Physics. When Eli ran the Institute, no one was in doubt who was in charge and at the same time this was, as it were, 'no big deal'. It was a simple consequence of the breadth and depth of her knowledge. Crucially, this leadership was never used to suppress divergences of opinion. On the contrary, the discussions between Eli and some of her brightest pupils were sometimes published (cf. e.g. Publ. 1973a).

It stands to reason that the inveterate antiauthoritarian sometimes would underestimate what awe she willy nilly would inspire in researchers less certain of themselves and their goals than she was and less prone to work all day and all night long. Thus in a sense, her leadership had a certain elitist aspect as well.

It is tempting to suppose that Eli simply carried through what she and Hjelmslev had had the possibility of doing together at the Institute of Linguistics and Phonetics from 1956 onwards. That is a mistake, however. Apart from the fact that Hjelmslev was ill and his health slowly but surely deteriorating, at least from the late '50s and till his death in 1965, he was not an inspiring head of department. Hjelmslev had the personal peculiarity of leading his life in several fully separate compartments. At the university he was formality itself. As a private person, at home he was witty, kind, sometimes almost childishly jocular and did not want to discuss linguistics at all. And at the Linguistic Circle meetings and elsewhere among fellow linguists, he was the princeps inter pares. Thus, Eli had learnt how to run an institute the hard way: She had had all the trouble and no formal responsibility which actually led to some slight controversies between her and Hjelmslev during the period from 1956 till the beginning of the '60s.

There is an old joke from this time - which may or may not be true - that for many years there was a small poster on the door of the Institute saying:

Institute of Linguistics and Phonetics,
for all matters of substance please refer to lektor Eli Fischer-Jørgensen.

It is rather easy to see the period between 1966 and 1981 as covering both the reign of Eli as the professor of phonetics and the golden age of Danish phonetics and thus to conclude that phonetics in Denmark was created by Eli and went downhill when she left the university. It would be wrong, however, to stick to this easy interpretation. First of all, as Eli has been the first to show, phonetics had a strong tradition before her and in many respects it still does. Nevertheless, the national and international visibility of the Phonetics Department is significantly less obvious at the time of writing this tribute than it was in 1981. Why? There are several reasons. Firstly, the financial situation in the period from 1980 to 1990 was disastrous for all humanistic research. Another reason: What had been created at the Institute of Phonetics was carried over into the new, integrated Institute of General and Applied Linguistics (IAAS) established in 1988, but not without casualties and restructuring. Some of this was a natural consequence of Eli's pupils' coming of age and being promoted to the higher echelons of academic society. Thus Hans Basbøll went to Odense to become a professor of Nordic Languages, Jørgen Rischel was appointed professor of Linguistics and had to teach courses in general linguistics even when he succeeded Eli as professor of Phonetics, and Niels Gunnar Davidsen-Nielsen became a professor of English at the Business University of Copenhagen. Some of the original phoneticians of the Institute took over responsibility for the linguistic side of the newly established study program in audiologopedics, and some of the experimental work was continued by them as well as by computational linguists. Finally, students were no longer recruited through the course in general phonetics since this was first taken over by the specific language departments and then gradually abolished. Finances later became streamlined according to the number of students received, and in this respect phonetics could not compete. Thus, conditions were different in the post-Eli era, and the results naturally depend upon the conditions.

It seems to us, however, that more than external conditions are at play here. Looking for instance at the themes chosen by the many ph.d. students in Denmark we note the scarcity of projects involving phonetics or phonology even though there is no shortage of projects focused on spoken language. We think it might pay off to speculate why some of the dominant trends in modern linguistics have, as it were, left the phoneticians to themselves when they were once so central. One reason is probably that phonetics has developed in ways that leave the abstract study of phoneme systems rather homeless. Modern phonology has not played the expected key role in establishing a fruitful interplay between phonetics and syntax/semantics/pragmatics. The trendsetting linguistic theories of the '80s and the '90s (Transformational Grammar, Functional Grammar, Lexical Functional Grammar, and Head Driven Phrase Structure Grammar, and so on and so forth) have

> all focused on syntax and semantics and have left phonetic description to the dialectologists and the sociolinguists, not bothering to integrate the expression level into their analyses. That this is not a specifically Danish development is shown by a recent evaluation of Swedish research in the Nordic languages (Barnes, Faarlund and Naumann 2000). Barnes et al. conclude their evaluation by enumerating seven desiderata for the coming period. Number six goes as follows (our translation from Swedish): „Modern Swedish phonology. Only one single researcher in Stockholm works within the field. Elert et al.'s comprehensive research on Swedish phonology from the '60s and '70s seems not to have been followed up by Nordic linguistics. A closer contact between Nordic linguists and phoneticians would be fruitful."

Eli started her career as a general linguist with a certain taste for syntax but soon concentrated her efforts on the expression side. Her bibliography may be divided into sections according to phases in her scientific life. The first items are works written when she was a student and a very young graduate. Next come the many reviews which were an outcome of the Circle activities as well as essential to these activities themselves. The first experimental work is from the beginning of the fifties (Publ. 1954) and the program is clearly presented in Publ. 1957, Eli's contribution to the Oslo International Congress of Linguists. Hjelmslev's death and, shortly after, that of Paul Diderichsen mark the next period and represent a temporary interlude since they made it imperative for Eli to secure for posterity the heritage of these two very different linguists as well as that of Hans Jørgen Uldall (cf. Publ. 1965a,b,c, 1966b, 1966k and 1967d). Experimental analyses are long under way and if the results began pouring out in 1966 this must mean that the experiments had started considerably earlier. Hardly any feature of stop consonants goes unresearched, while experiments with perception are a new feature.

In the middle of the 1970s Eli published her most voluminous and probably also her most important work, the majestic *Trends in Phonological Theory*, which was at once universally acclaimed as a landmark. Akin to Jespersen's *Fonetik* it summarizes the knowledge accumulated during the period of structuralism which Eli had herself been part and parcel of until the then recent generative phonology. It is a teacher's book in more than one sense. Eli had taught a course in phonology for very many years and so had tried out her material on successive generations of linguists (the first author of the present tribute was fortunate enough to be one of them) as indeed she would always do with her manuals (cf. Publ. 1970c). Sometimes this practice resulted in the manuscripts not being published at all, since the mimeographed versions were available. (This is a crying shame, cf., e.g., Publ. 1970e and 1979-80).

It clearly follows that Eli's professional life between 1956 and 1981 was focused on the many important experimental phonetic analyses. Thus, work at the new Institute became dominated by quantitative measurements and new techniques and sophisticated discussions on complex relationships between anatomy, measurements and perception, an interdisciplinary discussion within the science of experimental phonetics. But as Eli has herself remarked in one of the newspaper interviews, she has published more since she left the university than is normal e.g. in the natural sciences. We wish to single out the huge paper on vowel features, in itself a major summary of all that was known then on the subject (cf. Publ. 1984c, 1983c and 1985a), and the important paper on intrinsic F_0 and tense and lax vowels (Publ. 1990). Eli's contributions to the study of the Danish 'stød' are essential reading for anyone interested in this exotic local phenomenon (Publ. 1987c and 1988b) and recently she has completed her lifelong project on the history of stress in Danish compounds (forthcoming).

There is another aspect of Eli's career which merits reflection, viz. her function as a role model for female scholars. This is a subject which has been brought up in a number of interviews with Eli in her later years, and small wonder: As can be seen from the above she was 'a first' in so many respects .

Eli belongs to a generation which fostered the first female academics to be leaders of their fields. Eli is perhaps typical of this first generation (or of any first generation) in that she does not feel that her success has anything at all to do with her gender, neither negatively nor positively. She feels that whatever she has done has in no way been determined by her sex. This may be absolutely true, and she is not a person easily classified as typically feminine but her possible function as a role model is a different matter. Our guess would be that Eli has functioned as a role model for both male and female linguists simply by her critical rationalism, her impressive working capacity, her clear and sober teaching opening up vistas of new research promises, and her high scholarly ideals. But it is equally likely that she has been a prime example for all other female academics simply by making it: She was able to become world famous and universally respected - in short this meant that it was possible for a woman. Before her, the legendary Astrid Friis (professor of History 1945-63) was the only female professor at the Faculty of the Humanities, University of Copenhagen (cf. Odén 1994). After her there have been more: Else Kai Sass (Art history), Inger Ejskjær (Danish dialectology), Jonna Louis-Jensen (Old Norse philology) and lately Inga Floto (History) and Lene Schøsler (Romance languages). Three of them are active in the language sciences, in some measure reflecting the fact that these sciences have long been the favored province of female students.

Eli and Louis Hjelmslev

The relationship between Eli and Hjelmslev changed considerably over their lifetimes, and it can only be understood with Hjelmslev's history of collaboration with others as a backdrop.

In 1931 Hjelmslev had founded the Linguistic Circle hoping that he could attract collaborators for a joint project of a structuralist grammar along the lines of his *Principes de grammaire générale* (1928). Gregersen (1991b) has described how his high hopes were thwarted in 1933. This threatened to leave Hjelmslev isolated, but in 1934 Hans Jørgen Uldall returned to Denmark from his fieldwork in California on what was then called the Maidu language; it has since been renamed Nisenan (Uldall and Shipley 1966). Uldall and Hjelmslev immediately hit it off

and soon started to collaborate on a joint theory called glossematics, a collaboration which continued intensely while Hjelmslev was a reader in Linguistics at the new university in Aarhus (1934-1937).
Originally the two glossematicians had hoped to publish their work in two volumes in 1936 so that the International Congress of Linguists, which was held in Copenhagen that year, could be their breakthrough congress like the first one had been for the Praguians. However, they did not succeed in finishing the manuscript for publication in time, and Hjelmslev returned to Copenhagen to succeed Holger Pedersen as professor of Comparative Indo-European Philology in 1937.

In 1939 they were very nearly there, but Uldall, having published little, had no permanent position. So when he was offered a post with the British Council, he had to take it, and in 1939 he left for Athens. They could, however, still communicate by letter, but from April 1940 the war prohibited further contact.

The reason for this brief sketch of the relationship between Hjelmslev and Uldall is that in some ways Eli was to fill Hans Jørgen Uldall's place as a serious and involved critical discussant of Hjelmslev's ideas. From 1934 to 1939 Hjelmslev had a collaborator and a discussant whom he thought of also as a close friend. In the later periods of his life collaboration would be more or less determined by the fact that his theory (or his and Uldall's theory) had matured to a point where he was seen as the wizard with the key to all linguistic enigmas. The position of wizard is not one easily leading to symmetrical relationships and Hjelmslev's relationship with Eli was no exception. Still, apart from Uldall she is also the only one of his pupils or colleagues that Hjelmslev ever expressed truly warm feelings for and true gratitude to.

Eli was a pupil of Hjelmslev's before she became a colleague. She attended Hjelmslev's classes in 'evolutiv fonetik' in 1933 (based primarily on the works of Grammont but including - at least on the carbon copy of the list of readings for the course - various treatises from the *Travaux du Cercle Linguistique de Prague* I-IV). Eli's presentation in the Linguistic Circle in 1933 (with Paul Lier) of Grammont may be a spin-off of this course. Later, Hjelmslev would refer to her participation in this course, and Eli's notes survive in her archives. Eli had also attended Hjelmslev's lectures on Rasmus Rask in 1932. In the prize essay from 1935 Eli comments favorably on his *Principes de grammaire générale*, and in general Eli read what Hjelmslev wrote as soon as it was published.

The first letter from Eli to Hjelmslev is from 1937. Hjelmslev is still in Aarhus and the questions asked are answered kindly but also briefly and only after some time. Eli attended some of Hjelmslev's lectures on glossematics in 1938-39 (notes survive in her archives), but it cannot have been many since she was in Germany during most of that period.

The next letter is from Paris, 1939, and has a more straightforward style, vintage Eli. Soon after she had returned to Denmark, Eli was hired as secretary of the periodical *Acta Linguistica* and thus got to know Hjelmslev much better as her immediate boss. Eli would read the manuscripts submitted and correct the proofs as well. Later on, she would also comment on and correct the manuscripts themselves.

The following bunch of letters covers the period 1941-42 when Hjelmslev was working on his final version of the theory, and concerns various glossematic definitions. It is sparked by Eli showing Hjelmslev her paper on 'Phonologie' (Publ. 1941b). In this paper, Eli covers the contemporary phonological scene in a review of 30 pages. Hjelmslev commented thoroughly on the paper, primarily dealing with what is said about his own (and Uldall's theory) and congratulated her on the good work. The discussion about form and substance - which was to remain *the* topic of debate between the two - continues with a short break during all of 1942 until it is time for the great discussion of *Omkring Sprogteoriens Grundlæggelse*. It is well known how Eli and Paul Diderichsen introduced this discussion as representatives of the Linguistic Circle and the Society for Nordic Philology, respectively, cf. Gregersen (1991b). What may be added are various details from the correspondence between Eli and Hjelmslev with the purpose of illuminating their linguistic discussions and their friendship:

During the war Hjelmslev had prepared the final version of the glossematic theory for publication and had applied for money from the Carlsberg Foundation for a publication of 272 pages with 52 illustrations (November 1943). Almost concurrently, Uldall had prepared his version of the general introduction for publication in Cairo, which was later to become *Outline of the Theory of Glossematics*. The preface is dated Cairo 1942. None of this worked out, however, neither Hjelmslev's nor Uldall's version of the theory of glossematics appeared in print.

In the correspondence with Eli from those years, Hjelmslev does in fact sometimes refer to definitions and rules that unmistakably stem from the manuscript of the theory of language, but this only led to further questions and criticisms from Eli (and Diderichsen). Hjelmslev was finally convinced by Paul Diderichsen's attempt to apply the glossematic theory in 1946 to launch a new collaborative effort. This time however, the situation was quite different from the prewar one: Uldall was not around and there now was a full fledged, albeit still unpublished, theory; in Hjelmslev's opinion all that remained to be done was to apply it and thereby refine it. This, however, was easier said than done, because first the eager pupils had to become familiar with and to understand the theory. The pupils were Eli, Anders Bjerrum and Paul Diderichsen, sometimes also Paul Lier and Harry Wett Frederiksen. Note that although these glossematic trainees worked outside and alongside the Linguistic Circle as such, it seems to have been circles within the circle. The various smaller circles soon developed into a large scale effort to forge an accepted theory during the period of the so-called committee on glossematics (1950-51), a new committee under the auspices of the Linguistic Circle. The committee's meetings are detailed in the proceedings published in the *Bulletin VIII-XXXI*, 1970, p. 136-171. Eli played a central role in this endeavor and witnessed the attraction of the glossematic paradigm weaken as the members were gradually reduced to spectators to what the wizard had concocted in his lonely cell at home. She had abandoned syntax after having worked her way through countless sentence definitions in the prize essay, and now she became disappointed with general linguistics. She would concentrate her efforts on instrumental phonetics.

In 1948 the Comité permanent des Linguistes, the CIPL, scheduled the first post war congress for Paris and the Linguistic Circle was buzzing with activity preparing answers to questions posed. In the middle of this Hjelmslev wrote a moving letter to Eli taking the opportunity to thank her cordially for their renewed cooperation. This letter marks a new phase in their friendship, but it also shows the importance of her comments and questions from the earliest period, and consequently we would like to quote some of it:

> „Ligesom du med din prisopgave har jo ogsaa jeg - som det fremgaar af medfølgende - fundet gamle breve og optegnelser frem. Og det slaar mig, hvor ofte dine indlæg har betydet noget væsentligt, og hvor ofte de har bragt mig ud over et dødt punkt eller stillet problemerne i et andet lys. Det slaar mig ogsaa, hvor tidligt og hvor dygtigt du arbejdede dig ind for alvor i sprogteorien, herunder ogsaa [mine; overstreget og erstattet af:] de mange yderst haarde nødder, jeg i tidens løb har udkastet i smaa ubarmhjertige afhandlinger. (Jeg glemmer dig heller ikke, at du faktisk tidligere end nogen anden satte dig ind i mine synspunkter og tog dem med i dine overvejelser, dengang vinden iøvrigt blæste fra en anden kant; men det har jeg sagt dig før). Din evne til at slaa ned paa centrale punkter har jeg faaet et stærkt fornyet indtryk af baade forleden under samtalen om akcent og nu i dit exposé om morfologi og syntax. Naar jeg tænker paa hvor mange lange debatter der [undertiden; overstreget] jævnlig føres med iøvrigt højtbegavede, charmerende og dybt interesserede mennesker, uden at de fører til noget som helst, og jeg saa ser, hvad du og jeg kan udrette paa et par timer, fordi du med de nævnte egenskaber yderligere forbinder evnen til en konkret og klar indsats, - ja, saa vurderer jeg dig højt, Eli, - iøvrigt ikke blot som medarbejder, men altsaa ogsaa det.“ (Like you have done with your prize essay I have also - as it will appear from the enclosed - taken a look at old letters and notes. And it strikes me how often your interventions have had essential significance and how often they have carried me around a sharp corner or revealed a new perspective on the problems. It also occurs to me how early and how cleverly you seriously absorbed the theory of language including

> the tough problems which I time and again have sketched in brief uncharitable notes. (I shall never forget that you were the first to understand my views and to include them in your own thinking when the wind blew from another theoretical corner, but I have told you this before). Your ability to pounce on central points has once more been brought clearly home to me both by our conversation on accent the other day and now by your *exposé* on morphology and syntax. When I reflect upon the fact that so many long debates with persons who are gifted, charming and deeply interested lead to nothing whatsoever, and then see what you and I can accomplish in a couple of hours because you, apart from the just mentioned abilities, also have the capacity to work concretely and clearly - well, then I value you very highly, Eli - by the way not only as a collaborator but also as such.)
>
> Hjelmslev to Eli, handwritten 20.2. 1948, in Eli's archives *Correspondence with Hjelmslev*.

It is tempting to see the final passage as an indication that Eli was about to become the primary collaborator, and in a sense this was what happened. The complication was again Uldall. Uldall had developed his own version of glossematics and consistently sent his various versions to Hjelmslev who, however, had an uneasy feeling about some of it. Finally, Uldall was invited to Denmark. Now was the time to finish the version of glossematics, an undertaking which had been obstructed by the war. It was necessary for Uldall to have his thoughts published, and at the same time Hjelmslev thought that Uldall's coming to Copenhagen would solve his problems with the position as the professional glossematic wizard.

In the letter to Uldall in which Hjelmslev proposed that Uldall come to Denmark, Hjelmslev tries to analyze himself and his reactions to Uldall's version of the theory. He feels that Uldall's version is too general and too removed from the strictly linguistic problems and expresses his hope that he may be convinced of the contrary by having face to face conversations with Uldall.

His hopes were not fulfilled. On the contrary, the negotiations were frustrating in that the two glossematicians gave up on the reconciliation, and Uldall concentrated on writing his version of the general theory, the manuscript known now as *Outline of Glossematics*, Part I: General Theory. It was completed while Hjelmslev was in the USA and had to wait five years for Hjelmslev's preface before it was finally published in 1957, immediately before Uldall died. Eli has given her explanation for this in her Introduction to the second edition (cf. Publ. 1967d).

Eli's role in all this is difficult to ascertain half a century later, but we surmise that it was more central than has previously been assumed.

It seems to us that the grand theme of Hjelmslev's and Eli's correspondence remained comparatively constant over the years, it was invariably that of form and substance. This does not mean that they did not discuss other matters, rather it means that all other matters can be traced back to the fundamental discussion about the role of substance in a theory of language. It becomes obvious that discussions on phonetics and phonology (cenematics in the glossematic jargon), discussions on the relationship between content analysis and expression analysis and finally the relationship between language theory and language description are all versions of the form-substance controversy. Briefly, the influence of this discussion on Hjelmslev's thoughts may be summarized as follows. In glossematics as it was conceived originally, a dominant theme is the attack on naive realism and the vehement demand for an immanent linguistics. This threatens to sever off linguistics from the substantive reality behind the sign in two ways: If linguistics is only about form, then phonetics - which treats the substance side of the expression - has no role to play in it. Neither has semantics which treats the substance of the content side. This has consequences of all kinds. Eli, in her published papers, concentrates her discussions on the expression side: the role of substance in the identification of expression elements and on the classification of the units of analysis, but during the long period of discussion she would bring up the theme of form and substance in virtually every possible guise. Now, the semantic side of this discussion was brought to a conclusion in the very interesting paper by Hjelmslev on the stratification of language (Hjelmslev 1954). Eli comments on the publication of *Stratification* in a manner that lets us understand that she views the paper as a concession to her points in the discussion - which may very well be true. But it may be just as important to point out that some of the passages in the *Stratification* are more or less identical to passages in the very manuscript of Uldall's *Outline* which in 1954 was lying on Hjelmslev's desk still waiting for his imprimatur. In a sense, here Hjelmslev was supported by two of his closest collaborators. However, with the glossematic algebra, which is the pièce de resistance of the second part of the same Uldall manuscript, we find a completely different situation. Uldall had developed some of the ideas about the analysis of grammatical categories from Hjelmslev's early book on case and generalized them, so that they could - if we understand his ambitions correctly - be used to compute so to speak all possible values for categories valid for all possible linguistic worlds. Here Eli and Hjelmslev agreed in finding the very idea irrelevant for linguistic description. We think that this is where Eli's significance for the development of Hjelmslev's thinking lies: She consistently contributed to his working his own way towards the inclusion of the linguistic role of substance and away from the original abstractness (i.e. pure form).

Perhaps this is also the clue to the much discussed role of Hjelmslev in the subsequent career of Hans Jørgen Uldall. Since the glossematic algebra was seen as Uldall's claim to fame this was what he could use as a lever for a new career. This, on the other hand, presupposed that it was published, and Hjelmslev had difficulties signing the preface as a preface to a glossematic theory, since he did not believe in the algebra and had been led in the opposite direction by - we submit - primarily Eli. This predicament was not resolved although Hjelmslev in 1957 finally signed the preface so that the Outline was published. Eli wrote a very important introduction to the second edition (cf. Publ. 1967d), detailing the differences between Uldall's and Hjelmslev's thinking and giving facts about Uldall's life not available from other sources.

Eli and the Linguistic Circle in the period after Hjelmslev's death

According to the *Rapport sur l'activité du Cercle Linguistique de Copenhague 1931-51*, Eli Fischer-Jørgensen was elected a member of the committee in May 1941 when she was charged with the office of librarian. The president of the committee was Hjelmslev, and the secretary and treasurer was Harry Pihler. Members with no specific charges were: V. Brøndal, L.L. Hammerich and P. Diderichsen (p. 19).

This specific committee was dissolved (cf. Gregersen 1991:111ff), and the committee elected in november 1942 could be regarded as the permanent committee since it lasted from that date and until the 24th of May 1961 when Hjelmslev was too ill to continue. It consisted of Hjelmslev as president, C.A. Bodelsen as vice president and Harry Pihler as secretary and treasurer.

Hjelmslev's death in 1965 left a difficult legacy to his linguistic heirs in the guise of a huge empire consisting of various publication possibilities as well as important traditions.

The meetings of the Linguistic Circle were supposed to result in papers worth publishing for the international audience of the Circle's journal. *Acta Linguistica* was founded as a general European structuralist periodical in 1937 by Hjelmslev and Brøndal, who had both separately consulted Roman Jakobson on this matter before embarking on the joint project. In the beginning Hans Jørgen Uldall served as the editorial secretary (1938-39), later on he was relieved by Helge Poulsen whose name is on the first covers from 1939 (vol. I, fasc. 1-3). Eli took over in 1940. At first her function simply was that of a secretary to the editors, but soon she became much more like a second editor. This cannot be seen directly from the covers but from the first fascicle issued after Brøndal's death in 1942, i.e. volume II, fasc. 2-3, Eli is on the inside given as *Directeur adjoint*. *Acta*'s publication rhythm suffered badly from the chief editor's failing health, and the journal had periodically slowed down, until it finally ground to a halt long before his death: The last fascicle of volume V gives 1945-49 as the year of publication on the cover while volume VI appeared in 1950-51.

> "The journal ceased to appear regularly in 1953, the last issue being vol.VII, fasc. 1-2. A new number (VIII,1) containing papers and reviews from the years 1951-53 was prepared, but the printing was delayed until 1960. It was sent to the subscribers in 1965."
>
> Egerod, Fischer-Jørgensen and Sørensen: Editorial, vol. IX,1, p. I, 1965.

As with the *Acta Linguistica*, when Hjelmslev died the *Bulletins* had withered away, not having appeared since 1946. On the other hand, the *Travaux du Cercle Linguistique de Copenhague* seemed to thrive on the very fact that it was planned to be, and indeed turned out to become, an irregularly published series of major works by members of the Circle. Obviously, linguistics itself did not stop completely in Copenhagen during the late 1950s and the early 1960s.

As the reader can see from the list above, Eli did not give any presentations in the Linguistic Circle in the period from 1958 and until 1965. She suffered continually from her concussion, and apart from surviving while having to teach, she concentrated her efforts on experimental phonetics. When Hjelmslev died she had recovered completely and her sense of duty to the general linguistic scene called for an unprecedented effort of restoration. It is no exaggeration to say that without the collective effort of a number of prominent linguists, but first and foremost without Eli, the empire could not have survived and the traditions could not have been upheld. She was part of the first editorial team of the reconstruction of the *Acta Linguistica* and in the first volume published the obituary of Hjelmslev as well as the important paper summarizing their discussions on *Form and Substance in Glossematics*. The *Bulletins* were restored, indexed in various ways, edited and translated by a team vigorously supported by Eli so that the many important discussions in the circle between 1947 and 1965 were documented for the benefit of generations to come. And at the university, Eli saw to it that Hjelmslev's chair was temporarily filled by guests such as Eric Hamp and André Martinet before being filled by Gunnar Bech. Eli was also a prominent member of the 1969 committee which reorganized the studies in linguistics completely when Gunnar Bech had to retire due to illness. She wrote the introduction to the second edition of Uldall's *Outline*, an introduction which we suspect is read more often than the book itself. Finally, she was instrumental in the collection, editing and publishing of Hjelmslev's papers, firstly the collection of *Essais Linguistiques II* (1973), secondly, the Danish manuscript (partly prepared for publication by Hjelmslev himself) *Sprogsystem og sprogforandring*. And in the important Whitfield translation and edition of the *Resumé of a Theory of Language* the editor writes:

> "It was Eli Fischer-Jørgensen who introduced me to the *Résumé*, in its typescript version, and I also owe her gratitude for information, advice, and assistance that she has offered with customary liberality during my work on this edition."
>
> Whitfield: Editor's introduction: XXXI.

We have no doubt that Whitfield speaks for many, many linguists.

Eli served as a member of the various Linguistic Circle committees between 1965 and 1968 without having any particular charge, but in 1968 she was elected president. She continued to serve as president until October 5 1972. The following year she left the committee. Since then, the only official capacity she has had in the Linguistic Circle has been to be and behave as one of two honorary members, the other one being the only *membre fondateur* who was alive to see the 60th anniversary of the Circle in September 1991, Paul Lier. Eli has given a vivid memoir of her life and times in the Linguistic Circle in her speech to the 50th anniversary, cf. Publ. 1992a.

Epilogue

This volume is dedicated to Eli Fischer-Jørgensen who for the last 70 years has participated actively in the linguistic scene internationally and in Denmark, inspiring all of us with her remarkable overview, her quest for clarity and her ever precise and crucial questions; she has educated generations of scholars and has taught us to be critical and to persevere. The solid, uniform, and rare substance that Eli is made of manifests itself in her scholarship as well as in her deeply felt and unswervingly practiced humanity.

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The authors thank Eli Fischer Jørgensen for her gracious permission to freely use unpublished materials from her archives.

Sources for Eli Fischer-Jørgensen's life: Eli Fischer-Jørgensen's data and career are described in the *Dansk Biografisk Leksikon* (Jørgen Rischel). Hans Basbøll's biography in the *Kvindebiografisk Leksikon* volume I, which will appear in 2001, was kindly put at our disposal by the editors. The various interviews which Eli has given to newspapers are indexed there. Eli has written an autobiographical sketch, concentrating on her childhood and early years. The first author has had the opportunity to use this material by courtesy of Eli herself. Finally, we refer the reader to Eli's works in the list of her publications 1979a, 1979b, and in particular 1981a, 1992a and 1997c. We take this opportunity to thank the editors of this volume, in particular Jørgen Rischel, for extremely valuable comments on the first draft.

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What can be derived from just three binary features: Occam's razor and major classes for phonotactics

Hans Basbøll

1. Introduction

It is a great pleasure to dedicate this paper to Eli Fischer-Jørgensen. From the mid-sixties she was the teacher who had most influence on me, and later she became a good colleague and dear friend. I have chosen a topic for my paper on which Eli and I have exchanged views on a number of occasions (most often in personal communication, but cf. Fischer-Jørgensen 1984a,b vs. Basbøll 1984). Even though I shall not refer very much to Eli's work in this paper, she has in fact influenced it much since many points in it are reactions to questions and criticisms of hers.[1]

According to the principle of OCCAM'S RAZOR, I shall try with as few initial postulates as possible to define a simple set of major classes to be used in phonotactics, since excessive structuring which is not grounded in phonetics nearly unavoidably leads to strong postulates on innateness of a kind that I do not accept (for methodological reasons, given the state of the art). My position here implies that COVER FEATURES, in the sense of features exclusively defined by means of other features already defined, are in principle preferable to independently defined features for methodological reasons, ceteris paribus, see section 3.1 below. I shall therefore depart from the definition of the PROTOTYPICAL PEAK of a syllable, viz. the 'phonetic vowel' or 'vocoid', and thereby restrict myself to operating with just three binary features: Sonorant, Stop and Lateral.[2] Prototypical instances of major class categories are considered in particular, and the relation between FORMAL and REAL implications of the system is emphasized throughout, with focus on the DEGREE OF RELATEDNESS between major classes.

2. Distinctive features: general

For an excellent exposition of distinctive features in phonological theory, in the first three quarters of the 20th century, the reader is referred to Eli Fischer-Jørgensen's monumental *Trends in Phonology* (1975, 2d ed. 1995), with its in depth coverage of features in Prague phonology, in Roman Jakobson's later work, and in early and classical generative phonology. And for a recent treatment of distinctive features, see Ladefoged 1997 (cf. section 2.4 below) and Ladefoged & Maddieson 1996.[3]

2.1. Natural classes (NCs)

Two senses of NATURAL CLASS (NC) should be sharply distinguished: one is the REAL sense, evidenced e.g. in sound change or language acquisition (as when **b d g** in some language "behave alike", e.g. change in the same way historically, or undergo the same substitutions with children or aphasics); the other is the FORMAL sense, as defined in terms of distinctive features (in the case at hand, e.g. defined as the set of segments having the features for "obstruent", "voiced" and "stop" - whatever they are precisely, see below - at the same time).

The basic demand is that an NC in the real sense should also be an NC in the formal sense, i.e. specifiable by a conjunction (rather than disjunction) of distinctive features. An NC in the formal (or technical) sense will be an INCOMPLETELY SPECIFIED SEGMENT (which may also be called a SEGMENT TYPE). E.g. the NC "voiced obstruents" will be a segment (type) which is specified for the features "voiced" and "obstruent" (i.e. [-sonorant, +voiced] in the terminology used here), but not specified with feature values which distinguish sub-classes of voiced obstruents from each other (such as features for place of articulation). In another terminology representing a different conception, an NC could be characterized as a set of (fully specified) segments, e.g. the class of voiced obstruents as a class (or a set) of all voiced obstruents, i.e. all segments which are specified for the features [-sonorant] and [+voiced].

Furthermore, the relatively important NCs should be specifiable by a relatively simple conjunction of distinctive features. And the NCs which are closely related (in the real sense) should be formally distinct in only few feature values; or, put more generally, the more closely related two NCs are in the real sense, the fewer feature values should differentiate them. Finally, the distinctive features should not only define the relevant NCs of segments, but should also be able to characterize the "Natural phonological processes/rules" in question in an insightful way.[4]

Thus, in summary:
-(i) an NC in the real sense should be specifiable by a conjunction of distinctive features
-(ii) a relatively important NC in the real sense should be specifiable by a relatively simple conjunction of distinctive features
-(iii) the more closely related two NCs are in the real sense, the fewer feature values should differentiate them
-(iv) the distinctive features should characterize the "Natural phonological processes/rules" in an insightful way.

Point (iii) will be in focus in this paper.[5]

2.2. Phonetic homogeneity

The distinctive features used should have a solid grounding in phonetics: they should be phonetically interpretable and, more specifically, be PHONETICALLY HOMOGENEOUS. E.g. [+lateral] is phonetically homogeneous, in the sense that the segments which are [+lateral] are phonetically an NC (viz. in the real sense), i.e. they have something obvious in common phonetically speaking (central closure and lateral passage through the mouth); [-lateral], on the other hand, is not phonetically homogeneous: [-lateral] segments have nothing significant in common except the negative fact that they are not lateral (some have complete closure in the mouth, others free passage, etc.).

The demand that distinctive features be phonetically homogeneous can be fulfilled in either the auditory (perceptual) or the articulatory realm. In the long run, however, I suppose that there is, in fact, something common perceptually in real (as opposed to formal) distinctive features even when they are defined only articulatorily.

In order to emphasize the importance of the concept 'phonetic homogeneity', the positive value of a feature will not be indicated with plus:
$[\text{feature i}] =_{\text{def}} [+\text{feature i}]$

2.3. Strict - but not symmetrical - binarity
BINARY FEATURES are the classical Jakobsonian ones, employed in phonology for decades, which means that the conventions for their use are well understood, and many features "are" phonetically binary. UNARY FEATURES (as used e.g. in Dependency Phonology) present stronger and more interesting claims about phonological structure; and e.g. concerning laterality, it makes very good phonetic and phonological sense to say that some segments, viz. laterals, have the feature in question, and other segments have nothing.[6] MULTIVALUED FEATURES may be relevant in some specific cases where e.g. all vowels (or all vowels of a certain type) are lowered or raised by one degree. I have not found any case in Danish phonology where multivalued features are preferable after all, however, according to the strict methodological principles which I try to follow, even though the rich vowel system and the process of "r-colouring" might seem to constitute a genuine case for it, see Basbøll 1996 (differently in Grønnum 1998:354-7).

I think the main choice is between binary and unary features. I shall respect STRICT BINARISM in the sense that features are used either as positive or as negative, tertium non datur; this agrees with my basic methodological position on Occam's razor, etc.

2.4. A note on the auditory feature Grave
According to Ladefoged (1997:611-616), there are three functions assigned to distinctive features: (1) specifying distinct utterances in a language; (2) permitting the grouping of sounds into NCs so that phonological patterns can be described in terms of rules; (3) defining the set of possible segments in human language. Still according to Ladefoged, auditory features only serve the second function, whereas articulatory features serve all three. I have no objections to these statements, only

to his definition of the AUDITORY FEATURE GRAVE. It is by Ladefoged defined as having APERIODIC energy in the lower part of the spectrum which means that it will be restricted to obstruents. But Modern Danish offers an excellent example in favour of the Jakobsonian proposal (Jakobson, Fant & Halle 1952) that Grave is a perceptual feature applying to both vowels and consonants, viz. the auditory assimilation of short /a/ to a succeeding homosyllabic grave segment, thus, e.g., /ham/ will be pronounced with grave /a/: [hɑm].[7]

3. Major classes defined by the binary features Sonorant, Stop and Lateral

The aim of the present paper is to define a set of major classes for phonotactics as simply as possible, using only strictly binary features, and as few as possible. And the first challenge will be to choose the point of departure for the enterprise. Since I take the major principle of phonotactics to be the sonority slope of the syllable, my choice is the vocoid (see Basbøll 1994, 1999): all languages have vocoids as peaks, only some allow contoids in that function ("syllabic consonants"); and inversely, all languages have contoids as non-peaks, only some allow vocoids in that function ("glides" or "semivowels"). The prototypical peak of a syllable is thus a vocoid, and the more a segment deviates from this prototype, the less probable its occurrence as a peak will be (sonorant contoids - being closer to the prototype than obstruents - will therefore be more probable as peaks, for example, although less probable than vocoids).[8] I shall therefore now consider the question how vocoids should be defined in terms of distinctive features.

3.1. Vocoid as a "cover feature"

If one looks into the phonological literature on "Major Class features" like "vocalic", "consonantal", and so on, one meets a lot of unsatisfactory, and often phonetically quite unconvincing attempts to define "vowels", "consonants", and perhaps "glides" and "liquids". In my view, the crux of the matter lies in the special status of the feature which Peter Ladefoged (1971) called "consonantal", aptly illustrated by the following quotation (p. 91):

"CONSONANTAL [...] This feature has a different status from all other features in that it can be defined only in terms of the intersection of classes already defined by other features. Thus nonconsonantal sounds are nonlateral and sonorant. They correspond largely to what Pike (1943) called vocoids, which he defined as central, resonant orals."

The point is that the definition of "consonantal" as a COVER FEATURE (i.e., in Ladefoged's words, a feature that can be DEFINED "in terms of the intersection of classes already defined by other features") is preferable to alternative ("positive") definitions on empirical grounds, since definitions of the latter type are in general phonetically problematic. Since 1973 I have been using the following EQUIVALENCE AS A DEFINITION of "consonantal" (I shall consider the choice and definition of the distinctive features used in this equivalence below):

[-consonantal] $=_{def}$ [+sonorant, +continuant, -lateral]

Since nasal consonants are both sonorant and non-lateral, it is clear that Ladefoged is omitting something important in his characterization of "nonconsonantal" in the quotation above, viz. something corresponding to Pike's "oral". It cannot be "nonnasal", however, since nasalized vowels are obviously vocoids and should thus be [-consonantal]. I have therefore been using [+continuant] in the formula. As far as I can see, there is no other possibility - at least concerning articulatorily defined features - than to use a feature implying blockage somewhere in the passage between the lips and the glottis, regardless of whether the nasal passage is open, i.e. some feature like "continuant". This means that even if one would claim to need a feature meaning "continuant in the acoustic/auditory sense" (as the French term "continuante" has traditionally been taken to mean), then this feature could not replace "continuant" in the formula without making the definition of vocoids absurd; thus we would nevertheless need a feature for "stop (whether oral or nasal)".
According to our conventions for distinctive features, we should use a definition so that the positive feature value is phonetically homogeneous. This clearly means that "continuant" will not do, we must instead choose a feature positively indicating "stop (whether oral or nasal)", viz. what I shall now (following Ladefoged, e.g. 1997) call

STOP: the class of "nasal and oral stops" is phonetically a natural one, as evidenced by the fact that nasal consonants and plosives tend to have the same place of articulation and undergo assimilation processes in that respect.[9] On the other hand, the class of [-stop] segments is a phonetically heterogeneous class, comprising e.g. fricatives, vocoids, and laterals (since nasal consonants are not in this class, it cannot be defined as being "perceptually continuous" or the like). I use the following definition: segments which during - at least a significant part of - their production have a complete blockage of the air flow in the passage between the lips and the glottis are [stop].[10]

In agreement with Ladefoged (1971:58), SONORANT IS DEFINED ACOUSTICALLY: segments "having a comparatively large amount of acoustic energy within a clearly defined formant structure" being [+sonorant] according to him. Since sonorants are phonetically homogeneous according to this definition, [sonorant] can be the positive feature value. On the other hand, its complementary class, viz. obstruents, is also phonetically homogeneous, comprising segments with noise, basically. Furthermore, both of these two classes are relevant in phonology in general, and the distinction between them is crucial in phonotactics (in that essential subpart which has to do with the "sonority hierarchy"). It is thus no accident that one can find many instances of both Sonorant and Obstruent used as "normal binary features" in the literature: there is a genuine analytical ambiguity here (i.e. one that is not caused by the particular theoretical frameworks in question). In this paper I shall, for expository reasons, use [-sonorant] for obstruents, but it should be kept in mind that both values of the feature Sonorant are phonetically homogeneous (cf. Trubetzkoy's (e.g. 1939) notion "equipollent features").

Lateral is defined in articulatory terms (non-lateral meaning central), and [lateral] is evidently the positive feature value. We are now ready to give the formulation of the equivalence defining vocoids according to the conventions used here:

[vocoid] $=_{def}$ [sonorant, -stop, -lateral]

The main argument up to now can be paraphrased as follows: The most crucial major class to account for syllable structure (the most essential aspect of phonotactics) is the one representing the prototypical syllabic peak, viz. the vocoid (phonetic vowel).Vocoids, and the feature Vocoid, can be defined exclusively in terms of three binary features which are well established in general phonology and phonetics, viz. Sonorant, Stop and Lateral. According to the principle of Occam's razor, it will therefore be preferable to establish further major classes for phonotactics without introducing any additional features in the analysis, and that will be attempted in the following sections.

3.2. Depicting the classes defined by any pair of the features Sonorant, Stop and Lateral

In this section, I shall explore the possibility of defining major classes that are relevant in phonology, in particular in phonotactics, by combining any pair of the three features Sonorant, Stop and Lateral, before I turn to more elaborate proposals using the three features together.

When we combine the feature pair Sonorant&Lateral, the following NCs (in the formal sense) result:

[sonorant, lateral]: prototypical (sonorant) laterals belong here;

[sonorant, -lateral]: vocoids as well as prototypical (sonorant) nasals belong here;

[-sonorant, -lateral]: non-lateral obstruents belong here;

[-sonorant, lateral]: lateral obstruents belong here, in particular lateral fricatives (on the category "lateral stops", see just below).

This system of NCs is far from constituting a set of relevant major classes for phonotactics. E.g. the NC [son, -lat] comprises the union of vocoids and sonorant stops (protypical nasals, on r-sounds in this class, see section 4), but to the exclusion of sonorant laterals, which is a problem. And the distinction between lateral and non-lateral obstruents is certainly not an important one concerning major classes for phonotactics.

When we now turn to the combination of the feature pair Stop&Lateral, the following NCs (in the formal sense) result:

[-stop, lateral]: laterals (both sonorant and fricative) belong here;

[-stop, -lateral]: vocoids as well as non-lateral fricatives belong here;

[stop, -lateral]: nasals as well as plosives belong here;

[stop, lateral]: the category "lateral stops" is phonetically problematic; it could comprise laterally released nasals and plosives, to the extent that they occur as phonetic and phonological segments in the world's languages. See further the beginning of section 3.3 below.

Even though the first and third of the NCs in the formal sense above can be considered NCs also in the real sense, the system as a whole does in no way qualify as a set of major classes for phonotactics.

Whereas feature pairs including Lateral (Sonorant&Lateral, Stop& Lateral) thus did not yield any relevant set(s) of major classes, the result of combining Sonorant&Stop is more promising:

[sonorant, -stop]: vocoids ("V") as well as prototypical (sonorant) laterals ("L") belong here;

[sonorant, stop]: prototypical (sonorant) nasals ("N") belong here (see just below);

[-sonorant, -stop]: fricatives ("F") belong here;

[-sonorant, stop]: plosives ("P") belong here.
A segment which is [sonorant, stop] must either be a nasal (since a sonorant according to Ladefoged's definition, if its mouth passage is blocked during its production, must have a nasal passage and is hence

a nasal, glottal stops here being excluded anyhow); or it must be an uninterrupted sonorant during large parts of its production, as is the case with (sonorant) trills.[11]

Each of the above four classes is an NC also in the real sense, and furthermore a major class relevant for phonotactics: the union of vocoids and sonorant laterals represent segments which are nearer to the center of the syllable than any of the other three classes, and the distinction between fricatives and plosives is relevant phonotactically, although less important for syllable structure than e.g. vocoids and sonorants.

In the formal system defined by this pair (Sonorant&Stop), the NC furthest away, measured in different (opposite) specifications of distinctive features, from the NC containing vocoids (V&L here) is P (plosive), which is a satisfying result (i.e. with regard to the relation between NCs in the formal and the real sense). The other pair of NCs which are also maximally apart (formally speaking) are N and F which is a more debatable relation. In a system as simple as this (the NCs defined by Sonorant&Stop), it is not too difficult to assess the formal relatedness between NCs, but I would like here to develop a systematic way to depict such relations, so that the resulting figures can also be assessed when more features are involved and thence more NCs as well.

The system should, of course, respect the principle of Occam's razor, and be fully explicit and heavily restricted in order to facilitate a comparison between alternative proposals on distinctive features and the resulting NCs. The (very simple) figures are in two dimensions and drawn according to the following principles:

1) Sonority-hierarchical features will be depicted in the horizontal dimension, non-sonority-hierarchical features in the vertical dimension. Note that SONORITY-HIERARCHICAL FEATURE is a key concept in my model of phonotactics where they are formally derived from what I call universal segment logic.[12] Vocoid, Sonorant and Voiced are sonority-hierachical features: all vocoids are sonorants whereas some sonorants are not vocoids (viz. sonorant contoids like nasals and laterals); all

sonorants are voiced whereas some voiced segments are not sonorants (viz. voiced obstruents).

2) The figures are constructed starting (to the left) with the NC containing vocoids (i.e. containing the prototypical peak of a syllable). NCs are placed so that their distance in either dimension from their neighbouring NC, measured in terms of distinctive features, is minimal (no "diagonal" distances are defined). All distances between neighbouring NCs are equal ("1").

For the pair Sonorant&Stop, the resulting figure is given as fig. 1.

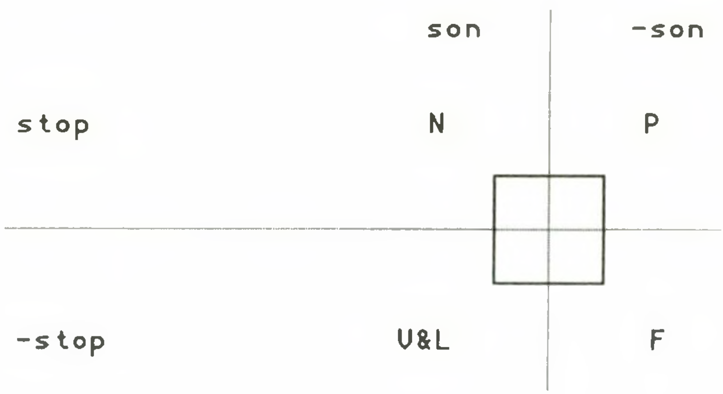

Figure 1 (Sonorant&Stop).

The principles given determine the figure totally, except for the fact that the non-sonority-hierarchical feature Stop has its positive feature value pointing upwards (rather than downwards), which is arbitrary here. In the following figures, Stop will still be directed upwards, to facilitate the comparison between figures.

It seems to me that there are two relevant ways to count when we try to establish a scale between the most sonorous and the least sonorous segments (i.e. with highest vs. lowest sonority) of a syllable: (1) counting in terms of sonority-hierarchical features only; this is the most important, and most restricted, way, and I have argued in detail in my work on phonotactics that e.g. Stop should not be used to define (any part of) the sonority hierarchy (in distinction to e.g. Sonorant). This measure is called SONORITY-STEP here. (2) A secondary way to count is to include also non-sonority-hierarchical features like Stop and Lateral, since they contribute to create distance from the vocoid (the prototypical peak), and in that sense P is the segment type furthest away from V, even more so than F. This measure is here called DISTANCE FROM V.

Below (table 1) I give the calculations for figure 1:

NC in the figure	V&L	N	F	P
sonority-step	0	0	1	1
distance from V	0	1	1	2
sum of these	0	1	2	3

Table 1.

It is interesting that the sum of "sonority-step" and "distance from V" results in a not unreasonable sonority scale for major classes in phonotactics.

I want to emphasize that these numbers are of course not results in any empirical sense. Rather, they represent an attempt to take the restrictions on NCs discussed in section 2.2 seriously, in particular principle (iii) concerning degree of relatedness between NCs, when we construct major classes from an extremely restricted set of binary features. The figures and the numbers concern NCs in the formal sense and should thus be compared to NCs relevant for sonority scales in the real sense. Now we turn to more complex patterns in the figures given in sections 3.3, 3.4 and 4, still according to the same conventions.

3.3. Major classes defined by Sonorant, Stop and Lateral: first scenario

Let us now explore the possibility of using together all three distinctive features serving as the DEFINIENS of the definitorial equivalence of vocoids given in section 3.1 above, viz. SONORANT, STOP, and LATERAL.

As said in section 3.2 above, the combination [stop, lateral] is phonetically problematic. I do not want to take any definite stand on whether this combination should be taken to refer to (e.g.) laterally released stops (this depends on how the time dimension is treated in the system of distinctive features). In order to give the system a chance - before we turn to the much more satisfying system of section 3.4 - I shall for the time being presuppose that [stop, lateral] is excluded as a kind of contradictio in adjecto, viz. because a complete blockage in the speech channel (between the glottis and the lips, excluding the nasal channel) as we have in "stops", is incompatible with a lateral passage as we have in "laterals" (any permission of the combination of [stop] and [lateral] would complicate the proposal of this section). The exclusion of [stop, lateral] is thus the methodologically simplest interpretation, and it can be formalized by means of the two reduncy rules: [stop] implies [-lateral]; and [lateral] implies [-stop].

Under this interpretation, the features Sonorant, Stop and Lateral define altogether six NCs (in the formal sense of the term), which are indicated in the following table 2 (with redundant feature specifications in parentheses):

	V	L	N	F	fL	P
sonorant	+	+	+	-	-	-
stop	-	(-)	+	-	(-)	+
lateral	-	+	(-)	-	+	(-)

Table 2.

The six columns represent (cf. section 3.4 below):

(1) vocoids (including glides) called "V";
(2) sonorant laterals, called "L";
(3) sonorant (non-lateral) stops, in particular including the nasals, called "N" (see below);
(4) non-lateral fricatives, called "F";
(5) fricative laterals, called "fL"; and
(6) (non-lateral) plosives, called "P".

In Danish, the sounds [a, l, n, f, p] may be taken to represent these sound types with the exception of (5) (since Danish has no fricative laterals in its phonological inventory). The symbols (mnemotechnic abbreviations) used for the categories of NCs are in principle arbitrary, the NCs are defined by the feature combinations given; notice in particular that the category "F" in this section is defined as being non-lateral (whereas lateral fricatives are included in the category F in the other figures of this paper). On sound type (3), cf. sections 3.1, 3.2 and 3.4.

In addition to the problems mentioned above concerning the combinability or non-combinability of the simple feature values [stop] and [lateral] (a decision on which does not follow from our approach), this system has two further weaknesses if it is considered as a potential inventory of major classes: First, it makes the distinction between lateral and non-lateral obstruents a "major" one, which seems clearly undesirable (cf. section 3.2). Secondly, the class of sonorant contoids - which plays a crucial role in Danish phonology - cannot be captured here: sonorant laterals and nasals are not "minimally distinct" by means of the three distinctive features used in the table.

Even though each of the six classes is an NC, they are thus not all major classes relevant for phonotactics (due to the role of the feature Lateral). I do not want to exclude, however, that the category [-sonorant, lateral] might be of some phonotactic relevance, viz. if the phonotactic description is made on a very superficial level (in the technical sense, e.g. if the description applies after voice assimilations, in the traditional generative understanding). But it should be emphasized that when "lateral" is referred to in the context of sonority hierarchies, generally prototypical and thus sonorant laterals are being meant.

Fig. 2 depicts the relations between the six NCs of this section (defined by Sonorant&Stop&Lateral). It is drawn according to the same principles as fig. 1 (starting, to the left, with the NC containing vocoids):[13]

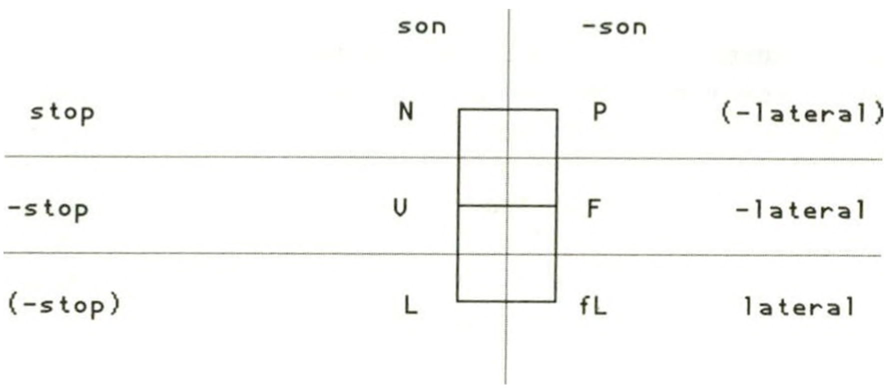

Figure 2 (Sonorant&Stop&Lateral).

By including the feature Lateral, we have now been able to distinguish V and L, which is, of course, a gain from the point of view of major classes (but it also has its cost, viz. the addition of a feature). But now new problems have arisen in the relation between the NCs defined. In the formal system defined by this triplet (Sonorant&Stop&Lateral), the two NCs furthest away from the NC containing vocoids (V) are P and fL, which is only partly a satisfactory result (i.e. with regard to the relation between NCs in the formal and the real sense). What is decidedly unsatisfactory, however, is the fact that the two pairs of NCs which are maximally apart in the figure (i.e. formally speaking) are on the one hand L and P, and on the other N and fL, both of these pairs of NCs being more different, formally, than V is from either P or fL. In the next section, I shall make a proposal in order to remedy this situation.

Below (table 3) I give the calculations exactly as I did for figure 1:

NC in the figure	V	L	N	F	fL	P
sonority-step	0	0	0	1	1	1
distance from V	0	1	1	1	2	2
sum of these	0	1	1	2	3	3

Table 3.

The distances depicted in fig. 2 and tabulated here represent one major advantage in relation to fig. 1, viz. that the NCs V and L can be distinguished; but in all other respects, there is no advantage in fig. 2, but rather some obvious disadvantages. I shall therefore try, in the following section, to use the information contained in just the three binary features Sonorant, Stop and Lateral in a different way, viz. by including the indirectly defined feature Vocoid in the argument (which has constituted the point of departure in the whole enterprise here).

3.4. The major classes revised: second scenario

All the weaknesses relating to the configuration of NCs depicted in fig. 2 disappear if we make another selection from the features involved in the definitorial equivalence: The three features Vocoid, Sonorant and Stop together define (logically) five, and only five, categories of segment types which turn out to correspond perfectly to important major classes of sound types (table 4):

	V	L	N	F	P	*	*	*
vocoid	+	-	(-)	(-)	(-)	+	+	+
sonorant	(+)	+	+	-	-	+	-	-
stop	(-)	-	+	-	+	+	-	+

Table 4.

The redundant feature specifications, in parentheses, all follow from the equivalence given in section 3.1 (and thus the problems connected with the combinability or not between [stop] and [lateral] are avoided: such problems in the case at hand are solved by the system itself). The three remaining mathematically possible combinations of the features Vocoid, Sonorant and Stop, which are thus excluded by this very equivalence, are presented in the starred columns.

The five columns represent:

(1) vocoids (including glides) called "V";
(2) (sonorant) laterals, called "L";
(3) sonorant stops, in particular including the nasals, called "N" (see below);
(4) fricatives, called "F"; and
(5) plosives, called "P".

In Danish, the sounds [a, l, n, f, p] may be taken to represent these five sound types (since Danish has neither trills nor (phonological) affricates). Notice that it follows – viz. LOGICALLY – from the equivalence that a segment which is [-vocoid, sonorant, -stop] must be a lateral; and it follows, as was noted in section 3.2 above, from the equivalence (including the definitions) and the nature of the speech organs etc. – i.e. LOGICALLY AND EMPIRICALLY – that a segment which is [sonorant, stop] must (as said in section 3.2) be either a nasal or an uninterrupted sonorant during large parts of its production (cf. trills). Notice that this whole line of argument has included nothing which is specific to any particular language (like Danish).

Fig. 3 depicts the relations between the five NCs of this section (defined by Vocoid&Sonorant&Stop). It is drawn according to the same principles as fig.s 1 and 2. New in fig. 3 is the inclusion of the sonority-hierarchical (and thus "horizontal") feature Vocoid, which according to our principles must have its positive feature value pointing to the left in the figure.[14]

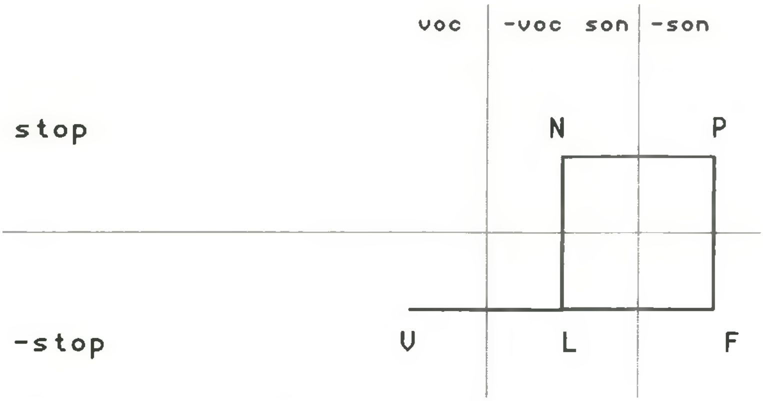

Figure 3 (Vocoid&Sonorant&Stop).

Below (table 5) I give the calculations exactly as for figures 1 and 2:

NC in the figure	V	L	N	F	P
sonority-step	0	1	1	2	2
distance from V	0	1	2	2	3
sum of these	0	2	3	4	5

Table 5.

The distances depicted in fig. 3 and tabulated just above, represent major advances in relation to fig. 2 on all points of difference. I conclude that fig. 3 not only presents five NCs that are highly relevant major classes for phonotactics, but also that their internal relatedness (measured in terms of different, i.e. opposite, specifications of distinctive features) is very reasonable. This is one important step towards satisfying the principles on NCs laid down in section 2.2, in particular concerning degree of relatedness (iii), measured by different specifications of distinctive features, between NCs. I want to emphasize that I have only been using the information contained in just the three binary features Sonorant, Stop and Lateral, in the construction of fig. 3, since the distinctive feature Vocoid is itself defined exclusively in terms of these three features. In a way, fig. 3 thus represents the conclusion of my paper, but I shall, at the end of section 4 below, extend fig. 3 by including the further sonority-hierarchical feature Voiced.

4. Major classes for phonotactics, weakening, and the feature Voiced

I have not included LIQUIDS in the discussion up to now, even though many would regard them as constituting an important major class for phonotactics. But I do not consider "liquids" as constituting a phonetically homogeneous NC, at least as far as articulation is concerned (but see below); in particular, the segments known as "r-sounds" are extremely diverse: in addition to trills, taps and flaps, this category comprises both vowel-like sonorants (glides) and obstruents (fricatives) - still phonetically speaking, of course. What unity there might be is probably perceptual (cf. the frequent dissimilations involving /l/ and /r/, which seem to have an auditory origin), and I would have no quarrels with an AUDITORY FEATURE "LIQUID". But in some cases at least, the reason why "liquids" may function as a phonotactically relevant class is diachronic, e.g. due to the fact that the r-sounds involved may have shifted phonetic category. In fact, "liquids" occur in all five categories of segment types summarized in fig. 3 and tables 4-5 above:

(1) "V": r-approximants, the final element of "r-diphthongs";
(2) "L": voiced lateral approximants;
(3) "N": sonorant trills;
(4) "F": lateral fricatives, r-fricatives;
(5) "P": taps and flaps.

It is thus a gross over-simplification, in my view, when liquids are often given a definite position in a "sonority" or "strength" hierarchy: in that case, only a limited subgroup of liquids occurring in the world's languages can have been taken into account, or alternatively, the word "liquid" has been used as an etiquette having no phonetic content. In

Danish phonology disregarding phonotactics, a category "liquid" plays no role whatsoever, as far as I can tell.

Let us now observe a particular consequence of the definition of the feature Vocoid, related to the phenomenon of "consonant gradation" (see Rischel 1970 and Bauer 1983), where we find the natural WEAKENING CHAIN: plosives > fricatives > glides. While the change from plosive to fricative is relatively unproblematic in most frameworks (like the loss of [stop] here), the change from fricative to glide is in many systems of distinctive features a complex process to state, in disagreement with the fact that it is indeed a very simple and natural one articulatorily. This is well in accordance with our definition of Vocoid: when a fricative is turned into a vocoid, it AUTOMATICALLY switches its value of Sonorant: this follows immediately from the equivalence defining Vocoid. And for the same reason, the change directly from a plosive like **d g** to a vocoid, which is an important alternation in Modern Danish, also AUTOMATICALLY switches both the value of Stop and of Sonorant.

Since "major classes for phonotactics" is a crucial notion in this paper, I shall briefly turn to the remaining two sonority-hierarchical features, according to my model, which have not been in focus until now, viz. Voiced and Spread glottis. The complete hierarchy in my "Sonority Syllable Model" can thus be illustrated by the chain

[vocoid] > [sonorant] > [voiced] > [-spread glottis]

The feature value [spread glottis] characterizes the margin of the prototypical syllable, viz. the stressed isolated monosyllable. For the articulatory basis for this feature in Danish, see Frøkjær-Jensen, Ludvigsen and Rischel 1971 and Hutters 1984; and for its particular function in phonotactics (both in general and in Danish), see Basbøll 1999 with references.

I now turn to the feature Voiced instead and return to the figures depicting NCs serving as major classes for phonotactics. If we extend the (optimal) fig. 3 (in section 3.4) by introducing the sonority-hierarchical feature Voiced, we can get a rather complete picture of NCs relating to essential aspects of syllable structure as formulated in terms of the sonority hierarchy (fig. 4).

New in fig. 4 (compared to fig. 3) is the cross-classification of obstruents by means of the feature Voiced. The pair Voiced&Stop results in the following NCs of OBSTRUENTS:

[-sonorant, voiced, -stop]: voiced fricatives ("vdF") belong here;

[-sonorant, voiced, stop]: voiced plosives ("vdP") belong here;

[-sonorant, -voiced, -stop]: voiceless fricatives ("vlF") belong here;

[-sonorant, -voiced, stop]: voiceless plosives ("vlP") belong here.

Fig. 4 is drawn according to the same principles as fig.s 1, 2 and 3. New in fig. 4 is the inclusion of the sonority-hierarchical (and thus "horizontal") feature Voiced, which must have its negative feature value pointing to the right in the figure, obviously (this follows from our principles). Fig. 4 represents the NCs defined by the quadruplet of features Vocoid&Sonorant&Voiced&Stop.[15]

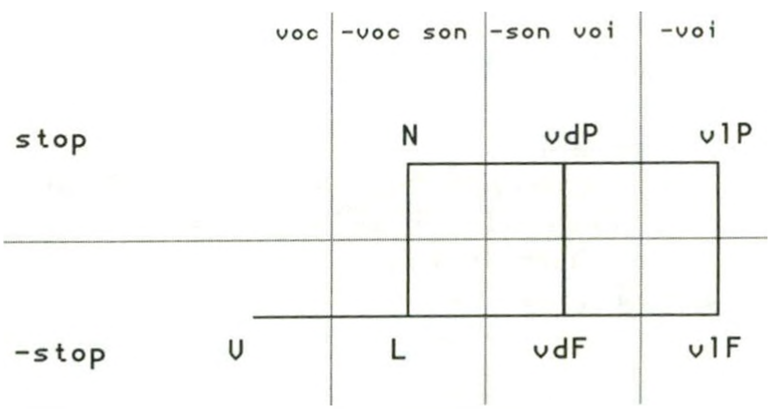

Figure 4 (Vocoid&Sonorant&Voiced&Stop).

Below (table 6) I give the calculations for figure 4, exactly as for figures 1, 2 and 3:

NC in the figure	V	L	N	vdF	vdP	vlF	vlP
sonority-step	0	1	1	2	2	3	3
distance from V	0	1	2	2	3	3	4
sum of these	0	2	3	4	5	6	7

Table 6.

The distances depicted in fig. 4 and tabulated just above, do not represent any major deviation in relation to fig. 3 (cf. section 3.4), but rather an extension. As far as the distinction between voiced (vd) and voiceless (vl) obstruents is concerned, the relations of fig. 4 are not unreasonable, and in particular I agree with the central position of Voiced as compared to Stop.

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Notes

[1] Parts of the following text are revised versions of parts of Basbøll ms., in an earlier form printed in Basbøll 1991: 5-8. The discussions of the main topic of this paper, viz. relatedness between Natural Classes, including all figures and all tables with calculations, are new.

[2] For segments functioning as peak vs. non-peak of their syllable I use the term "syllabic" vs. "non-syllabic" segment. For the phonetic sense of "vowel" and "consonant", irrespectively of syllabic vs. non-syllabic function, I prefer Pike's (1943) terms "vocoid" and "contoid" (see section 3.1). A non-syllabic vocoid is called "glide"; a syllabic contoid (such as the final lateral of the English word *little*) has no term of its own here.

[3] Questions relating to phonetic and phonological typology, although they are very important for the total picture, are not considered in this paper (see also Maddieson 1984, 1997). Questions of feature hierarchies ("feature geometry", "hyper features", etc.) are also not treated here. There is no doubt that features "in reality" do not all function "at the same level": some features presuppose some others, etc. However, I have chosen here, in accordance with the principle of Occam's razor in my understanding, not to impose any hierarchy on the features at the outset, but to consider them as belonging to an UNORDERED set, exhibiting a number of redundancy relations. This is a case of minimizing the structure, as I see it (cf. section 1), but the issue is primarily of a methodological nature.

[4] Morphonological rules do not count here, since even the most productive cases of the latter may be analogical in character.

[5] Unlike NC, "major class" is not a technical term as used here. The "major classes for phonotactics", as I employ the term in this paper, are NCs (in the real sense) which play a role in accounting for the sonority aspects of the basic syllable structure (but phonotactics has other aspects too).

[6] However, if one is allowed to operate with complementary classes to unary components or the like, as seems to be the case in some versions of Dependency Phonology, the system is not strictly unary anyhow.

[7] The rule was proposed in this form in Basbøll 1974:66 and discussed in Brink & Lund 1975:71ff, Davidsen-Nielsen & Ørum 1978, Molbæk Hansen 1979, and Basbøll 1980, 1996:52 and 1999:83.

[8] On the use of the cognitive linguistic notion of prototype in phonology, see Taylor 1995 with references.

[9] The union of nasal consonants plus plosives are thus "nasal and oral stops", or "mundlukkelyd" (= 'mouth-stops'), according to Otto Jespersen's (1897-99) old terminology.

[10] Ladefoged's system is more detailed on this point; notice that according to the definition used here, laterals are [-stop], nasal consonants and trills are [stop] (on the time dimension, see just below in the text, and note 11).

[11] I want to emphasize that the time dimension ("dynamics") is not taken into account here, although it is crucial in accounting for many types of r-sounds, like trills, taps and flaps, and for affricates, etc. It should also be mentioned that e.g. fricative laterals are, of course, [-sonorant, lateral], and that the feature Nasal is needed in the phonology of many languages (certain Danish dialects have nasal vowels in their phonology, for example), also under the present definitions. Thus the features Lateral and Nasal can absolutely not be reduced to "cover features" (defined by features such as Sonorant and Stop).

[12] There is no circularity in my model as is often the case in phonological proposals of sonority, cf. Ohala 1992; see Basbøll 1994, 1999.

[13] The principles given determine the figure totally, except for the fact that the non-sonority-hierarchical feature Stop has its positive feature value pointing upwards (rather than downwards), and Lateral its positive value pointing downwards.

[14] The principles given determine the figure totally, except for the fact that the non-sonority-hierarchical feature Stop has its positive feature value pointing upwards (rather than downwards).

[15] As note 14.

Fronting in Irish English

Niels Davidsen-Nielsen

1. Introduction

In a comparative description of constituent order in (standard) English and Danish, one crucial difference which needs to be pointed out is the following: while fronting of objects, complements and adverbials which are closely connected with the verb is relatively rare in English declaratives and requires that the fronted constituent be emphatic and/or contrastive (e.g. *I don't like the project generally, but this idea I support*), it is very common and independent of emphasis/contrast in Danish. In an example like *Planen om tilbagetrækning har vi længe støttet* The-plan of withdrawal have we long supported (We have long supported the plan of a withdrawal) fronting may be due to nothing more than a wish on the part of the speaker to foreground the object and to select this element of the sentence as his communicative point of departure. In Danish declarative sentences the initial position can readily be occupied by any sentence constituent, even the verb. There is thus in Danish, unlike English, an initial field of many purposes – a so-called FUNDAMENTAL FIELD. For that reason it is useful to describe constituent order in Danish by means of a topographical schema with a number of positions some of which may be filled out by different types of constituent. Such a schema was worked out by Paul Diderichsen fifty year ago and is still extremely influential among Danish grammarians. As pointed out by Eli Fischer-Jørgensen (1965: 119) it constitutes Diderichsen's most important contribution to grammatical analysis and kept on occupying him throughout his career.

What has just been stated about English also applies to the institutionalised type of English used in Ireland, which in its written version is virtually indistinguishable from standard British English. It does not, however, apply to the SPOKEN VERNACULAR, and it is that variety of English which is investigated in the present paper. In Ireland there is a long tradition of representing this vernacular in fiction and drama, and unless indicated as originating from other sources all my examples are taken from a recent Irish novel: BREAKFAST ON PLUTO by Patrick McCabe (1998). What is striking here is that we often – as in Danish – find fronting of objects, complements and adverbials closely connected with the verb which would be unacceptable or strongly marked in standard English. This can be illustrated by the following examples (the notations after which require the following explanations: S = SUBJECT, V = VERB, Od = DIRECT OBJECT, Oi = INDIRECT OBJECT, A = ADVERBIAL, C = COMPLEMENT):

(1) A story now he told me when he was young. (Filppula 1986: 196)
Od A S V Oi A

(2) Sweet he is.
C S V

(3) To the town of her birth she now returns.
A S A V

As can be seen, Irish English resembles Danish in having a fundamental field into which objects, complements and adverbials can be readily fronted. As can also be seen, however, Irish English differs from Danish in that such fronting is not accompanied by subject-verb inversion (compare e.g. *Sweet he is* with *Sød er han*).

2. The topographical schema applied to Irish English

As Irish English (the spoken vernacular) resembles Danish in having an initial field of many purposes, I shall describe its constituent order by means of a topographical schema. If for the moment we ignore examples with inversion (like *Never will I forgive you*) and examples where the position after the subject is not filled by a verb (like *That the end of it would be*), the relative position of constituents can in main declarative clauses be represented like this:

1	2	3	4	5	6	7
F	S	v	A	(vv)V	O/C/Sr	A

Here F symbolises the fundamental field and can be filled by any sentence constituent. Position 2 is occupied by subjects, position 3 by finite auxiliaries (or by BE or HAVE used as main verbs), position 4 by short adverbials, position 5 by main verbs (accompanied or unaccompanied by preceding nonfinite auxiliaries) and position 7 by adverbials. Position 6 is the place of objects and complements and – in sentences with a provisional subject (Sp) – of real subjects (Sr). The following example (without fronting) illustrates the case where all of these positions are filled (position 1 by a clause): *Although I'm afraid I won't get too many clients these days / I / can / just / imagine / the reaction of my old acquaintances / if they saw me now.*

The topographical analysis of Irish English can first be illustrated by examples like the following in which constituent order does not differ from that of standard English (The sentence function notation requires the following explanations: Cs = SUBJECT COMPLEMENT, Co = OBJECT COMPLEMENT, Sp = PROVISIONAL SUBJECT, Sr = REAL SUBJECT, – = MARKER OF DISCONTINUOUS REALIZATION.):

	1 F	2 S	3 v	4 A	5 (vv)V	6 O/C/Sr	7 A
A S V O A	Sometimes	I	–	–	find	myself	on the verge of calling back
S V O Co A	–	I	'll	–	leave	the door open	tonight
S V Cs	–	That	was	–	–	what he called me	–
S V A	–	I	–	–	bawled	–	for days
S V - A –V O	–	I	wo(n't)	n't	pretend	I wasn't upset	–
S A V O A	–	You	–	certainly	made	a right idiot of yourself	this time
Sp V Sr	–	There	is	–	–	no harm in hoping	–

Positions 4, 6 and 7 can be filled by more elements than one, as illustrated by 'He will *probably soon* be home' (A + A), 'I'll leave *the door open* tonight' (O + Co) and 'I put the gun *in my pocket as casually as I could*' (A + A) respectively.

Fronting of OBJECTS, COMPLEMENTS and REAL SUBJECTS can be illustrated by the following examples:

	1 F	2 S	3 v	4 A	5 (vv)V	6 O/C/Sr	7 A
O SV-A – V	That sort of thing	she	does	n't	say	–	–
Cs SV	Sweet	he	is	–	–	–	–
Co SV O A	Old Mother Riley	they	–	–	call	me	around here
Sr Sp V A	A happiness	there	would	–	be	–	too

Fronting does not only affect complete constituents but also parts of constituents, as in *What this was all about I hadn't the faintest idea*, where only the last part of the object is fronted (O-SV A–O).

Fronting of ADVERBIALS which are closely connected with the verb can be illustrated by an example like *To the town of her birth she now returns* (A S A V).

In SUBORDINATE CLAUSES we find the same pattern as in main declarative sentences, and here as well fronting is very common:

	1	2	3	4	5	6	7
	F	S	v	A	(vv)V	O/C/Sr	A
O S V-A-V	(as) havoc	she	would	most definitely	wreak	–	–
A S V	(as if) into the spoon of a ballista	she	'd	–	been placed	–	–
A A S V	(as) by the surging throng once more	she	was	–	swallowed up	–	–

As appears, position 1 can be filled by more elements than one, like positions 4, 6 and 7.

In Danish, not only subjects, complements and adverbials can be fronted but also the nonfinite part of the verb phrase, as in *Synge særlig godt har hun nu aldrig kunnet* Sing particularly well has she now never could (She has never been able to sing very well, though). As appears from the next examples, both of which are cited from Filppula (1986: 210), this type of fronting is possible in Irish English as well:

(1) … and then come home. Danced all night we did, in the home, a crowd.
(2) Oh, it's frightfully interesting, yes, though it really drives me mad. Bring my white hairs with sorrow to the grave it will.

As also appears, fronting of a nonfinite verb form may pull other constituents (adverbials and objects) along with it into the fundamental field.

In some varieties of Irish English, there is a tendency for a fronted noun phrase to leave a pronoun 'trace' of itself in its canonical position. This can be illustrated by the following examples quoted from Harris (1993: 174):

(3) Anything you wanted you could a (= have) got it.
(4) That baby from it was born her mother had it.

Such examples should obviously be kept apart from sentences with left-dislocation like *These books, did you read them?* A trace might also be said to be left in examples like *Danced all night we did*, though in this case the pro-form is not a pronoun but an auxiliary.

3. Partial fronting

Let us now turn to those cases where an object, complement or adverbial is fronted but not all the way to position 1. The following examples illustrate this pattern (from the context in which (1) occurs it is clear that *everybody* is the subject, not the object, and that complete fronting is therefore not involved here):

(1) Everybody would my children love. S V- O -V
(2) We nothing spied but a raggedy-edged old Pussy rolling around the floor. S O- V -O
(3) ...(as) lashings of cash upon her were laid. S A V

As appears, the fronted constituent is placed after the subject (examples 2 and 3) or after the auxiliary (example 1). In either case the effect of this less common type of fronting seems to be one of foregrounding, though probably in a weaker version than the one brought about by complete fronting.

In some cases partial fronting is accompanied by the introduction of a form of the auxiliary DO:

(4) …who once the catwalks of the world did storm as flashlights popped. S A O V A (cp. …who once stormed the catwalks of the world as flashlights popped.)
(5) (…dearest Papa,) that did from nothing spring me. S V- A -V O (cp. … that sprang me from nothing…)

Fronting in Irish English has been examined in great detail by Markku Filppula, particularly in a monograph dating from 1986. However, Filppula does not draw attention to partial fronting, and apart from a reference to a split perfect construction where the object precedes the past participle (Harris1993: 160) I have not come across any mention of it in other studies on Irish English grammar.

As a result of fronting – whether partial or complete – the verb phrase (or part of it) frequently occupies the final position in Irish English, even in those cases where the semantic content of the verb is highly general:

(6) Sweet he is. Cs S V
(7) To the town of her birth she now returns. A S A V
(8) Everyone would my children love. S V- O -V
(9) …(and) that the end of it would be. S Cs V
(10)…(as) lashings of cash upon her were laid. S A V

Here Irish English differs not only from standard English but also from Danish, for in these two languages the verb phrase (or part of it) does not normally occupy the final position in sentences with objects, complements or adverbials. The pattern is well known from other languages, though, for example German (cf. *Alle würden meine Kinder lieben*).

4. Explanations of fronting

According to Filppula (1990) there are three possible ways of accounting for the prevalence of fronting in Irish English: it may be due to the influence of Irish substratum, to features of archaic English and/or to universal features of contact languages. Let us consider these three explanations in turn.

4.1 Influence from Irish substratum

For the expression of information focus (unlike emphatic focus, which is expressed through special suffixes) Irish typically uses the CLEFT CONSTRUCTION, not prosody the way e.g. English extensively does. This can be illustrated by the following examples (Filppula 1982: 51):

(1) Chuaigh Seán go Doire inné.
Went John to Derry yesterday.
(2) Is é Seán a chuaigh go Doire inné.
(It is John who went to Derry yesterday.)
(3) Is go Doire a chuaigh Seán inné.
(It is to Derry that John went yesterday.)
(4) Is inné a chuaigh Seán go Doire.
(It is yesterday that John went to Derry.)

As appears, an Irish cleft sentence contains a form of the copula *is* placed in initial position. (The word *a* is a relative particle and *é* a (masculine) subject dummy.) The reason why clefts are used rather than fronting is to be found in the rigid VSO order of Irish and the ensuing pressure to insert a verb at the beginning of the sentence. Filppula notes in this connection (1986: 67) that according to Jespersen (1937: 86) clefting arose as a means of compensating for the disadvantages of fixed constituent order, a hypothesis which is supported by the fact that this construction is not found in languages with relatively free constituent order, for example the Slavic ones. In Irish, fronting only occurs in clauses containing the copula *is*, as illustrated by an example like *Fear is ea é* 'A man it is' (in which *ea* is a remnant of an Old Irish neuter pronoun which functions as a dummy complement (Filppula 1986: 84)). In Irish English, clefting is extremely common and functionally more varied than in standard English (where it virtually always serves to signal an identification), and that this is due to Irish influence seems more than likely.

Now in modern Irish, the (unstressed) copula is often omitted from clefts, particularly in informal speech. In such cases clefting is virtually the same as fronting. In e.g. *Go Doire a chuaigh Seán inné* (cf. example (3)) it is only the relative particle *a* which reveals that it is a truncated cleft rather than pure fronting which is involved.

Given these facts, it is not hard to see that fronting in Irish English can plausibly be explained in terms of Irish influence. In Irish, the use of clefting – with or without the copula – is the way in which information focus is expressed, as already noted, and considering the long co-existence of English and Irish in Ireland this is a likely explanation not only of the frequent use of clefts but also of the frequent use of fronting in Irish English. Even indefinite expressions may readily be fronted (cf. *A story now he told me when he was young*), and in this respect fronting has an even freer rein in Irish English than in Danish.

While an explanation in terms of substratum influence makes perfectly good sense, it does not shed light on a problem mentioned by Filppula (1990: 45): in his corpus of spoken Irish English there was the same amount of fronting in the western and eastern rural varieties. If nothing more than Irish influence were involved, one would expect the degree of Irish impact to be stronger in the west, where Irish had a much stronger foothold than in the east. But that is not the case, and the similarity of impact therefore remains unaccounted for.

4.2. Influence from archaic English

In earlier types of English, constituent order was freer than it is today. Like Modern English, Old English had SVO order (though with some SOV features), but this order was frequently changed through fronting. Such fronting might be accompanied by inversion, but the SV order was frequently retained. This is illustrated by the following examples quoted from Allen (1980: 48):

(5) *Micele fling* abædon fla mæran apostolas æt flam halgan Fæder æfter flas Hælendes upstige. O V S A A
'*Great things* the famous apostles asked of the holy Father after the Saviour's ascension.'

(6) *flam biscope Wulfhere* se cyning gesealde landes fiftig hida. Oi SV Od
'*The bishop Wulfhere* the king gave fifty hides of land.'

If the subject was pronominal, there was VS order after a fronted adverbial and SV order after a fronted object.

The introduction of the English language to Ireland is conventionally associated with the year 1169, but English made little headway against Irish and «waned to such an extent that by 1600 it was more or less restricted to a small enclave on the east coast« (Harris 1991: 37). What really altered the linguistic landscape in Ireland were the 17^{th} century 'plantations' (Kallen 1997: 14). Modern Irish English essentially derives from the language brought to Ireland at that time by English settlers. In this type of English, i.e. Early Modern English, constituent order was also freer than it is today, and fronting of objects, complements and adverbials was common (Filppula 1990: 46). It is therefore possible to explain fronting in Irish English as a case of diffusion from Early Modern English. The English brought to Ireland in the 17^{th} century has been largely unaffected by later developments of English elsewhere (Filppula 1986: 8), and that is obviously also likely to apply to fronting. Altogether, Irish English is a fairly conservative variety of English.

As mentioned by Filppula (1990: 46), there is no way of knowing what the relative contributions of Irish influence and archaic English influence are to fronting in Irish English. What seems highly plausible is that a syntactic operation characteristic of the type of English used by English settlers in the 17^{th} century has been preserved and reinforced by the Irish substratum, i.e. that multiple conditioning is involved.

4.3. Universal features of contact languages

The two explanations just described compete with a third explanation arising particularly from research on creole languages: some of the features of Irish English may be due neither to Irish nor to archaic English but to 'linguistic universals activated by the language contact process itself' (Kallen 1997: 4).

Filppula (1990: 49) refers to Bickerton, who in a particularly influential book (1981) argues that the shared features of creoles cannot be explained as input from either the substratum or the superstratum. According to Bickerton, creole languages very often resort to fronting for the expression of contrast or emphasis. In Hawaiian English, for example, we find examples of the type '*Eni kain lanwij* ai no kaen spik gud'

(I can't speak any kind of language very well). Now if fronting is a characteristic feature of all contact languages, its use in Irish English may be explained on these grounds alone. Fronting in modern Irish English 'could then be explained as a reflection of the earlier stages of the emerging contact vernacular' (Filppula 1990: 50).

Filppula (1990: 50f) mentions that there are several problems with Bickerton's theory. The evidence from different researchers in the field is conflicting, and many of the features on which the theory is based have been found to be common to West-African languages, including fronting. They might therefore reflect substratal influence rather than universal properties of contact languages. Altogether the third, universal explanation appears to be much less solidly founded than the two first ones.

5. Connective fronting

In standard English, fronting is particularly common if the speaker can in this way establish linkage with the preceding part of a conversation or of his own message. This illustrates that the position of a constituent is dependent not only on factors within the sentence or clause in which it occurs but also largely on the relation between that constituent and the preceding text, as exemplified by

(1) Speaker A: What do you see?
Speaker B: That I will tell you another time.

While connective fronting of objects and complements is relatively rare in standard English, adverbials are frequently placed in initial position to give prominence to them and to link them to the preceding text:

(2) Lo's room contained an iron bed and one chair, over which he had thrown his black trousers and a shirt. In a corner of the room was a gas ring, a kettle and a single glass.

In the book from which my Irish examples are drawn there are many instances of connective fronting, and these are by no means restricted to fronting of adverbials. In some of them fronting is not only connective but also contrastive:

(3) I don't regret writing all this ... because *some of it* he definitely did like... . O S A V
(4) It might be sad, of course it would. But *a happiness* there would be too. Sr Sp V A

In others, the connective function is unaccompanied by contrast:

(5) If Sandra wants to go and see Gene Stuart, then *Gene Stuart* she shall see. O S V
(6) Radios were spitting like fat in a frier and *on telly* we could see ourselves. A S V O
(7) 'It's her! I swear it's her!' for *Mitzi* she did, in truth, resemble. O S V- A -V

Partial fronting may also be connective. This can be illustrated by the next example in which fronting of the adverbial establishes linkage with the preceding discourse while fronting of the subject complement has no such function:

(8) I took up my position at the railings opposite Eros [...] I began to give serious consideration to the probability that one day I might *at those very railings* simply expire and that *the end of it* would be. A S V- A A -V / S Cs V

What these examples seem to show is that connective fronting is much commoner in Irish English than in standard English. A main reason for this is that other constituents than adverbials can readily be fronted for connective purposes.

6. Properties of Irish fronting

6.1. Syntax

Through fronting a constituent is moved to the beginning of the clause or – in the case of partial fronting – forward in the clause to the position after the subject or after the auxiliary verb. The topographical schema given in section 2 does not accommodate sentences with partial fronting, but if such sentences are relatively rare (like declarative sentences with inversion), it is still useful as an overall representation of constituent order in Irish English.

Unlike passivization, for example, fronting does not affect the syntactic functions of the constituents involved. If *They call me Old Mother Riley around here*, for example, is changed to *Old Mother Riley they call me around here*, the subject, object, object complement and adverbial are still realized by the same elements as before. If, on the other hand, an active sentence like *He spent that day recuperating on his bed* is changed to *That day was spent recuperating on his bed*, the subject is realized by another element (*That day*) than before (*He*).

The sentence functions capable of being fronted are objects (direct or indirect), complements (subject or object), adverbials, real subjects and verbs. As pointed out in section 2, parts of constituents can also be fronted.

6.2. Phonology

According to Filppula (1991: 56), fronting is in Irish English coupled with fairly NEUTRAL STRESS, and that is hardly surprising. As fronting is very common, one would expect a fronted constituent to be given the same degree of prosodic prominence in Irish English as in Danish, for example, where fronting is also very common, compare *His brother I don't remember* and *Hans bror kan jeg ikke huske* (literally 'His brother can I not remember'). In standard English, on the other hand, fronting is accompanied by stronger stress.

It goes without saying that a fronted constituent may also be pronounced with strong stress, namely in those cases where it is contrastive and/or emphatic. Strong stress is therefore likely to occur in an example like 'It might be sad, of course it would. But *a happiness* there would be too.' On the other hand, a fronted constituent is likely to be pronounced with weak stress in some of those instances where it is a verb which is fronted. In the example *Bring my white hairs with sorrow to the grave it will* given in section 2, I would expect the stresses to fall on *white, hairs, sorrow* and *grave* and the nuclear stress to fall on the last of these words. In Danish, a fronted verb may also be unstressed, for example if an indeterminate object is fronted along with it as in *Synge frække sange kan han også* Sing dirty songs can he also (He can sing dirty songs too).

In order to form an impression of how fronted constituents are pronounced in Irish English I asked an Irish phonetician to provide recordings of passages from the book from which my examples are culled. I also asked her to provide recordings of two of Filppula's examples with fronted verbs. Three speakers of Irish English each recorded 22 examples twice, 13 with full fronting of an object, complement or adverbial, 7 with partial fronting and 2 with full fronting of a verb. The speakers, who were not informed about the purpose of the investigation, were JD (from Mayo), JW (middle class Dublin) and ANC (mixed rural background). The recordings were analysed auditorily, and the following picture emerged:

In the examples with FULL FRONTING of an object, complement or adverbial, two of the speakers in most cases pronounced a fronted constituent with moderate non-nuclear stress (nine examples in the case of JD and ten in the case of JW). The following selected examples, in which tonetic stress marks are used, illustrate this pronunciation

(1) …to ˈthis day we could have been toˋgether. (JW)
(2) For ˈthat sort of ˈthing she doesn't ˋthink, actually. (JW)

In those cases where a fronted constituent was given more prosodic prominence (nuclear stress) by these speakers, the extra prominence can be easily explained in terms of new topic, focality and/or contrast:

(3) 'Old Mother `Riley | they 'call me a'round `here. (JD)
(4) (It would be sad, of course it would.) But a `happiness | there would be `too. (JW)

Not surprisingly, a fronted constituent was also pronounced as a separate tone unit with nuclear stress if it was very long:

(5) 'Just how 'beautiful 'that might have `been (I certainly haven't the words to describe.) (JD)

The third speaker (ANC) differed from the others in regularly pronouncing a fully fronted constituent as a separate tone unit with nuclear stress, as illustrated by the next example:

(6) ('Good luck,' I said) and by the 'surging `throng | once 'more was 'swallowed `up.

In the case of this speaker, then, the expectation that a fronted constituent is pronounced with fairly neutral stress was not confirmed.
In the examples with PARTIAL FRONTING the fronted constituent was pronounced with moderate non-nuclear stress in all examples except one on the part of ANC. The nuclear stress was placed either on the verb or on an object or adverbial after the verb:

(7) 'Everyone would my 'children `love. (JD, JW, ANC)
(8) (...dearest Papa,) that 'did from 'nothing 'spring `me. (JD)
(9) When I 'dreamed of being from 'this 'world gone `early. (JW, ANC)

The single case in which a partially fronted constituent was pronounced with nuclear stress was the following:

(10) (One day I might) at 'those 'very `railings | 'simply ex`pire.

ANC also differed from JD and JW in sometimes pronouncing a partially fronted constituent with relatively strong non-nuclear stress, as illustrated by

(11)...who 'once the "catwalks of the 'world did `storm | as 'flashlights `popped

In the two sentences with a FULLY FRONTED VERB the fronted verb was pronounced with high level stress, not only in *Danced all night we did* but also, contrary to my expectation, in

(12) 'Bring my 'white `hairs | with 'sorrow to the `grave it will. (JD)

Only in one of the two recordings of this sentence by ANC was the fronted constituent pronounced with weak stress.

Although the overall picture is not entirely clear, and although a fuller investigation is obviously called for, the present small auditory investigation seems to show that in Irish English a partially fronted constituent is pronounced with moderate non-nuclear stress and that a fully fronted constituent is often pronounced in this way too. A fully fronted constituent is pronounced as a separate tone unit with nuclear stress in those cases where contrast, emphasis or new topic is involved, or if it is very long. As fronting is much commoner in Irish English than in standard English, the fact that it is often unaccompanied by special prosodic prominence is to be expected, as stated at the outset of this discussion of phonology.

6.3. Semantics

A sentence with fronting has the same propositional meaning as a sentence without fronting, for example *That man I don't know/ I don't know that man*. In the same way that fronting does not affect the syntactic functions of the constituents involved, it does not affect the semantic functions (or roles) of these constituents either. In both sentences the semantic function performed by the subject (*I*) is CONTROLLER (= the volitional participant for whom a state obtains) and that performed by the object (*that man*) is AFFECTED. For a discussion of semantic functions the reader is referred to Bache and Davidsen-Nielsen (1997: 197ff).

6.4. Pragmatics

While there is no difference of propositional meaning between a sentence with fronting and a corresponding sentence without fronting, there is clearly a difference of THEMATIC MEANING (= 'what is communicated by the way in which a speaker or writer organizes the message, in terms of ordering, focus and emphasis', see Leech 1981: 19). The fronted constituent is FOREGROUNDED, and the hearer is instructed to select this constituent as his COMMUNICATIVE POINT OF DEPARTURE in processing the utterance. In the case of partial fronting, it should be added, it is only foregrounding which appears to be involved. In a sentence like *Everyone would my children love*, for example, the object is foregrounded through its non-canonical position, but the hearer is not instructed to select this constituent as his communicative point of departure.

Fronting of a constituent for the purpose of foregrounding this constituent and of instructing the hearer to select it as his communicative point of departure is by many linguists termed TOPICALIZATION. Topicalization is not a sharply defined concept, though, and that is the reason why I have been using the term fronting instead. One of the clearer – though still pretty vague – attempts at pinning down topicalization I have come across has been made by Simon C. Dik.

Dik defines a topic as 'that entity about which the clause predicates something in a given setting' (1989: 216), i.e. typically a subject. Topicalization can accordingly be understood as a process, for example fronting, by which a constituent is assigned that pragmatic function. The pragmatic function of a fronted constituent is often that of GIVEN TOPIC, i.e. a topic which has already been introduced into the discourse. This can be illustrated by an example like 'I've just met your sister Susan. *That girl* I simply cannot resist', in which the NEW TOPIC introduced in the first sentence is *your sister Susan*. As shown by an example like *Old Mother Riley they call me around here*, the pragmatic function of a fronted object may also be that of a new topic, however.

According to Dik new topics combine properties of topicality (the things we are talking about) with properties of FOCALITY, which he defines as what characterizes the most important or salient parts of what we say about the topical things (1989: 264). In an example like *Yesterday in the pub I met your sister Mary* the object is topical in introducing a TOPICAL ENTITY into the discourse and focal in INTRODUCING this entity into the discourse (269). The constituent *your sister Mary* is both what we are talking about and what is most salient. In the Irish English sentence *Old Mother Riley they call me around here* the initial constituent is accordingly both topical and focal. Cross-linguistically, the focalizing devices mentioned by Dik are emphatic stress, special constituent order, special focus markers (particles) and special focus constructions (for example clefting)(278).

Filppula (1986: 182ff) defines topicalization as 'an operation which moves a constituent to the very beginning of the clause', i.e. as FRONTING, but for the purposes of his study topicalization only refers to fronted constituents which realize the main information FOCUS of their clauses. In this way he can exclude, for example, thematic scene-setting adverbials, which cannot carry the main information focus. As he also excludes those cases where the main information focus falls on some other element than the fronted constituent, it would seem that topicalization is not found in examples of the type *That man I simply detest*, in which the main information focus clearly falls on the final constituent.

If the pragmatic term topicalization is to be used instead of the syntactic term fronting (which might be assumed to cover also e.g. question formation and thus be too broad), I suggest that it be defined as a (complete) fronting operation which foregrounds a constituent and instructs the hearer to select this constituent as his communicative point of departure.

7. Fronting and clefting

In section 4 it was pointed out that clefting is very common in Irish English and that this is probably due to influence from Irish, where it is virtually the only thematic marking device. In Irish English there are fewer restrictions on the type of constituent that can be singled out by clefting than in standard English. This is illustrated by the following examples (cited from Harris 1993: 175) in which a subject complement and the nonfinite part of a verb phrase accompanied by an adverbial that are singled out:

(1) It's asleep he is.
(2) It's looking for more land a lot of them are.

According to Filppula (1986: 178) clefting is also functionally more varied in Irish English than in standard English. Cleft sentences serve not only to identify but also to specify, as in *It is a Dutchman there's down there now, having that pub* (97), and it may also be used for the expression of contrast and emphasis (200). As fronting is used for these purposes as well, fronting and clefting share a number of functional properties. There are differences too, though. In reply to questions, for example, it is typically clefting which is used (Filppula 1986: 216), and for connective purposes it is fronting. In spite of the functional similarities, there is thus a certain division of labour between fronting and clefting.

That clefting is more varied in Irish English than in standard English is also mentioned by Harris, who illustrates this by means of the following example (1993: 176):

(3) So it were Daniel O'Connell then fell into the house in Derrinane.

Here the scope of *it were* is the entire sentence, as shown by the fact that *Daniel O'Connell* is pronounced without special prosodic prominence.

In section 4.1 it was mentioned that in modern Irish the copula is often omitted from cleft sentences and that in such cases clefting is structurally very close to fronting. As noticed by Odlin (1997), the same phenomenon is found in Irish English and in the English spoken on the Hebrides:

(4) …down on the west end there, you could cut it [the grass] like corn. But not now. [It's] *The cattle's that eating it.*

As the use of this construction seems to be entirely distinctive of the English of the Celtic lands, Odlin argues, it has to reflect Gaelic influence. Here the substratum theory is very strong.

As already mentioned, Irish English differs from standard English in that fronting and clefting are highly frequent as well as functionally quite similar. In trying to keep fronting and clefting apart functionally it is natural to consider FOCALIZATION. Clefting is typically accompanied by focalization, cf. Harris, who states that 'clefting generally serves the discourse function of presenting the fronted element as new and contrastive information' (1993: 175). A fronted constituent, however, is often not focal, as appears from the next example:

(5) If Sandra wants to go and see Gene Stuart, then Gene Stuart she shall see.

In this example (repeated from section 5) it is obviously not the fronted object which constitutes the focus of the second clause but the verb. A problem with using focalization as a criterion (+/- obligatory focalization), however, is that the constituent following *it is* in cleft sentences is not invariably focal, as shown by example (3).

What appears to be the situation in Irish English is that fronting and clefting are not functionally identical but that there is a great deal of functional overlap between the two constructions.

8. Conclusion

In this paper I have argued that in order to give a revealing account of fronting in Irish English it is useful to operate with a topographical schema of the type proposed for Danish by Paul Diderichsen. Like Danish, but unlike standard English, Irish English has an initial field of many purposes, and it is therefore particularly useful to recognize a fundamental field in this variety of English.

As pointed out by Filppula (1986, 1990, 1991), the prevalence of fronting in Irish English can plausibly be explained as a combination of influence from the Irish substratum and from archaic English, i.e. it seems very likely that a construction commonly used by English settlers 350 years ago has been preserved and reinforced by the Irish substratum.

Phonologically, fronting is characterized by stress on the constituent moved to initial position, but as shown by the recording of my examples this stress is often not very strong. As fronting is very common in Irish English, unlike standard English, this is to be expected. In the degree of prominence it gives to a fronted constituent Irish English resembles Danish.

Pragmatically, fronting serves to foreground the constituent moved to initial position and to instruct the hearer to select this constituent as his communicative point of departure in processing the utterance. While fronting is pragmatically closely related to clefting in Irish English, it appears to differ from it in often being unaccompanied by focalization, i.e. unlike a constituent singled out by clefting a fronted constituent is often not the most important or salient part of the utterance in which it occurs. In order to establish linkage with a preceding part of a conversation or of one's own message, furthermore, it is fronting which is used, not clefting.

All my own examples were culled from a recent Irish novel (BREAKFAST ON PLUTO by Patrick McCabe), and it was on reading that novel that I first became aware of the special properties of constituent order in Irish English. Its protagonist, Patrick Braden, is from a little village on the southern side of the Irish border, i.e. from a rural district, and has no education beyond secondary school. The novel is written in the first person, and it is Patrick Braden who tells the story of his life and times in it. As mentioned above, there is a long tradition in Ireland of representing the spoken vernacular in fiction, and it seems clear that McCabe has attempted to capture the language used by his protagonist and in so doing to create an authentic Irish atmosphere.

In BREAKFAST ON PLUTO there are surprisingly few cleft sentences. On the other hand, there are several examples of partial fronting. Many of these result in the verb phrase (or part of it) occupying the final position, so in this respect constituent order in Irish English is similar to that found in e.g. German. As partial fronting is not discussed in the literature I have had access to, it appears to deserve attention in future studies on Irish English.

Typologically, Irish English is an SVO language like standard English, but its constituent order is considerably freer than that of standard English. As we have seen, the ordering OSV is by no means rare. That is not surprising, for unlike VSO and SOV languages SVO languages do not constitute a unified type (see Dik 1989: 336). In terms of Dik's cross-linguistic principles of constituent order (340ff) we can say that the principle of functional stability (according to which constituents with the same syntactic function are preferably placed in the same position) is overruled by the principle of pragmatic highlighting much more readily in Irish English than in standard English, though less so than in languages like Italian, Greek, Spanish and Russian.

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F0 analysis and prediction in Swedish prose reading

Gunnar Fant and Anita Kruckenberg

1. Introduction

This is an attempt to approach analysis and synthesis of F0 contours along somewhat unconventional lines. A novelty lies in an extended normalization of data, not only in the frequency domain but also in the temporal domain which is an advantage when comparing utterances of several speakers.

The continuously scaled syllable and word prominence parameter labeled Rs, first introduced by Fant and Kruckenberg (1989), has provided a quantified perceptual measure supplementing established phonological categories such as stress, accentuation and focal prominence. It has been correlated with duration, intensity, F0 and other physical parameters (Fant and Kruckenberg, 1994, 1999b,c, 2000).

A first attempt of systematic analysis and modeling of F0 contours was reported by Fant and Kruckenberg (1998). It was based on our standard text from a Swedish novel, a paragraph of about one minute length which was read by a male subject, SH. Simultaneous recordings of sub- and supraglottal pressure were made. A perceptual assessment of Rs-values of each syllable of the recorded speech was carried out by a jury of 15 listeners.

Our present survey, devoted to the same text, employed 5 speakers, three males and two females. A preliminary report was given in Fant and Kruckenberg (1999a). Respiratory pressures were not recorded. In order to simplify the perceptual assessment we relied on two expert judges only, which proved to be sufficient for our purpose.

It was found that the magnitude of the F0 declination within a breath group, or in the part of an utterance between two successive junctures, was approximately independent of the length of the unit. This was the incitement to adopt a normalized time scale, from 0 to 1, as a reference for data positioning. In an earlier study devoted to the same text (Fant and Kruckenberg, 1998) we had quantified accent positions as one out of five, initial, next to initial, medial, next to final, and final. In our present work we have abandoned this discrete quantification for the continuous 0-1 position scale.

The second major novelty of our work lies in the extensive use of the Rs-parameter in intonation modeling. In other respects our modeling follows established lines with declination, grouping and accent type as major components, e.g. Gårding (1981, 1989, 1993), Grønnum (1995,1998), Collier (1991).

2. The prominence parameter

Our technique for prominence rating originates from Fant and Kruckenberg (1989). A listener crew was engaged in the assessment of each syllable or word from a recording, presented in repeated chunks of the order of a sentence. A direct estimate technique was adopted, involving the setting of a pencil mark on a vertical line scaled from 0 to 30 for each syllable or word. The continuous interval scale thus generated has been labeled Rs. As the only guideline subjects were told that typical values for unstressed syllables would be Rs=10 and for stressed syllables Rs=20.

A more recent study (Fant and Kruckenberg, 1998) involved the previously mentioned one-minute-long paragraph from a novel read by subject SH. The standard deviation among the 15 subjects in the listening crew was of the order of 2-4 Rs-units only, which implies an uncertainty of the means of the order of $0.7\sigma/(N^{0.5})$, i.e. of the order of 0.4 – 0.8.

It was found that lexically unstressed syllables averaged Rs=11 and stressed syllables Rs=19. The greatest spread occurred in the secondary syllables of accent 2 words and compounds.

Our earlier tests from the Fant and Kruckenberg (1989) study showed that word prominence assessments closely follow those of the syllable carrying maximum stress in isolated lexical pronunciation. Word prominence has accordingly been quantified indirectly as that of the dominant syllable of the word as shown in the following tabulation.
Table 1. Syllable prominence Rs versus word class.
N = number of words.

Content words	Rs	N	Function words	Rs	N
Numerals	22.8	1	Pronouns	12.5	22
Nouns	19.8	31	Prepositions	11.1	18
Adjectives	18.2	5	Auxiliary verbs	10.7	8
Verbs	17.1	22	Others	9.4	18
Adverbs	17.0	6	Weighted mean	11.0	64
Weighted mean	18,6	65			

These data originate from the recording of subject SH which included a simultaneous recording of sub-and supraglottal pressures. They are similar to those found for subject AJ (Fant and Kruckenberg 1989, 1994) but with a somewhat greater stressed/unstressed span.

Content words are usually stressed and function words unstressed. However, content words may be de-emphasized and function words may be raised in prominence, but we also encounter an extra high emphasis on some content words and a far reaching reduction of function words. Typical domains for unstressed syllables are Rs=5-12, stressed unaccented Rs=12-15, stressed non-focal accented Rs=15-20, focal accentuation Rs=20-25, extra high focal prominence Rs>25.

3. Data analysis

3.1. Frequency normalization

F0 traces on a log scale were printed out in synchrony with oscillogram, spectrogram and intensity curves (Fant and Kruckenberg, 1999c, 2000). Our calibration standard was 2 mm per semitone (st), i.e. 24 mm per octave. Measurements were made within 0.5 semitones. All F0 values were initially expressed in an absolute scale of semitones (st) relative 100 Hz.

A normalization based on each speaker's average F0 in unstressed syllables was introduced. Accordingly, a correction of -7 st respectively -9.5 st were applied to the female data and -1 st respectively +1 st and 0 st for the male data. As a result the female data were effectively lowered to match the male data.

3.2. Accent 1 and 2 sampling procedure

For F0 data sampling and processing we have adopted the canonical description and notations of Bruce (1977) of the Swedish word accents 1 and 2. A few minor additions and some specific interpretations of data labels have been introduced. The domain of an accentuation is generally not confined to a single word. Accent 1 is initiated by an HL* fall from a high position H in the preceding syllable (if existing) to a low position L* in the early part of the main syllable of the accented word, whereas accent 2 has an H*L fall within the primary stressed syllable. H* is located close to the left boundary of the stressed vowel.

A prototype feature of accent 2 is that the H*L contour is followed by a rise of F0 to a high level in the next or a following syllable. The height of a secondary peak thus created increases with prominence. In accent 1 increasing prominence is associated with an F0 increase from L* to a high position Ha in the main syllable. These conditions of high prominence, typical of contrasting lab sentences, are traditionally referred to as sentence or focal accent.

In our study, on the other hand, we are confronted with a continuity of accentual realizations from low to high prominence levels. We therefore have to adopt labels for F0 measures and specific sampling routines that are independent of phonological classification. Accordingly we have labeled the core parts of accent 1 as HL*Ha and accent 2 as H*LHg. One of our findings is that Ha and Hg, potentially carrying a »sentence accent«, display an approximately equal rate of increase or decrease with prominence which suggests that they reflect one and the same underlying physiological mechanism.

Additional notations (Fant and Kruckenberg, 2000), generally not used in routine work, include a starting point Lo preceding H* of accent 2 in sentence initial position. Another is a terminating low tone Lt at a juncture which also may occur inside a sentence after a high point Ha or Hg adding emphasis to a word. Unstressed syllables are denoted Lu. As a rule Lo is close enough to Lu to be omitted.

Our present routine is confined to the sampling at two positions within the major syllable of an accented word, L* and Ha for accent 1 and H* and L for accent 2. All other syllables, i. e. those denoted H, Hg or Lu are given one sampling point only. Thus the word »margarinlåda« would be denoted: Lu Lu H* L Hg Lu.

Lu measurements are referred to the middle of the vowel. In a weak accent 1 syllable the F0 contour may show a continuing fall instead of an L* Ha rise. As a consequence, our routines in these instances of sampling L* at the beginning and Ha at the end of the vowel produces a negative (Ha-L*). At higher degrees of prominence Ha refers to the peak of an F0 maximum in the middle of the vowel.

3.3. F0 data display

In order to visualize a connected F0 contour from the sampled data of a sentence we performed a smoothed continuous record of successive points based on Excel routines. The result is a time and frequency normalized intonation contour in which unvoiced portions are overbridged. The time scale is substituted by a sequence of data point labels, slots, and the frequency scale is in semitones relative 100 Hz. Individual variations in timing and tempo are thus excluded and the data for any speaker is corrected for his or her deviation from an average male F0.

This system has obvious advantages for studies of the intonation of several subjects, and it provides efficient means of calculating average contours and individual variations.

Figure 1 shows three graphs from the analysis of prose reading. First a short sentence: »Ingrid fick brev från Arne«, *Ingrid received a letter from Arne,* followed by the first part of the next sentence: »Han hade legat och skrivit de i en stor sal«, *He had been lying writing it in a big hall,* and finally the clause: »vars fönster vette mot Klarälven«, *with windows overlooking Klarälven.*

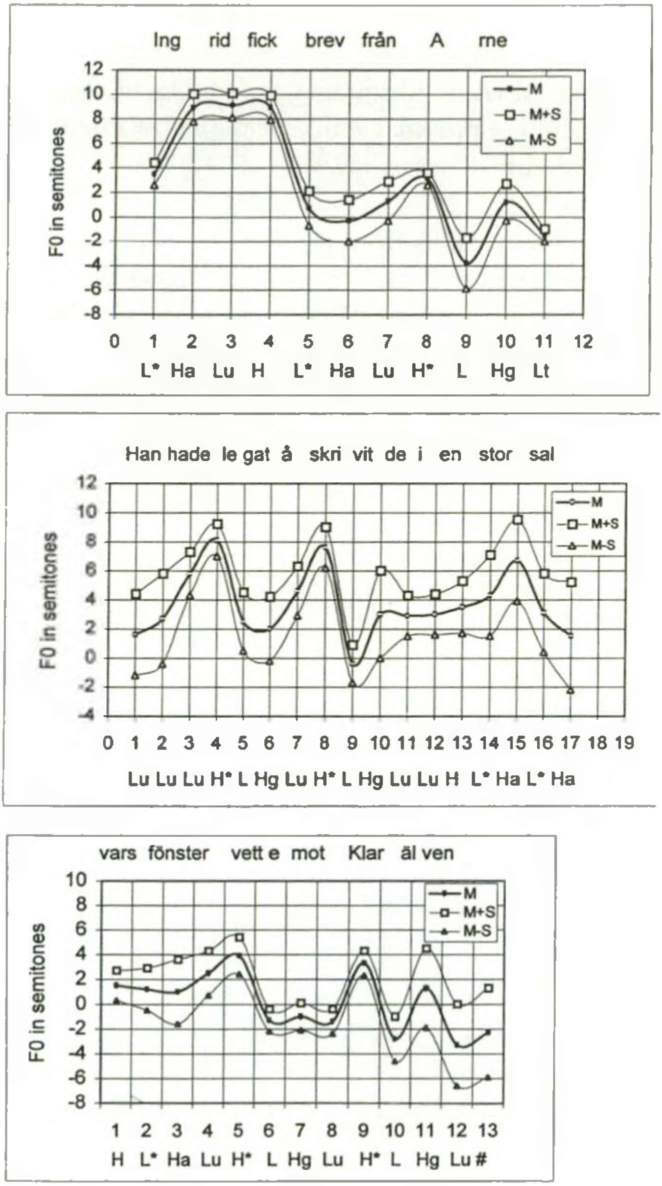

Figure 1. Stylized F0 patterns within a succession of three parts of speech, a single sentence, a primary clause and a secondary clause. Each graph shows the mean of five subjects, two females and three males, and the mean plus and minus the inter-subject standard deviation.

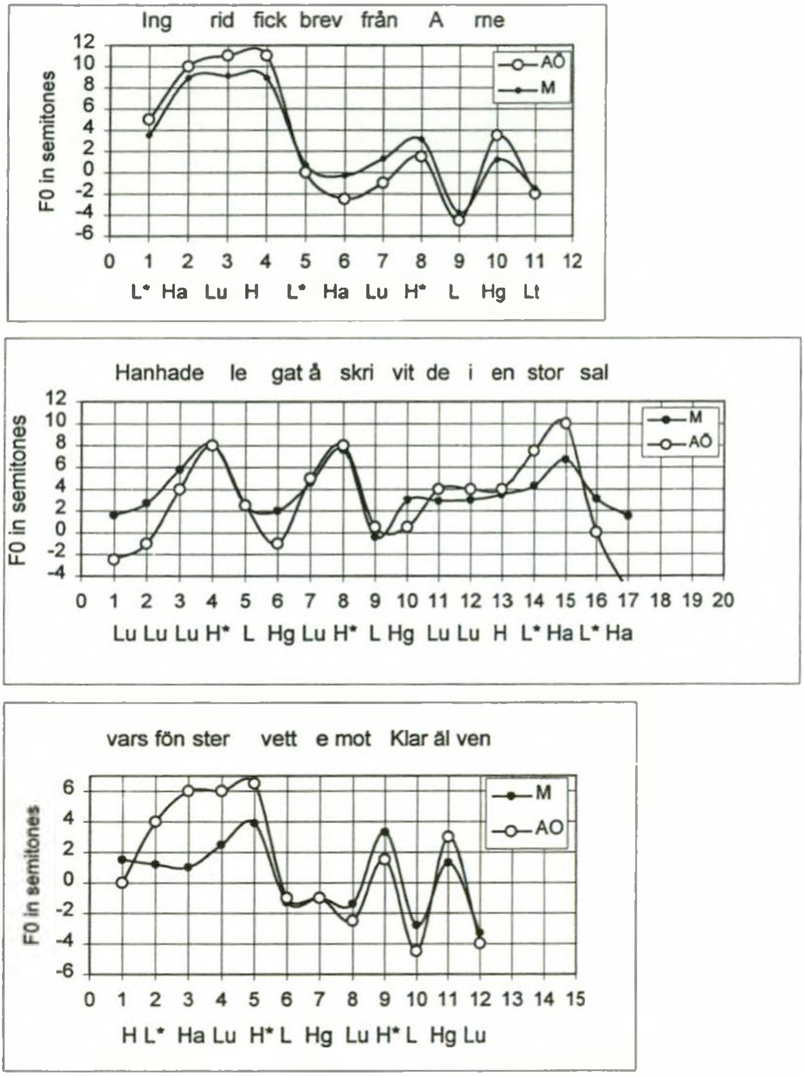

Figure 2. Same as Figure 1, but here the mean of the five subjects is compared with the female subject AÖ.

The three curves in each graph represent the mean of the five subjects, three males and two females, and the mean plus and minus one standard deviation of the inter-subject variation. The consistency is apparent, especially in the first declarative sentence, where the standard deviation does not exceed 2 semitones.

The L* Ha rise of the initial accent 1 word »Ingrid« is in part boosted by the underlying initial rise of the sentence base contour. A similar L* Ha rise appears in the adjective »stor« at the end of the second graph, while the following noun »sal« is subject to an early onset of the sentence final F0 drop which explains the negative (Ha-L*).

The typical H*L drop of accent 2 is apparent in the words »Arne«, »legat«, »skrivit« »vette«, »Klarälven« An apparent Hg peak appears only in the relative prominent words »Arne« and »Klarälven«.

Figure 2 provides a comparison of the female subject AÖ and the mean of the five subjects. Apart from an overall similarity, it is apparent that AÖ has a greater F0 span and a tendency of a more marked phrasing. This tendency was not shared by the second female subject.

4. Modelling and prediction

4.1. Method

The next phase of our study was to attempt a prediction of observed data. The basic constituents of any intonation model is grouping and weighting of relative prominence, and also the choice of a basic utterance frame of F0 onset, declination and offset (Bruce 1977, Gårding, 1981,1989,1993, Bruce and Granström, 1993, Lindström, Horne, Svensson, Ljungqvist, Filipson 1995). Special rules for focal accentuation and tonal rises and falls of specific denotations are included.

Our approach has been the following:

(1) Perform a prediction of major junctures which would segment speech into units suitable for a pause with or without breathing. The duration of a pause, if present, is related to the syntactical level. A typical value is 1000 ms after a complete sentence and in the range of 200-600 ms at lower levels. A more general aspect of pausing, not dealt with here, is quantal durational traits (Fant and Kruckenberg 1996), see also Fant, Kruckenberg and Nord (1992).

We have noted a strong correlation between the duration of the pause at a juncture and the size of the F0 reset and its components, the final and the initial F0 values, see Figure 3.

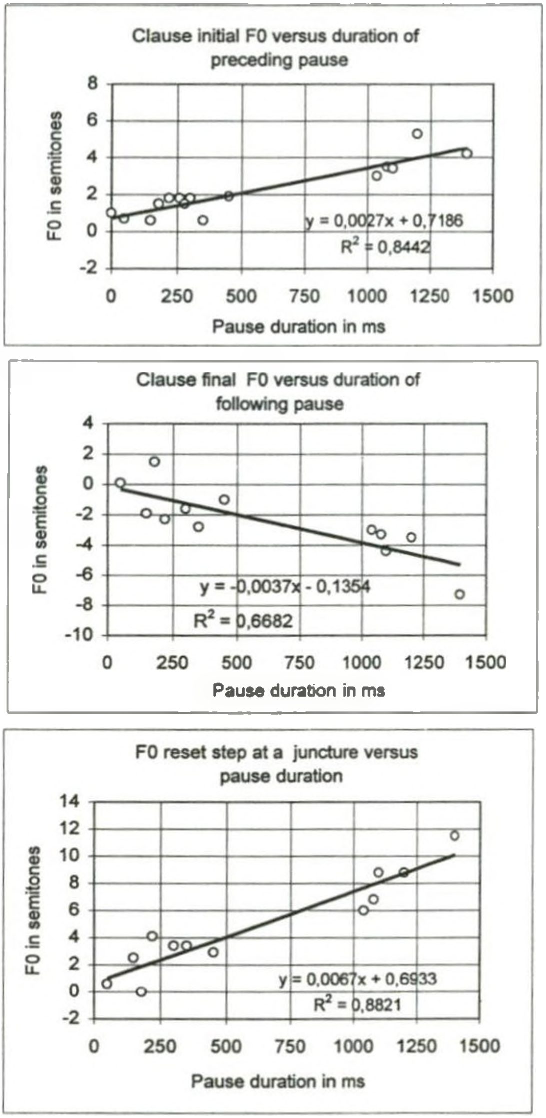

Figure 3. Clause initial F0, final F0 and F0 reset at a juncture as a function of the five speakers, average pause durations.

As a result we have selected two prototype base contours which specify F0 values of unstressed, i.e. Lu syllables. Their domains have been labeled as »primary clause« and »secondary clause » which usually correspond to the initial and following parts respectively of a complete sentence. They are initially specified as a sequence of data slots. For calculations of the influence of a particular position we transfer the sequence to a normalized scale from 0 to 1, which conforms with our observations that the extent of the declination drop, 4-6 semitones, tends to be independent of the duration of the unit. A similar tendency in Danish has been observed by Grønnum (1995, 1998). The size depends on starting level, rate of declination and onset and offset characteristics as shown in Figure 4. The final fall is greater in a secondary than in a primary clause.

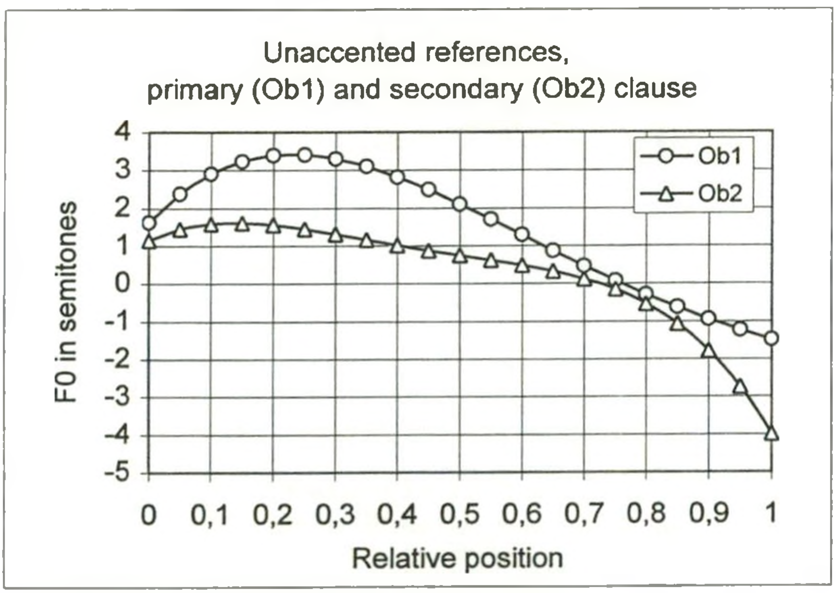

Figure 4. Base curves of Lu, unaccented F0 values, for a primary clause and a secondary clause as a function of position on a 0-1 normalized time scale.

(2) The expected degree of word and syllable prominence can be predicted from word class. In the present study predictions are based on the assessed Rs data of the spoken material.

(3) A transcript of the text in terms of a sequence of accentuation and stress labels is made, and corresponding prominence values Rs are noted. Observe that all F0 slots within an accentuation domain share the same Rs, i.e. H attains the same Rs as L* and Ha, and Hg attains the same Rs as H* and L.

(4) The absolute position of a parameter slot is temporally translated to a relative position on the normalized 0 to 1 scale.

(5) F0 values are now predicted on the basis of the relative positions of accentuations and their prominence Rs. This is the central core of the prediction scheme. It is based on a detailed statistical survey of parameter values from the analyzed data. Regression equations have been derived in two steps, relating parameter values to Rs followed by a correction for position. This operation is performed separately for primary and secondary clauses. Syllables not belonging to an accent domain are given the Lu values of the particular base curve.

(6) The results of the prediction are now displayed on the original scale of successive slots as a sequence of smoothly connected data points. In the same graph, see Figure 5 and 6, we have included the corresponding mean value contour of the 5 subjects.

(7) Observed differences between this first stage of prediction and measured values are analyzed in order to be understood and corrected for in a more complete model. This is the main purpose of the present study.

4.2. Results of prediction

An overall impression from the nineteen analyzed parts of speech is a high degree of coherence between the spoken data and predictions. Apart from some obvious deviations differences are of the order of 1-2 semitones only.

The prediction rules do not consider syntactically determined groups within a sentence, e.g. preposition phrases. This is one frequent source of deviation. Another is the appearance of local dips at Lu slots between high points, which is interpreted as a lack of assimilation, see Figure 5.

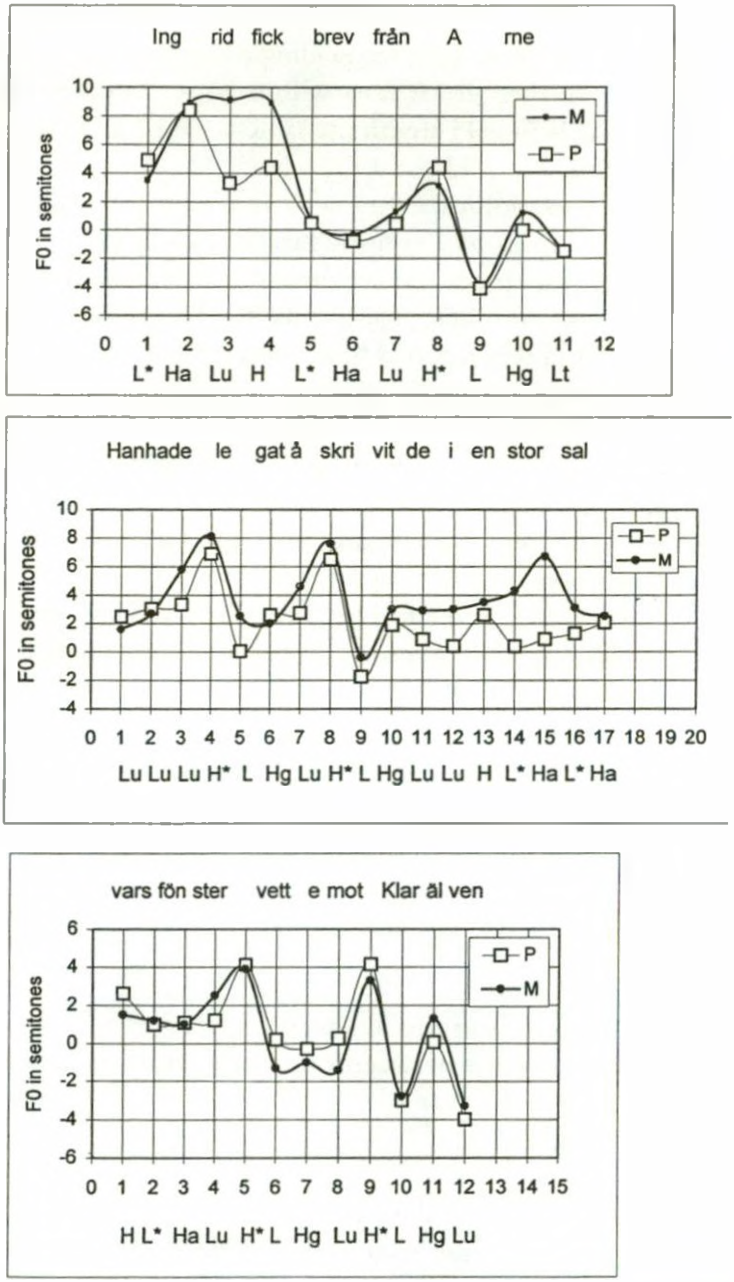

Figure 5. Results from the preliminary prediction of F0 contours and corresponding observed data of the utterances in Figure 1.

A related error is a lacking carry-over of a high F0 from an accent 1 Ha to the next syllable, see »Ingrid fick...« in Figure5. In this case one could also argue that the assimilation is a matter of a syntactically determined grouping which also applies to the negative Lu errors in Figure 6, i.e. at position slots 5 and 22. In this sentence we also encounter a positive Lu error at slot 8, in the second syllable of »väggarna«, where the speakers apparently preferred to insert a low F0 preposition phrase boundary.

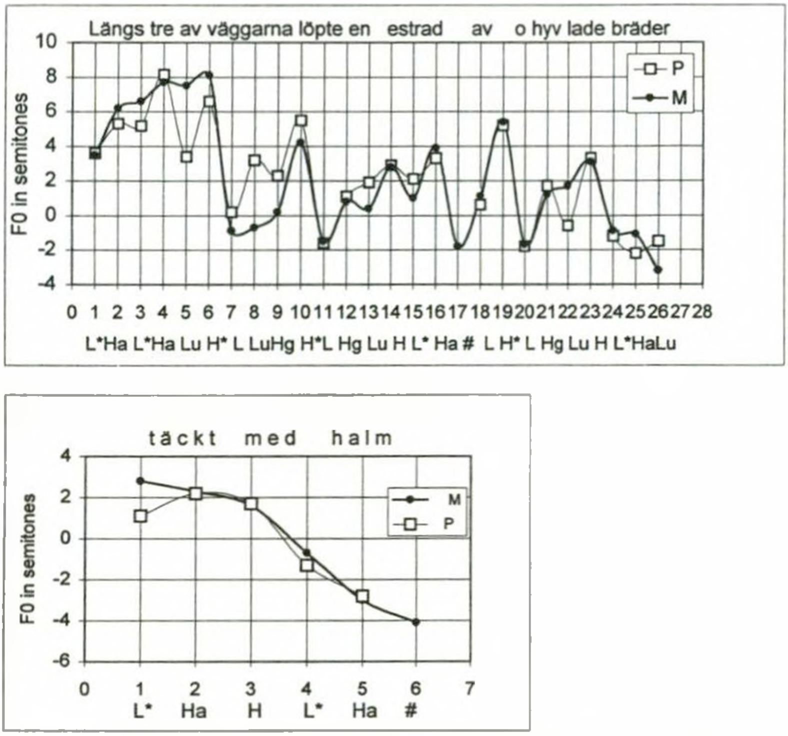

Figure 6. Predicted and observed data of a primary clause and a secondary clause of the text following Figure 5.

A frequently occurring source of prediction uncertainty related to speaker variability is an early timing of voicing offset at the end of a sentence.

A major shortcoming of our prediction appeared in the middle graph of Figure 5. Here this primary clause ends with the adjective plus noun »stor sal«. In the spoken version, see Figure 1, the Ha of »stor« attains 4 semitones higher F0 than the Ha of »sal«. This is quite at variance with the Rs= 20,8 of »stor« and Rs=22,6 of »sal«. Accordingly, the Ha of »stor« attained a prediction error of –6 semitones, whereas Ha of »sal« was predicted correctly. At first sight, the discrepancy would indicate an error in prominence assessments. However, this is not likely. A control listening did not reveal any substantial miss-judgements. In order to eliminate the prediction error in »stor« we would have needed an Rs=25.

A statistical study of predicting Rs values from syllable durations gave a support of the established Rs values. Furthermore, in nearly all accent 1 words including »stor« and »sal« a high correlation was found between the 5 subjects' individual Ha measures and corresponding Rs judgments. Intersubject variations are thus predictable.

Considering the Rs measures to be correct, how do we explain the large negative prediction error of Ha in »stor«? One could argue that the combined words »stor sal«, which form a semantic concept, rather than »stor » alone is a focal target zone, a pivot in the terminology of Gårding (1981, 1989, 1993). It is preceded by a gradual rise which adds an F0 component to the Ha level of »stor« which appears to be disregarded in Rs judgements.

5. Accent patterns and prominence

Our study adds some insights in the realization of accents in a rather homogenous group of subjects from the Stockholm area. We shall discuss accent specific patterns and their variations with the prominence parameter Rs and the position in a breath group or a similar unit.

Figure 7 pertains to accent 1 and accent 2 at a relative position around 0,5 in a primary clause and for four Rs values, 15, 20, 25 and 30.

As already shown by Fant and Kruckenberg (1999A) the H parameter of accent 1 shows a negative dependency of Rs. The range of covariation with Rs is small, 2 semitones only, but the trend is significant. The Ha parameter increases 8 semitones from Rs=15 to the focal level Rs=25, i.e. 1,6 semitones per unit Rs. Above Rs=25 there is a saturation effect. The preceding L* also shows an essentially positive correlation with Rs but of smaller magnitude. Of special interest is the step from L* to Ha which is positive for Rs>20, level for Rs=20 and negative for Rs<20.

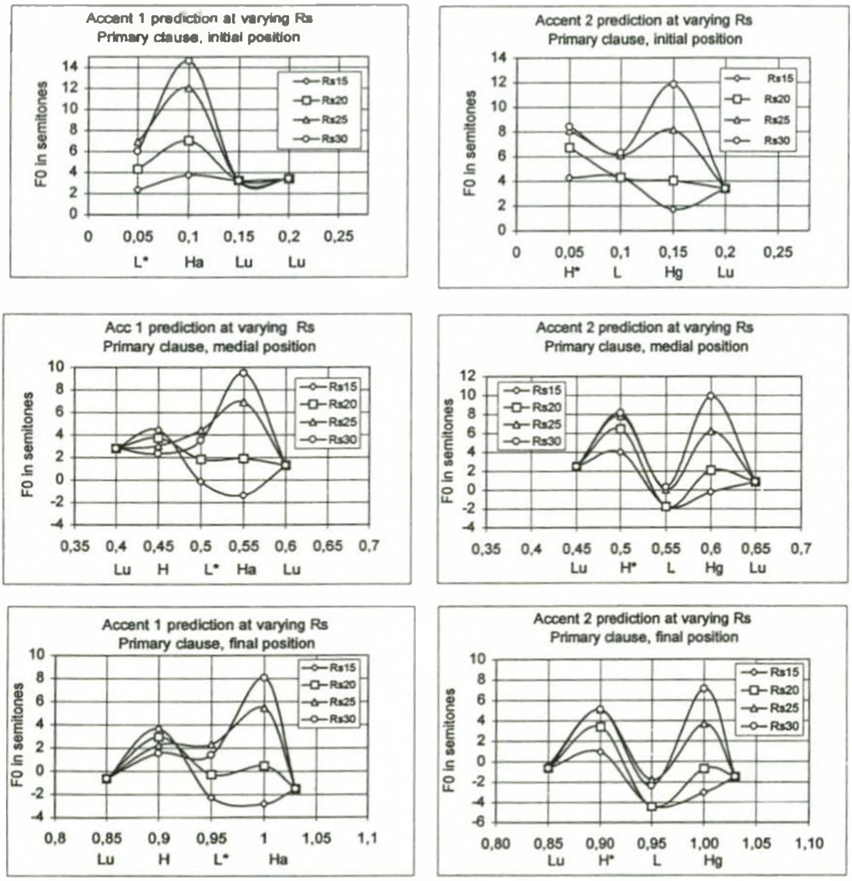

Figure 7. Accent 1 and accent 2 patterns in a primary clause; initial, medial and final positions. Four prominence levels, Rs = 15, 20, 25 and 30 are included.

In accent 2 the dominant Rs related parameter is the secondary peak Hg. The increase of Hg with Rs in the range Rs>20 is approximately the same as for Ha in accent 1. H* variations are less apparent. There is an increase of H* by the moderate amount of 0,5 semitones per Rs unit in the range of 15<Rs<20values and a limit is reached at Rs=25. A shift from normal to focal accent 2, e.g. from Rs=20 to Rs=25, accordingly produces a much larger shift in Hg than in H* (Fant, Kruckenberg, Hertegård and Liljencrants, 1997).

Except for relative early occurrences in a sentence the accent 2 parameter L is about 2-4 semitones below the unstressed level Lu. At relative positions below 0,2 the L parameter approaches Lu.

At Rs=20, the upper limit of the F0 contour in a primary clause is mainly set by H* points and the lower limit by L points. In the terminology of Gårding (1981, 1989, 1993) these turning points determine the grid. H* runs essentially parallel to and 4,5 semitones above Lu. Also, as shown in Figure 8 at Rs=20, the average position of Hg is one semitone above Lu (Ob1) and Ha is close to H* in early positions. At Rs>23, Ha and Hg compete in level with H* at the upper limit of the grid.

Accordingly, the span of the grid is largely set by accent 2 words. In a medial position of a primary clause the (H*-L) fall is of the order of 8 semitones. In initial positions, on the other hand, (H*-L) is heavily reduced to the order of 2 semitones, which is mainly a matter of the increase of L as described above. A possible explanation is that the initial F0 rise at the onset of voicing appears to have an inhibiting effect on the execution of a simultaneous accent 2 fall suggesting competing muscular commands.

Clause final F0 patterns are more predictable from a superposition point of view which applies to both accent 1 and accent 2. Here, we also find a more consistent correlation of Rs with H* than in other positions whilst Hg becomes sensitive to individual variations in the timing of final F0 lowering.

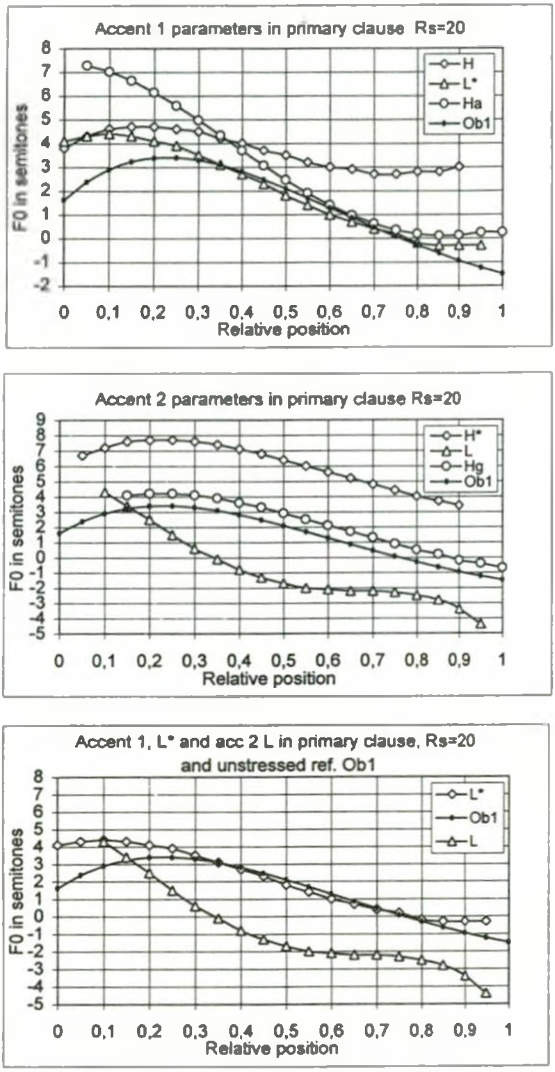

Figure 8. Accent 1 and accent 2 parameters in a primary clause as a function of relative position at Rs=20.

A study of the positional distribution of Rs values in the spoken material indicates that accented words attain about 2 units higher Rs in initial and final positions than in medial positions. This finding reflects well known default conditions for sentence accent.

A study of positional traits within a secondary clause did not reveal the same specific influences of early positions as was found for primary clauses described above.

6. General discussion

We have developed a novel scheme for analysis and prediction of F0 data based on normalization in both frequency and time domains and the introduction of a continuously scaled prominence parameter, Rs. Particular conventions for defining and quantifying accent parameters are introduced. These are coherent with the traditional models developed by Bruce (1977). However, the demand for continuity across a large range of Rs values has called for a specific data sampling procedure and specific parameter notations.

Our study employing three male and two female subjects reading a one minute long passage of a novel has benefited from time and frequency normalization procedures which bring out average trends as well as individual patterns.

The prediction is not complete. It is based on (1) the identification of accented versus non-accented words, (2) the accent 1 and 2 dichotomy, (3) accentual prominence Rs and (4) the relative position of an F0 data point on two alternative base lines. The difference between measured and predicted data is on the whole rather small, but there exist major discrepancies which are related to syntactical groupings on a phrase level, rising and falling intonation and to assimilation demands not included in the prediction. These are inferred and highlighted by this analysis-by-synthesis approach, but in order to include them in the prediction scheme we need to extend the reading corpus.

The Rs assessments were limited to accented words, thus excluding unstressed words and weakly stressed words with non-significant accent modulation. Earlier studies (Fant and Kruckenberg, 1998, 1999b,c, 2000) have provided a more complete data set for predicting Rs from word class.

Another limitation of the Rs assessments in the present study is that they were performed by two listeners only, both experts. However, as judged from the overall accuracy of prediction the results appear reliable. An additional support of the validity derives from regression equations for a number of words relating individual Rs values and corresponding Ha or Hg of the five speakers for one and the same word. These provide correlation coefficients r^2 of the order of 0,8. In other words, the individual F0 variations are systematically related to corresponding Rs ratings.

A follow up question is how Rs ratings are related to duration and intensity parameters. Rather extensive data appear in Fant and Kruckenberg (1994, 1998,1999b,c, 2000), but less on the combination of F0 and all other parameters. We have made some simple tests in our material correlating Rs with durations. These are coherent with the data on Rs versus F0 but occasionally of less significance, especially in a focal range of high Rs levels in sentence final positions where duration may show a rather small increase with Rs.

An interesting finding is that a subject's speech rate in terms of average syllable duration is positively correlated to his or her average Rs. A low tempo promotes distinctiveness and prominence.

A remaining question for future studies is to what extent Rs assessments follow F0 peak measures in a focal range. As already discussed, a higher than expected F0 in a focal region could derive from a superimposed rising intonation contour counteracting the normal declination but not contributing much to the assessed Rs. In these cases a local F0 measure such as (Ha-L*) appears to be a better Rs correlate than Ha alone.

An overall impression of our material is that accent 2 patterns possess more apparent visual characteristics than accent 1, the H*L fall dominating the width of the grid at non-focal accentuations. In sentence medial position at Rs=20, H* is located four semitones above the unstressed reference Lu, the base contour of the clause, and L is symmetrically located 4 semitones below Lu. The low point L* of accent 1 has an F0 level close to Lu and is thus consistently higher than L of accent 2. At medial positions we also find the Hg of accent 2 and Ha of accent 1 about 1 semitone above Lu. However, with increasing prominence Rs there is a rise of both Ha and Hg to levels close to and even exceeding H*.

The accent 1 parameter H was found to be higher than Lu and to vary inversely with Rs (Fant and Kruckenberg, 1998, 1999a). Relative high values of H appear in the latter half of a clause at non-focal prominence levels, Rs<22. However, the relative prominence of the H syllable was found to be speaker dependent, a possible dialectal trend. At higher prominence levels, Rs>22, the H parameter attains an F0 close to L* at the foot of the rising accent 1 contour.

The size of the rise from L* to Ha is an efficient relational correlate of Rs. At Rs=20, Ha is reduced to the same level as L* and for Rs<20 there is a fall from L* to Ha, the (Ha-L*) measure becomes negative. This trend violates the meaning of high and low points but is the consequence of our notations for sampling points chosen at more or less predetermined positions in order to secure a continuity of measurements over a large range of Rs values.

A common trend in our data, to be seen in Figure 8, is that observed relations between accent parameters at one and the same Rs in a primary clause may vary considerably within the positional scale and the particular Rs. Thus at a low Rs the accent 1 parameter Ha is much more dominant in the early part of the position scale than at later positions, whilst the opposite trend is found for the H parameter. As stated above, the accent 2 parameter L reaches relative high positions close to Lu at early positions in a primary clause.

Our study adds some insights in the nature of accent contrast. It has been suggested by Elert (1995: 127) and Engstrand (1995) that accent 1 could be considered as phonologically unmarked compared to accent 2. A common feature of both accents (Bruce 1977) is the sentence accent, i.e focal accent, here represented by the rise to Ha and Hg respectively. In addition accent 2 possesses the H* to L fall which is apparent even at low degrees of prominence. The accent 1 H parameter is more illusive. It is absent in sentence initial position of the accented word, and according to our findings it varies inversely with Rs and attains a level close to the unstressed Lu in early positions. In focal accentuations it assimilates with L*.

A well documented and fundamental distinction (Bruce 1977) lies in the relative timing of accent 1 and 2 patterns. The rise of the sentence accent as well as the initial fall towards or within the main accented syllable is timed later in accent 2 than in accent 1. Moreover, the finding in the present study of rather high H levels in medial and late positions of a primary clause adds to the accent 1 pattern.

The perceptual salience of the H parameter remains to be tested. This is one of several aspects of F0 modeling to be included in forthcoming synthesis experiments. Our modeling, which apart from the prominence parameter Rs is production oriented, appears to be more detailed than what has been the case in existing text-to-speech systems, which primarily aim at preserving perceptual essentials. Local details are considered less important than connecting structures (Carlson and Granström 1973, Gårding 1991) but there is a need to perform more detailed studies within a maximally complete frame.

In retrospect, we claim our analysis system to be novel, and that it should have several advantages as a research tool. It is backed up by a detailed documented data base of several subjects' reading. It now remains to evaluate the specific benefits of our prediction scheme and to formulate appropriate rules for incorporating identifiable syntactic and phonological structures of a text. For this purpose we need to extend the corpus of read material.

7. Acknowledgements
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The feature Spirantized

Osamu Fujimura

0. Background

I visited Eli Fischer-Jørgensen in Copenhagen and met her for the first time in 1964, I think. At that time, I was working for Gunnar Fant in Stockholm. I remember she invited me to her house with several of her students and we had a very pleasant and interesting discussion of experimental phonetics. I knew her work on stop consonants through her papers, which she kindly sent me in Tokyo as they came out, and my synthesis-listening work around 1960 at MIT on the voicing of initial stops drew upon her pioneering work on stop consonants. At her house, I raised one of the linguistic questions that had been on my mind for some years: if the special characteristics of the consonant clusters /sp, st, sk/ with respect to aspiration was a peculiar property of English, unique to Germanic languages, or more general among different languages. She found the question interesting, but nobody had a definitive answer. I still do not have a clear-cut answer to this question, despite a large number of relatively recent publications on this topic in the literature. It now seems clear, however, that some special properties (at least on the surface) of this type of obstruent cluster are recognized in a large variety of languages (for an Optimality Theory-based account which claims there is nothing special about this type of cluster, see Morelli 1999). I have worked on related issues with a somewhat radically speculative view of feature analysis and phonetic organization of syllables in English and other languages. I would like to summarize here my current interpretation in terms of a syllable-based account, the Converter-Distributor (C/D) model of phonetic implementation (Fujimura 1992), and ask the same question again.

1. English /sp, st, sk/

In my presentation at the Acoustical Society Meeting in 1976 (see also Fujimura 1979, Fujimura & Lovins 1978, and Macchi & Spiegel 1990), I proposed a phonetic analysis of English syllables by demisyllables, that is, in terms of initial and final demisyllables and syllable affixes.[1] Instead of treating syllables as linear strings of phonemic segments, I proposed to analyze each demisyllabic component in terms of features. In particular, the consonant clusters /sp, st, sk/ in the phonemic analysis were represented by an unordered set of features {spirantized, stop, place} without specifying the voicing distinction which does not have any phonological function in this context. In my current analysis using an underspecification scheme, the feature specification for these clusters does not include {stop}, while it adds {nasal} for the clusters /sm, sn/ in syllable onset. The feature {spirantized} is used also for coda and s-fix. Thus, the English word 'spear' has the onset specification {labial, spirantized}, as opposed to {labial, nasal, spirantized} {labial, stop, voice}, {labial, stop}, {labial, nasal} for 'smear, beer, peer, mere', respectively.[2]

This class of consonantal gesture clusters[3] has special properties in several ways. First, as mentioned above, there cannot be a voicing distinction in English. In fact, phonetically, the stops, unlike initial voiceless stops of stressed syllables, are not aspirated. If the [s]-fraction of 'spear' is eliminated by a waveform editor, American English speakers usually hear 'beer' not 'peer', even though the stimulus may not be perfectly natural. This phonetic property of the cluster in syllable-initial position was identified by Davidsen-Nielsen (1974) to explain the perceptual distinction between two phonemically homophonous words like 'mis-take' and 'mistake'.

Another notable property of this set of obstruent clusters is that, unlike other consonant clusters involving /s/ such as /sl/ vs. /ls/, seen in a comparison of /sleJt/ 'slate' and /els/ 'else',[4] the phoneme sequence /sp, st, sk/ can appear without inversion of order when they appear in syllable final position, as seen in 'rasp', 'past', and 'ask'. These forms minimally contrast with the other phonemic ordering, for example, 'raps', 'pats', and 'ax' (in American English). This ordering contrast does not occur in syllable initial position. Note that this ordering contrast between /sk/ and /ks/ in word-final position defeats any sonority contour account, regardless of how we define sonority for phonemic segments (see e.g., Clements 1990, Basbøll 1974).

Still another distributional peculiarity of this set of obstruent clusters from a phonemic point of view is that the first phonemic segment cannot be anything but /s/. In other words, when an obstruent gesture is immediately followed by another tautosyllabic obstruent gesture (including a nasal stop which implies an oral closure though the consonant is also sonorant, see Sproat & Fujimura 1993), whether the cluster is immediately followed by a vowel or another sonorant gesture, /l/, /r/, or /w/, the first obstruent event has to be an apical frication. Thus there cannot be a word 'fky' in parallel to 'sky', in analogy to the paradigm 'fly' vs. 'sly'. Clearly, any place specification for the /s/ in this phonological context is redundant. I actually claim that there is only one place specification for each syllable component, i. e., onset or coda.[5]

2. S-fix

Another separate but somewhat related characteristic of my analysis in connection with underspecification of syllable features is the issue of separating s-fixes from the syllable core, which comprise what I call onset and coda along with the syllable nucleus. In my 1976 paper, I proposed that s-fixes (syllable suffixes) be treated separately from other components that form the syllable core. All s-fixes in phonetic manifestation satisfy the following criteria in the current terminology of the C/D model (as in Fujimura in press):

(1) The consonant must be implemented as an oral obstruent gesture.
(2) The crucial articulator must be the tongue tip.
(3) The phonetic voicing status (see Fujimura 1996) must agree with that of the tautosyllabic coda.

These conditions imply that the phonological specification for an s-fix in English is only for the distinction among possible manner features: {stop}, {fricative}, or {interdental}.

More than one s-fix can be attached to the core of the syllable with explicit specification of the sequential ordering by counting (generally for s-fix or p-fix, the latter preceding the onset although there are no p-fixes in English) from inside out with designated numeric index attached to S or P, as needed. After separating s-fixes, English obstruent clusters are substantially simplified, and in fact I claim that there is only one place specification in onset or coda (and no place specification for s-fixes) as mentioned above. S-fixes or p-fixes are assumed to occur, presumably universally, only at the edge of a phonological word.

According to this analysis, a form like 'ax' in the phonemoidal transcription, which can be considered an abbreviatory alphabetic transcription for the phonological feature specification based on the demisyllabic analysis (see Fujimura & Erickson 1997), is /ak.s/ with the /s/ treated as an s-fix (separated by a dot), as opposed to /ask/ which treats the /sk/-cluster within the core: the feature specifications for these syllables are, respectively, {dorsal^C, low, fricative^S} and {dorsal^C, spirantized^C, low}.[6] We thus maintain that the manifestation of the feature {spirantized} whether in onset or coda is always a temporal sequence (roughly) of apical frication + oral stop.

3. Some remarks on other languages

Is this seemingly ad hoc treatment of the consonant clusters justifiable in view of other languages? I am aware of apparent counterexamples. Providing my arguments about such cases may evoke some motivation for clarifying other situations, whether for or against my analysis.

Before we discuss different languages, however, let me mention one important property of the C/D model. I claim that any serious account of phonetic phenomena must accept that phonetics is different for different languages. I believe that there is a universal framework for describing any language in the world and the variation we observe can be described as differences in parameter setting for the linguistic systems, in the domain of phonetics as in other areas of linguistics. Within the phonetic implementation process, therefore, I need to allow the system properties to vary substantively from language to language. This claim must be obviously true in some sense, but how it is true, i.e., what are the parameters, is the question. In order to address this question, however, it is necessary to assume some framework of phonological representation, in particular in this case, lexical representation based on phonological opposition. The specific scheme of such phonological representations does not matter for our discussion, but the factual pattern of functional oppositions must be examined, also considering the morphological properties of the particular language. Lexical correspondence among related languages, of course, provides us with useful clues, and in fact the necessary justification, for comparing phonetic properties of individual languages.

In the informal meeting I mentioned above, I think Eli mentioned immediately that German has a different implementation of the corresponding cluster. In stressed syllable, as is well recognized, German uses a more retracted place of articulation for the corresponding cluster as [ʃp, ʃt], as in 'Spiegel' and 'Stein', while [ʃk] seems to be absent. We may assume that the same feature specification {spirantized} applies to German as well as to English, but that the articulatory realization is more retracted as the inherent phonetic gesture of the preceding frication, just as in some languages the same feature {apical} is articulated as a dental obstruent and in others as alveolar. The identification of the tongue tip as the articulatory device by calling it apical as opposed to labial, coronal[7] and dorsal (without referring to the detailed manner of articulation such as apical vs. laminal unless it is necessary to account for the phonological opposition in the language) is more robust than that of the place of vocal tract constriction, since the former is discrete due to the nature of anatomy unlike the latter, which is continuously variable as the result of more complex combinatory patterns of the muscle actions. English has the obstruent manner feature {interdental} which implies the tongue tip as the articulator, while German does not use this feature specification.

A related remark may be made with respect to the so-called manner of articulation as opposed to place. In Spanish, voiced bilabial stops are often produced as voiced labial fricatives, depending on the preceding syllable, if any. Spanish has no phonological contrast for the voiced labial obstruent, which can be specified as {labial, voice} without any manner feature specification. The phonological category is {obstruent}, but this feature value is implied by the specification of {labial}. In other words, the phonetic bilabial stop, bilabial fricative, and labiodental fricative are not distinguished from each other phonologically when they are lax/voiced, while the bilabial stop {labial, stop} and the labiodental fricative {labial, fricative} are opposed to each other when the concomitant {voice} is not specified, leaving the consonants tense and in their full forms.

The manner {spirantized} in English and German, as well as other Germanic languages like Swedish and Dutch, is commonly used quite extensively in their lexicons. There are differences, of course, in their usage patterns. As mentioned above, all {apical, labial, dorsal}, but not {coronal}, as place features can be combined with {spirantized} in English, both in onset and coda and also as an s-fix (as in 'text', /tɛk.st/). In German, {dorsal} cannot be combined with {spirantized} in any syllable component. In Swedish, related to the adjectivization morphemic suffix /sk/, this cluster seems to be used as an s-fix, thus necessitating a phonological specification of place in the s-fix (unless there is some special morphemic treatment like the /t/ in 'dreamt' in English mentioned above). This does not mean that in Swedish the morphemic word-final /sk/ is always phonologically an s-fix. An s-fix is, like onset and coda, a purely phonological/phonetic concept and is independent from the morphology of the language, even though, statistically in the lexicon, there is a high correlation between the two factors. In English, the s-fixes /st/, /s/, /z/, /t/, and /d/ in words like 'text', 'tax', 'lens', 'act', and 'tend', respectively, are all not morphemic.

There seems to be abundant usage of the feature {spirantized} and quite interesting patterns about its distribution in Iberian Romance languages, but I do not have sufficient knowledge to be able to discuss the issue here. I have some comment on Modern Greek spirantization, however. In Greek onset, there is a contrast between /sp, sk/ with /ps, ks/, as seen in examples like 'σπαθα' [spáθa] (sword): 'ψαθα' [psáθa] (straw mat) and 'σκηνη' [skiní] (tent): 'ξυνη' [ksiní] (sour-fem.). Do these example, then, indicate the necessity of place specification in

Greek onsets more than once? A critical consequence would be that, if place has to be specified twice in the same syllable component, then the sequential ordering of features must be specified. If place is specified only once for each syllable component, then, as explained below, all temporal organization including the phonemic sequential ordering is a matter of automatic computation that belongs to phonetics rather than phonology. The description of phonology of the given language would be dramatically simplified. If obstruents are treated without specifying occurrence order information, then the sonority contour principle (see Clements 1990) seems to handle the temporal ordering within a syllable much more completely. There may be some exceptions to this principle, but a general trend, considering historical change which again is outside my linguistic competence, seems to favor this simplified description as a basic structure of language.[8]

4. Temporal organization

As discussed above, the minimal opposition in Greek onset between /sp/ and /ps/, for example, does not imply an order specification of obstruent features if we consider the domain of contrast to be a syllable (or a larger phonological unit) rather than a phonemic segment context free. The opposition can be accounted for if we assume two opposing manner features {spirantized} and {prespirantized}, along with the usual {stop}, {fricative}, and {nasal}. This situation is exactly the same for the English /sp, st, sk/ to be treated by the manner feature {spirantized}, forming a paradigm of, for example, /k, sk, g/ for dorsal obstruents in onset, except that English, like most other languages, does not use the feature {prespirantized}. In English, this paradigm can be represented by contrasting feature specifications for the onset clusters as a whole, namely by specifying the pertinent manner feature {stop}, {spirantized}, {stop, voice}, or {nasal}, all in combination with the shared place feature {dorsal}. By contrast, in the conventional phonemic analysis in terms of feature values, the /sk/ cluster would be specified as an ordered sequence of feature bundles {apical, fricative, voiceless} + {dorsal, stop, voiceless}. This representation misses the generalization that our representation method captures because, when this phoneme sequence occurs in syllable initial position, this specification of the set of six features (or any equivalent set of distinctive feature values) is mostly superfluous. In addition, the feature {voiceless} or {-voiced} is not manifested by any inherent phonetic gesture. All these points are captured precisely and sufficiently if we specify a single privative manner feature {spirantized}. To emphasize, in English, there could not be an opposition between /sk/ and /fk/ or /sk/ and /sg/, which would be predicted by sequencing independent phonemes /s/, /f/, /k/, and /g/.

For either {spirantized} or {prespirantized}, the concomitant place specification determines the articulator not for the frication generation but for the stop closure. The relative timing of the two gestures, frication and stop closure, differs between the two manner features. This temporal difference is, in the C/D model, described quantitatively by specifying different local time functions for elemental gestures, called IRFs for impulse response functions, that are inherently associated with the manner features.

This treatment may sound odd and excessively ad hoc. However, I would like to point out that the common concept (since the proposal of the basic concept of distinctive features as the minimal units of phonological description by Jakobson, Fant, and Halle 1951, 1952, 1963) that a phoneme is a simultaneous bundle of features, is clearly counterfactual. This issue has been discussed rather extensively in the phonetic literature (see Fujimura & Lovins 1978, Fujimura 1981a, 1981b, Browman & Goldstein 1986, 1992, Krakow 1999). For example, the bilabial nasal /m/ has two main inherent gestures, bilabial closure and velum opening, manifesting the distinctive feature specifications underlying a bilabial oral stop gesture ({labial} and {stop}, in effect) and the velum lowering gesture ({nasal}, in effect).[9] But these two gestures do not occur simultaneously. In coda, as opposed to onset, the two gestures are considerably asynchronized, the velum lowering, as observed in American English and Japanese, at least, showing its maximum effect typically near the center of the vowel portion of the syllable rather than toward its end during the oral closure. The relative timing between the peaks of the two gestures differs between the onset /m/ and coda /m/ significantly and consistently (see Krakow

1999). Furthermore, this timing relation is systematically designed: the velum lowering gesture, which is inherently more »vocalic« in the sense that it does not attempt an obstruction of the vocal tract, occurs more toward the temporal »center« of the syllable than the stop closure which is more »consonantal«. The syllabic gestures in onset and coda are implemented according to a general syllable organization principle rather than as inherent gestures that belong to autonomous phonemic segments (see Sproat & Fujimura 1993 for discussion).

Qualitatively similarly to this situation in nasal consonants, the timing discrepancy of the two gestures, the dorsal stop closure and apical frication in either /sk/ or /ks/ in onset, is a matter of choice of the language in designing the IRFs of these manner features, {spirantized} or {prespirantized}. Unlike the »single segment« gesture set as in nasal stops, however, these complex manner features have meaningfully fixed temporal order of gesture occurrences as their inherent properties of phonetic implementation. The gesture implementation process is still prescribed within the phonetic system, as specified by their IRFs, whether it is for a traditional (single-segment) type or complex-gesture type.

The more common usage of the {spirantized} feature than the {prespirantized} feature in the world's languages may be explicable in terms of anatomy and physiology, but I do not have this explanation ready.[10] We should also compare these observations of relative timing to the seemingly ad hoc choice of one group of languages to aspirate voiceless stops and the other not to aspirate them, when there is no phonological contrast between aspirated vs. unaspirated. In this case, the timing relation refers to the oral closure release and the laryngeal adduction.

5. Final remarks and acknowledgment

I have argued that we should treat the obstruent clusters /sp, st, sk/ in both onset and coda of English syllables (and similarly /sm, sn/ in onset) as phonologically coherent elements by a manner feature {spirantized}. An appropriate phonetic implementation process, somewhat more complex than traditionally conceived, must be assumed to allow this treatment. I have discussed one explicit formulation of a generative process using the concept of impulse response functions in the C/D model. The complexity of phonetics along with its parametric dependence on the particular language (in this case the parameter values involved in designing specific impulse response functions for elemental gestures) is necessary, regardless of the adoption of the feature {spirantized}, as many recent studies of articulatory movement patterns have demonstrated. With this or another alternative new concept of phonetic implementation, I hope different languages will be studied and compared systematically with each other, considering their quantitative characteristics as Eli Fischer-Jørgensen pioneered, exploiting all means of experimentation available at the time with everlasting diligence and deep insight into the phonological and phonetic patterning of language (Fischer-Jørgensen 1963, 1975).

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Notes

1. The syllable affixes are called p-fixes and s-fixes in later terminology, which is due to Cari Spring (personal communication).
2. For obstruents, we use the feature specification {voice} when applicable, but no specification when voiceless (see Fujimura 1996, Fujimura & Williams 1999, in press). We use privative features for syllable margins, and features are underspecified (see below).
3. I call them clusters referring to the concomitant (i.e., coexisting in the same syllable component, onset, coda, or s-fix) set of gestures, not phonemic segments.

[4] In this paper I use the phonemoidal transcription as discussed in Fujimura & Erickson (1997). The diphthong [eɪ] in English is represented by /ej/, the palatal glide as a phonological consonantal element being implemented phonetically as a weak vowel.

[5] There are a very limited set of exceptions in English involving apical morphemic suffixes, such as 'dreamt' and 'warmth' (I owe this observation to Briony Williams, personal communication). In these cases, apparently, the morphemic suffix has a special status (see Haraguchi 1999). The feature {interdental} is a manner feature, not place (see Fujimura 1996) and therefore 'warmth' is not an exception, the syllable being entirely within the syllable core with only one place specification {labial}.

[6] The feature {low} specifies the vowel [æ]. With the lack of coda glide element specified, it implies a lax vowel. The tense vowel as in 'ox' [ɑks] in American English is represented with an elongation glide /H/ as (phonological) coda, i.e., /aHk.s/ in the phonemoidal transcription.

[7] My analysis of English palatoalveolar obstruents /tʃ, dʒ is {coronal, stop} with {voice} for the latter. This term »coronal« is used differently from most phonological literature. The affricative nature in English and other languages is explained by physico-physiological characteristics of the place of articulation, but German has a manner feature {affricate} combined with {labial} as well as {apical}, but not {coronal}.

[8] Remaining counterexamples may be accounted for by the optimality theoretical treatment deviating from the generative framework as adopted for the C/D model. The feature specification scheme, as discussed here, would still serve as the representational framework in the OT account (McCarthy & Prince 1995).

[9] The original distinctive feature system uses binary oppositions for place as well as manner specifications throughout the segmental paradigm.

[10] It may be of interest to note that {spirantized} prescribes a deviation from the generally observed sonority contour principle in onset, which is by far a more common site for an obstruent gesture than coda in the world's languages.

The behavior of the larynx in speech production

Hajime Hirose

The larynx is generally regarded as the organ of voice. Phylogenetically, however, the larynx has developed as an organ which protects the airway, preventing foreign substances from entering the lungs. In all mammals, including humans, this major function of the larynx is still well maintained and very important.

The primary larynx appeared in lung fish, which still live in Africa and South America. In the lung fish, the primary lung is separated from the food passage with a connecting tube corresponding to the trachea. Around the tube, a sphincter muscle developed in order to prevent water or food leakage from the foodway into the airway. This is the origin of the larynx.

During the course of evolution, a sphincter around the orifice of the trachea developed and, in higher animals, the glottis opening muscle and cartilagenous framework of the larynx appeared. Thus, the airway protection mechanism became more subtle and the glottis could open when necessary (Negus 1962).

The shape of the vocal tract has also changed in the course of the evolution from lower animals to humans, in that the position of the larynx in the neck descended, and the vocal tract bent almost 90 degrees. As a result, the pharyngeal cavity was enlarged and the tongue became more freely movable.

In humans a similar change in the shape of the vocal tract is noted in the course of growth after birth. The larynx of the new-born is at relatively high position in the neck, but it descends gradually with age. Thus, the pharyngeal cavity of the adult is much larger than that of the new-born.

The human larynx is situated at the anterior portion of the neck and hangs below the hyoid bone by several kinds of anterior neck muscles and ligaments.

The anterior neck muscles are strap muscles, and support the laryngeal framework. There still is a question concerning the function of the strap muscles in human speech production, and this topic will be discussed again later.

The larynx is at the entrance of the airway to the lungs, and the false and true vocal folds slightly protrude into the laryngeal cavity from the lateral wall. The protrusion of the vocal folds is clearly seen in the frontal plane, and the vocal fold has a certain thickness and consists of the muscle and the covering mucosa.

In certain animals, the use of voice for communication seems to have developed together with the structural development of part of the vocal fold. In humans, in particular, the so-called layered structure of the vocal fold consists of the two separable layers of the cover and the body, as proposed by Hirano (1974). Histologically, the vocal fold consists of the epithelium covering the external surface, the lamina propria mucosa underneath the epithelium, and the vocalis muscle in the deeper part of the fold representing the body. The superficial part of the lamina propria is so loose that the epithelial or cover layer can shift freely over the mass of the vocalis muscle. As a result, the cover portion of the vocal fold can easily vibrate in a wave-like fashion when the air stream comes up from the trachea and the physical condition at the glottis is appropriate.

In the production of human speech, the role of the larynx is quite essential. In order to understand the contribution of the larynx to human speech production, it is appropriate to propose several laryngeal features in physiological terms. They are, for example, the abduction vs.

adduction of the vocal folds, stretch vs. relaxation along the anterior-posterior direction of the vocal fold, the raising vs. lowering of the entire larynx, and the constriction vs. relaxation of the supraglottal portion. For the precise analysis of these features, different experimental approaches are necessary (Hirose 1997)

During the past 25 years, marked developments have been achieved in the field of experimental phonetics in physiological terms. They include: the developments in fiberoptic viewing of the laryngeal configuration, in laryngeal electromyography, in different types of glottographic techniques, in the use of miniature pressure transducers, and developments in computer data processing and image processing.

In this paper, some of the laryngeal behavior in speech production is discussed with special reference to the experimental results related to the laryngeal articulatory adjustments, which were obtained using different types of recently developed experimental techniques.

The feature of abduction vs. adduction of the vocal fold is closely related to the voiced-voiceless distinction of speech sounds and the degree of aspiration.

The abduction and adduction of the vocal folds are based on the movements at the cricoarytenoid joint and are precisely controlled by the abductor and adductor muscles of the larynx.

Early in the 1970's, based on electromyographic (EMG) and fiberoptic studies, it was pointed out that for different types of spoken languages the reciprocal activities between the abductor and adductor laryngeal muscles control the size of the glottis and the timing of the glottal movements relative to the oral gestures. In those studies, the time course of the glottal size was measured by means of a fiberoptic film analysis, and the result was compared with the EMG patterns of the laryngeal muscles. Figure 1 shows a typical example of the relationship between the glottal size and the pattern of the computer processed laryngeal EMG activity for the production of the Japanese test word /iseh/.

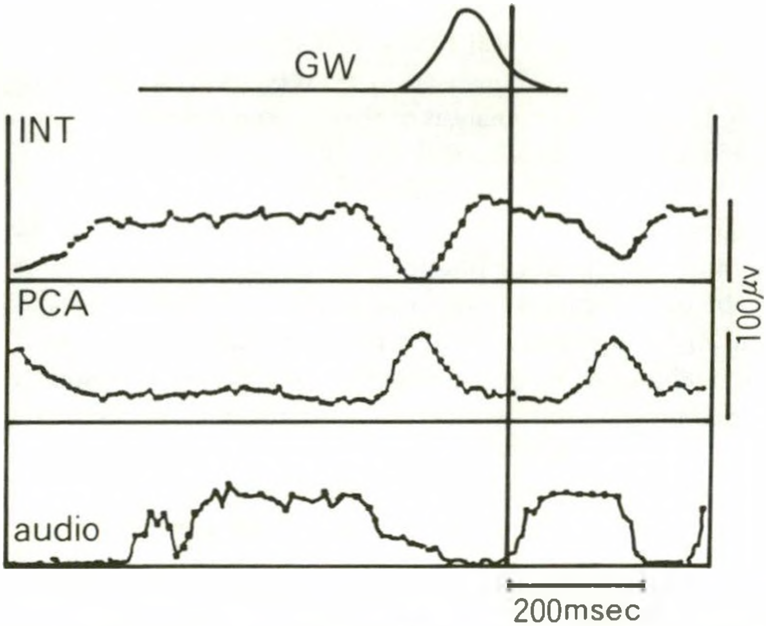

Figure 1. Time curves of the glottal width (GW), the smoothed and integrated EMG curves of the INT and PCA, and the speech envelope (audio) for the Japanese test word /iseh/ produced by a Japanese subject. The curves are aligned on the same time axis. The vertical line indicates the voice onset for the vowel /e/.

The glottal width (GW) increases for the voiceless consonant /s/, for which posterior cricoarytenoid (PCA) muscle activity increases and interarytenoid (INT) activity is reciprocally suppressed. This type of clear reciprocal pattern between the PCA and INT is generally observed in many spoken languages, although the pattern does not necessarily show a complete mirror image as shown in this figure.

Such a reciprocal activity was also observed in the case of aspirated vs. unaspirated segments. Figure 2 shows computer averaged EMG patterns for the Danish test sentences /han sa: panə/ and /han sa: banə/ comparing aspirated /p/ and unaspirated /b/, both of which are voiceless at the word initial position. It is apparent that the INT suppression and PCA activation are much more marked and more long-lasting for aspirated /p/ than for /b/.

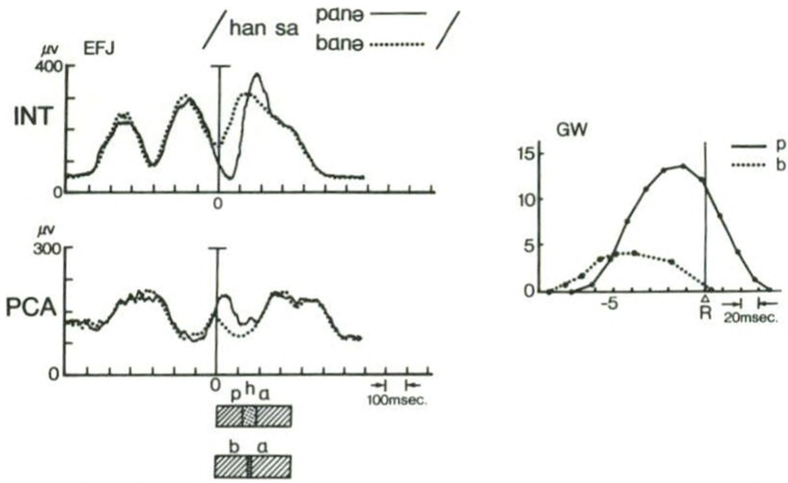

Figure 2. Left: Time curves of computer averaged EMG curves of the INT and PCA for the Danish test sentences produced by a Danish subject. Zero on the abscissa indicates the implosion of bilabial stops. Right: Time curves of the glottal width observed using a fiberscope for the same pair of the labial stops in the same subject. The vertical bar on the abscissa indicates the release of bilabial stops.

A fiberoptic analysis indicated that the glottal width is much larger at the time of the oral release for /p/, while it almost closes for unaspirated /b/ at the oral release (Fischer-Jørgensen and Hirose 1974a).

In animals, PCA is known to be activated solely for glottal opening during inspiration. In this sense, PCA can be regarded as an inspiratory muscle. On the other hand, only in humans, PCA is activated during the expiratory phase of speech to open the glottis, allowing the outflow of the air stream from the lungs. This adjustment is characteristic of human speech production.

In addition to the above mentioned two muscles, the other adductors are often involved in glottal closing gestures to some extent. As shown in Figure 3 in which the voiced-voiceless contrast in Swedish is compared, the vocalis (VOC) and lateral cricoarytenoid (LCA) muscles are both more suppressed for voiceless sounds at least in the prestressed position. Also, it can be noted that the cricothyroid (CT) muscle, which is primarily a tensor of the vocal fold, appears to participate in the realization of voicelessness in that CT is more active for voiceless consonant production. It is thus assumed that CT may contribute to stretching the vocal fold to suppress the vocal fold vibration in some cases (Hirose,Yoshioka and Niimi 1979).

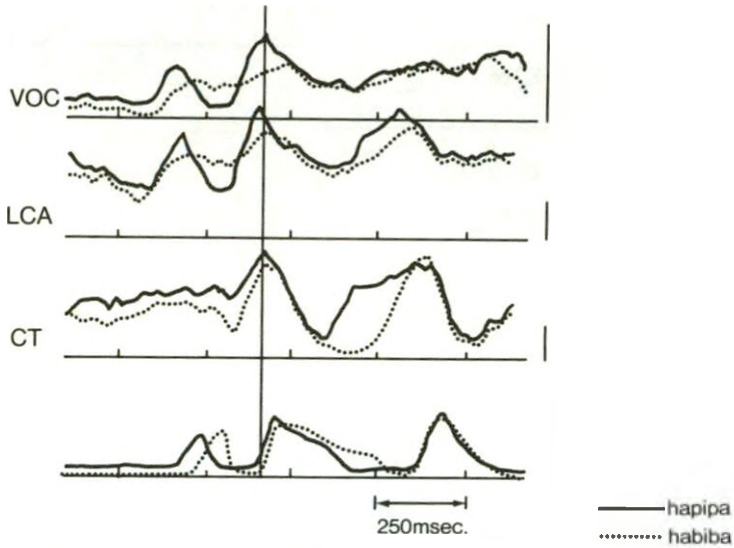

Figure 3.Time curves of computer averaged EMG curves ofVOC, LCA and CT for the Swedish test words produced by a Swedish subject.The vertical line on the abscissa indicates the voice onset of /i/. Each calibration bar indicates 100 μV.

There are certain cases where another physiological dimension must be taken into consideration. Figure 4 shows an example of the averaged EMG curves ofVOC and INT for three types of Korean labial stops of theTaegu dialect in word initial position. For all types an opening gesture for the glottis was proved by fiberoptic observation. It can be seen for type I, or the forced stop (p'), which is illustrated at the bottom of the figure, that there is a sharp increase inVOC activity immediately before the oral release.This apparentVOC activity presumably results in an increase in the inner tension of the vocal fold and can be taken as a physiological correlate of so-called laryngealization of Korean (Hirose and Ushijima 1974).

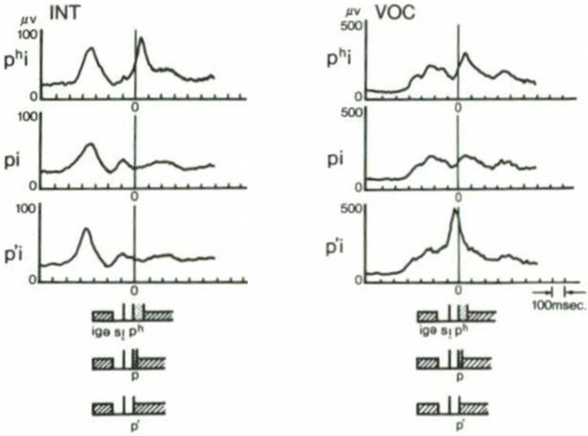

Figure 4. Averaged EMG curves of INT and VOC for the three bilabial stops of Korean in word-initial position. The test sentences were uttered by a Korean subject of Taegu dialect. The postconsonantal vowel is /i/ for all cases. Timing of speech events are given below the graphs; striped areas represent voiced segments, open areas represent voiceless segments, and dotted areas represent the period of aspiration.

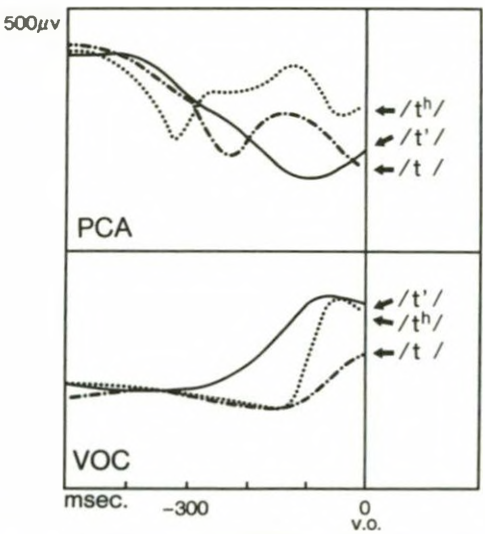

Figure 5. Averaged EMG curves of VOC and PCA for the three dental stops of Korean uttered by a Korean subject of Seoul dialect. Zero on the abscissa indicates the voice onset after dental stops.

In another Korean subject of the Seoul dialect, both PCA and VOC activities were examined for the three types of Korean dental stops. As for VOC, an early and marked activation is observed for the forced type (t') in this case too, while PCA activation is earliest and highest for the aspirated type as shown in Figure 5.

A similar type of VOC activation is also seen in the case of Danish stød production. As shown in Figure 6, the stød vs. non-stød opposition was compared for meaningful Danish words. For the stød group, a sharp increase in VOC activity was always observed (Fischer-Jørgensen and Hirose 1974b).

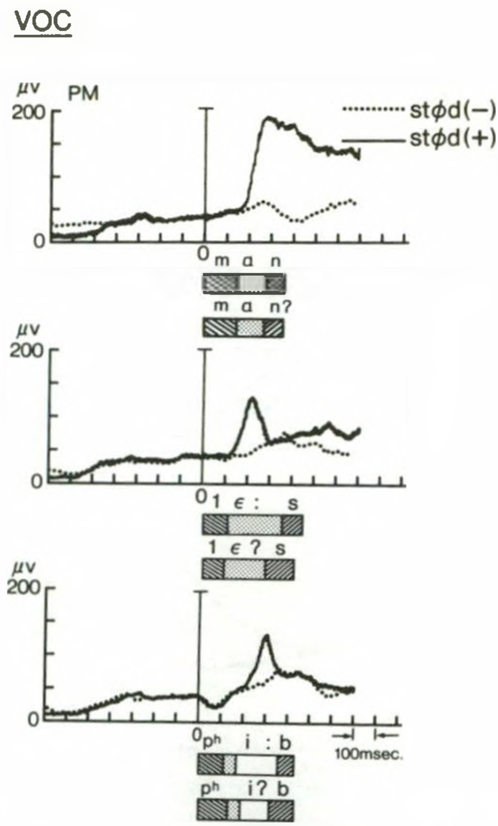

Figure 6. Averaged EMG curves of VOC for the pairs of Danish words with and without stød produced by a Danish subject.

Although the nature of the increasing VOC activity still seems to be open for further discussion, it was assumed that an additional dimension independent of simple abduction vs. adduction of the vocal folds will be necessary.

Although the significance of the adjustment of the vocal fold separation by muscular activity has so far been stressed, it should be realized that the adjustment of vocal fold separation is only one parameter which determines whether or not the vocal folds will vibrate during a consonantal period. In other words, there must be an adequate transglottal air flow for generating vocal fold vibration, and its amount should depend on both the subglottal pressure and on the configuration of the supraglottal articulators. Furthermore, the physical properties of the vocal folds, particularly the stiffness, are important factors that relate to the initiation and cessation, as well as the mode, of vocal fold vibration.

In order to clarify the relationship between transglottal pressure difference and the glottal configuration during the production of voiceless consonants, a physiological experiment was performed in which the sub- and supraglottal pressure values were measured by means of pressure transducer systems, and the size of the glottis was estimated using photoglottography.

Figure 7 shows a block diagram of the data recording and processing system. A miniature pressure transducer was inserted through the nasal cavity into the subglottal space. The intraoral pressure was measured by another transducer system. The glottal width was estimated through photo-sensor output illuminated by a fiberoptic light from the inside of the larynx.

The data were obtained at the offset of the vocal fold vibration at the oral closure, at the onset of the vibration after the oral release, and during the maximum glottal opening. The transglottal pressure (P) was calculated by subtracting the subglottal pressure value from supraglottal pressure value.

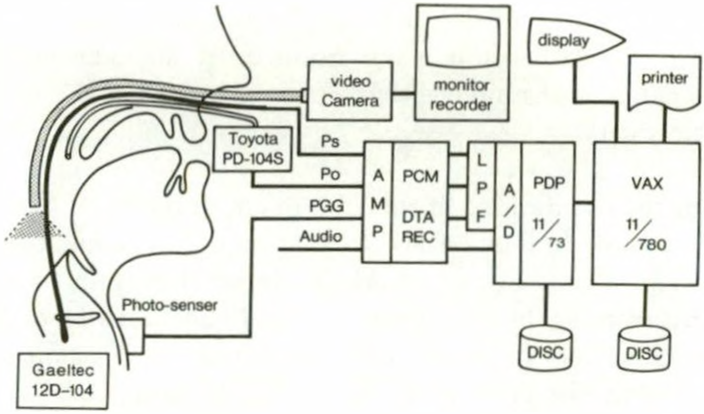

Figure 7. A block diagram of the data recording and processing system for investigating the relationship between glottal opening and the transglottal pressure difference during consonant production.

Figure 8 shows the relationship between the ratio of the transglottal pressure to the subglottal pressure (ΔP/Ps) and the relative size of the glottal width (GW) for word-initial /s/ and word-initial /t/. In this figure, the 90% range of the distribution is circled for each of the following sets of data: namely, the voice offsets for /s/ and /t/, and the voice onsets after /s/ and /t/.

It can be seen here that both /s/ and /t/ demonstrate a difference in the physiological conditions for the cessation and initiation of voicing related to obstruent production. Namely, in both cases, voicing following the consonantal closure period occurred with a relatively small glottis and a higher ΔP/Ps ratio compared to those values with which voicing stopped around the implosion of the consonant.

It can also be seen that there is a subtle difference in the pattern of the distribution of data between the fricative /s/ and stop /t/ in terms of the laryngeal conditions for the voice offset. In the case of /s/, the vocal fold vibration stops with a relatively wider glottis than for /t/, whereas the ΔP/Ps ratio is comparable. On the other hand, there is no apparent difference between /s/ and /t/ distribution for the initiation of vocal fold vibration.

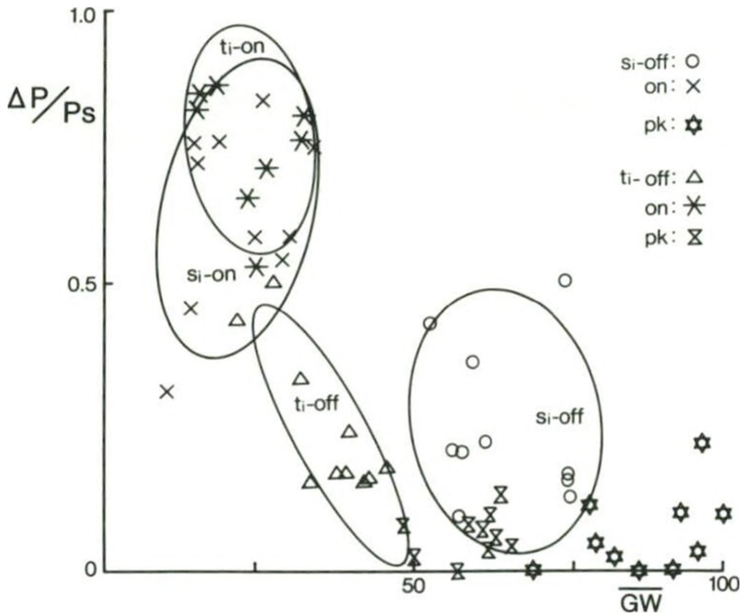

Figure 8. Patterns of data distribution for word-initial /s/ and /t/ representing the relationship between transglottal pressure (ΔP) vs. subglottal pressure (Ps) ratio and relative glottal width (GW: The largest glottal opening during the consonantal period of /s/ was taken as 100%, and relative glottal width was calculated as a percentage of that value for each token). In the figure, the 90% range of distribution is circled for each of the following data sets: voice offset for /s/ and /t/ (si-off and ti-off) and voice onset after /s/ and /t/ (si-on and ti-on), respectively. The symbol 'PK' indicates the coordinates for values at the time of maximum glottal opening for each token.

Thus, it appears that there is a hysteresis in the glottal mechanism defined by the initiation and cessation of oscillation. That is, vocal fold vibration tends to be maintained at the implosion of obstruents with relatively favorable physiological conditions for oscillation, while vibration does not start after the voiceless period until more favorable conditions are obtained by a narrowing of the glottis, associated with an elevation of the transglottal pressure difference, although the reason why the vocal folds continue to vibrate with a wider glottis for /s/ than for /t/ is still unclear (Hirose and Niimi 1987). There may be a possibility that it is due to greater volume velocity associated with lesser oral obstruction.

As for the other dimensions of laryngeal adjustment during speech production, the significance of stretch vs. relaxation along the anterior-posterior direction of the vocal folds should be stressed, especially for the control of the fundamental frequency of the voice. It is well known that this dimension is controlled by apparent reciprocal activity between CT and the strap muscles, the sternohyoid (SH) in particular.

As for the raising vs. lowering of the entire larynx, the role of the strap muscles is also very important. Figure 9 shows an example of averaged EMG activities of SH and the orbicularis oris (OO) for Sindhi test words produced by a native Sindhi speaker, in which explosive vs. implosive labial consonants are compared. For the production of the implosive sound in the second syllable, the entire larynx descends quickly, and it can be observed in this figure that there is a sharp increase in SH activity corresponding to the larynx lowering (dotted line), while the pattern of OO activity appears to be similar for both consonant types.

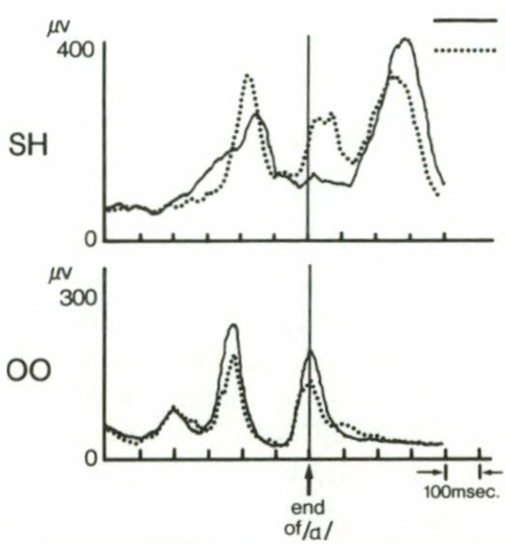

Figure 9. Averaged EMG curves of SH and OO for a pair of test words contrasting explosive and implosive bilabial stops produced by a native Sindhi speaker. There is no apparent difference in the pattern of OO activity, whereas SH shows a peak at the release of the implosive stop.

As so far described, the larynx is one of the important organs of articulation in human speech production. Although the mechanism of laryngeal control has been remarkably explored in recent years, there are still many questions which remain unsolved. It is hoped that future research will shed further light on the role of the larynx in human speech production.

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Plosive-related glottalization phenomena in read and spontaneous speech. A stød in German?

Klaus J. Kohler

1. Introduction

1.1 Definitions and linguistic functions of glottalization phenomena

In this paper, GLOTTALIZATION PHENOMENA are to comprise the glottal stop and any deviation from canonical modal voice, i.e.

- glottal stop or low frequency irregular glottal pulsing (variable in frequency, amplitude and waveform) = GLOTTALIZATION (see Figure 1)
- BREATHINESS (see Figure 2)
- BREATHY VOICE (see Figure 3)

These glottalization phenomena fulfil a number of different linguistic functions in the languages of the world:

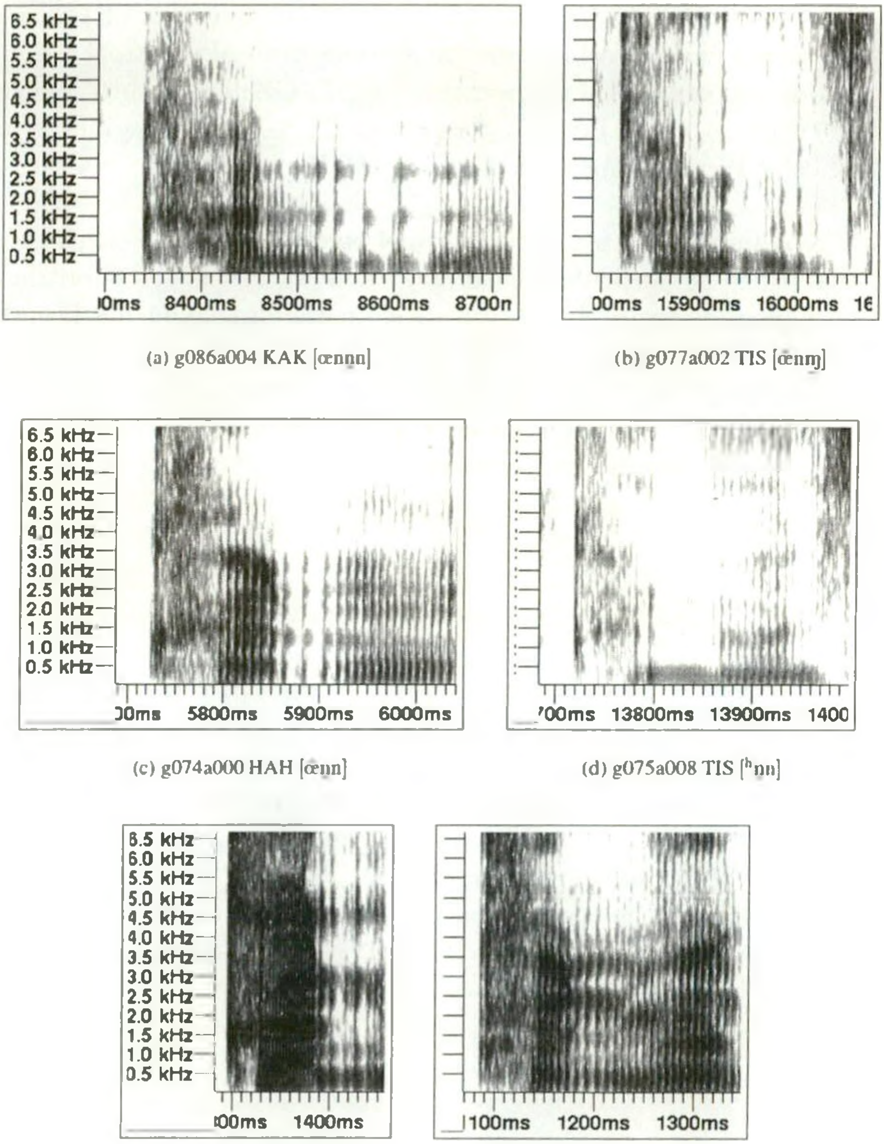
(a) VOWEL-RELATED GLOTTALIZATION PHENOMENA signal the boundaries of words or morphemes beginning with vowels, typically in German, but also in other languages, e.g. English or French. The occurrence and phonetic manifestation of this function is also controlled by prosodic features, such as sentence accentuation, resulting in specific glottalization patterns for different languages (see Rodgers 1999 for German, and Dilley and Shattuck-Hufnagel 1995 for English). The variation between glottal stop and any other glottalization phenomenon observed for this boundary signalling occurs along a scale of phonatory strength, associated with, e.g., degrees of sentence stress (cf. the link with ACCENT D'INSISTANCE in French).

(b) PLOSIVE-RELATED GLOTTALIZATION PHENOMENA occur as reinforcement of plosives by a glottal stop or as replacement of plosives along a scale of phonatory weakening from glottal stop to any other glottalization phenomenon, e.g. in German (Kohler 1995a, 1996a, b) or in English (Grice and Barry 1991; Higginbottom 1964; Pierrehumbert and Frisch 1994; Roach 1979).

(c) SYLLABLE-RELATED GLOTTALIZATION PHENOMENA occur as characteristics of particular syllable types along a scale of phonatory weakening from glottal stop to glottalization, e.g. in the Danish stød (Fischer-Jørgensen 1989a, b). The TENSE VS. LAX LARYNX SYNDROME set up for south-east Asian languages by Matisoff (1973) also relates to whole syllables, combining glottalization phenomena with prosodic and segmental features in phonological opposition.

(d) THE PARALINGUISTIC FUNCTION OF GLOTTALIZATION PHENOMENA manifests itself at the utterance level in two ways:

- as LARYNGEALIZATION in prosodic phrase-final RELAXATION of phonation, where the vocal folds prepare for abduction and where glottalization, therefore, alternates with breathiness and breathy voice, but not with a glottal stop (see Figure 4(b));
- as TRUNCATION GLOTTALIZATION in prosodic phrase-medial TENSING of phonation at utterance breaks, where the vocal folds are adducted and where glottalization, therefore, alternates with a glottal stop (Nakatani and Hirschberg 1994; Local and Kelly 1986; see also Figures 4(a) and 5).



(a) g086a004 KAK [œnnn]

(b) g077a002 TIS [œnŋ]

(c) g074a000 HAH [œnn]

(d) g075a008 TIS [ʰnn]

(e) g091a014 FRS [œnn]

(f) g072a014 HAH [œn]

Figure 1. Different manifestations of glottalization in *könnten* from the Kiel Corpus of Spontaneous Speech, 1 female (FRS) and 3 male speakers.

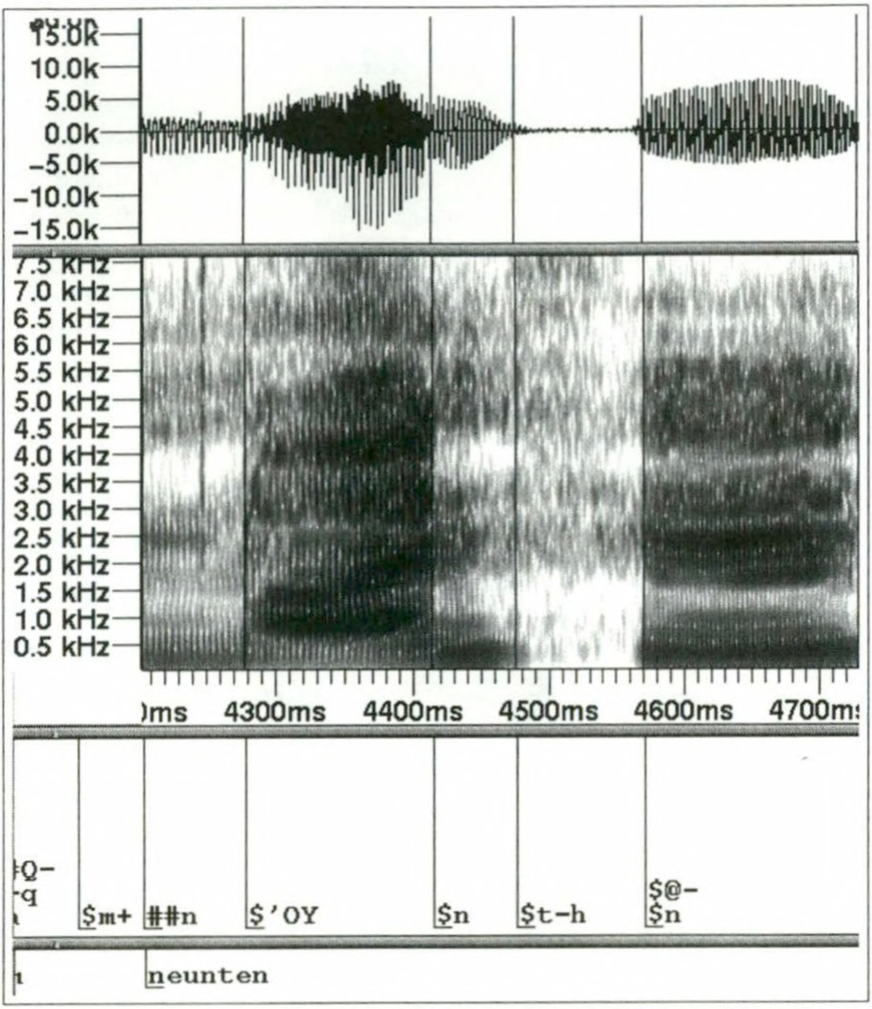


Figure 2. Breathiness in *neunten*. Kiel Corpus of Spontaneous Speech, g106a014 NAR, female speaker; speech wave, spectrogram and SAMPA labels.

The question now arises as to whether these glottalization phenomena, which are controlled independently for these four linguistic functions but may nevertheless occur in the same utterances, are kept separated in speech production as sequential or superimposed events and whether they can then also be distinguished in speech perception. Figure 6 (top) shows an instance of clearly distinct sequential vocal tract resonances for plosive and vowel-related glottalizations in the German sentence *wir könnten ihn fragen* 'we could ask him'. This contrasts with the presence of only vowel-related glottalization in *wir können ihn fragen* 'we can ask him' of Figure 6 (bottom). Similarly, in Figure 7 the manifestations of plosive and vowel-related glottalization are separated temporally in *achtzehnten elften* '18th November': the glottalization for [ntn] is shifted left into the preceding vowel, and the glottalization for the vowel [ɛ] occurs well inside it, thus ensuring a clear separation between the two. This temporal indeterminacy of glottalization will be discussed in 2.1. Finally, Figure 8 shows the sequencing of plosive and vowel-related glottalization as well as phrase-final laryngealization; the former, although contiguous in time, are also distinguished spectrally and are auditorily attributable to two different functions.

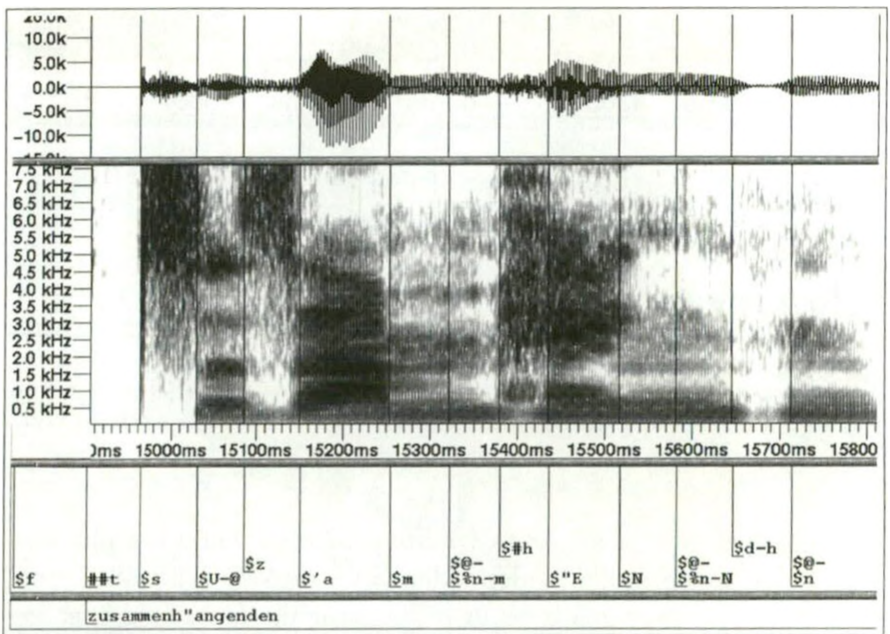


Figure 3. Breathy voice in *-hängenden*, Kiel Corpus of Spontaneous Speech, g105a009 NAR, female speaker; speech wave, spectrogram and SAMPA labels.

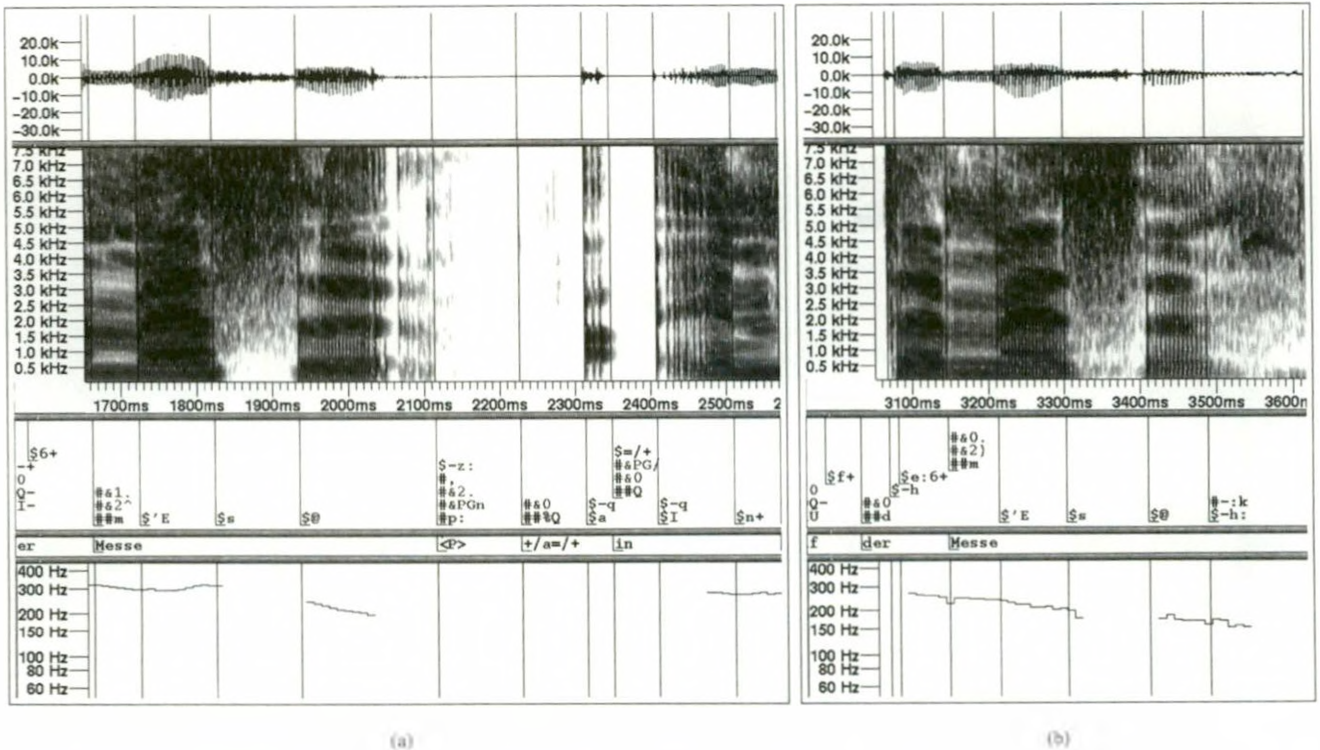


Figure 4. Truncation glottalization and final breathiness. Figure 4(a) shows truncation glottalization in *(in einer) Messe/+ a=/+ in (Hannover auf der Messe)*, Kiel Corpus of Spontaneous Speech, g274a008 SIH, female speaker; speech wave, spectrogram, SAMPA labels, and fundamental frequency. Figure 4(b) shows final breathiness in 2nd occurrence of *Messe* in utterance of Figure 4(a).

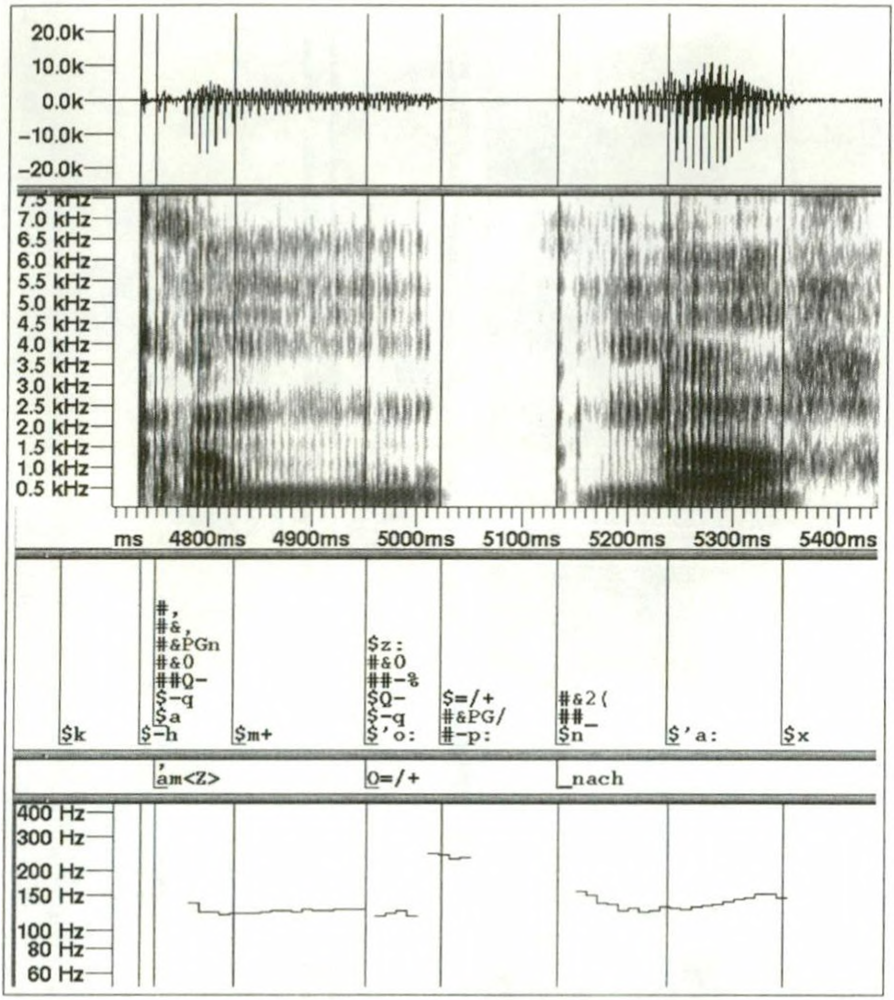


Figure 5. Truncation glottalization in *am O=/+ nach (Ostermontag)*, Kiel Corpus of Sponta-neous Speech, g315a009 SVA, male speaker; speech wave, spectrogram, SAMPA labels, and fundamental frequency.

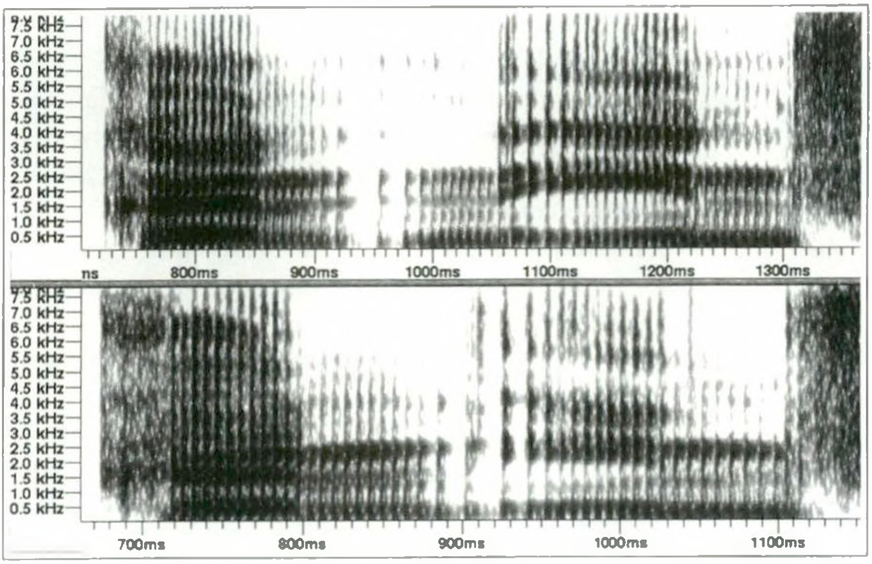


Figure 6. Spectrograms of *(wir) könnten ihn (fragen).* (top) and *(wir) können ihn (fragen).* (bottom); scripted lab speech, male speaker KJK.

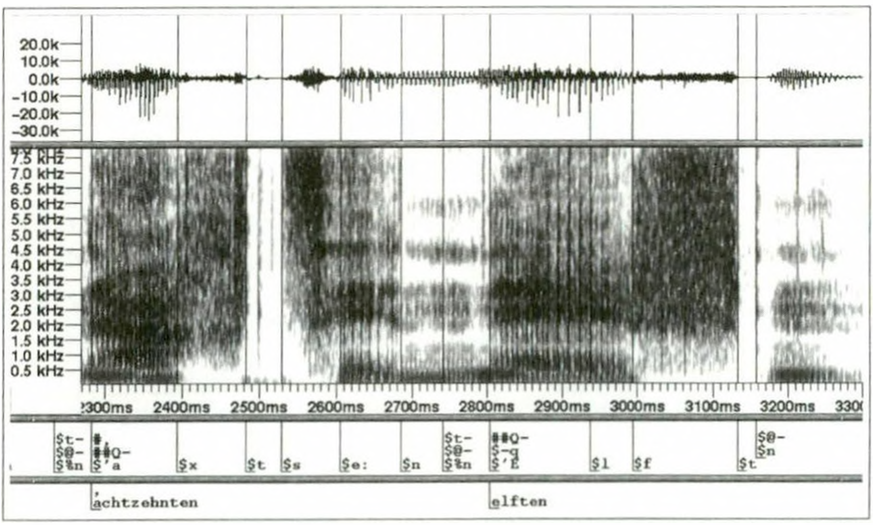


Figure 7. Shift of plosive and vowel-related glottalization to the left and right into each vowel, respectively, in *achtzeh**nten** elften*, Kiel Corpus of Spontaneous Speech, g411a004 HEE, female speaker; speech wave, spectrogram and SAMPA labels.

1.2 Physiological explanation of glottalization phenomena

Physiological data on the Danish stød (Fischer-Jørgensen 1989a, 1989b) show different degrees of medial vocal fold compression, due to increased/decreased vocalis and lateral crico-arytenoid muscle activities for glottal stop as against glottalization. So the glottal stop can be associated with a feature of reinforcement, compared with one of weakening in other glottalization phenomena. Extrapolating from these data of one particular language to the comparable alternation of glottal stop and glottalization in vowel and plosive-related phenomena in other languages we may hypothesize that the same strength relationship obtains there as well.

Phrase-final laryngealization (CREAK or CREAKY VOICE) and its alternation with breathy voice or breathiness fits in with low-F0 utterance-final relaxation in preparation of glottal opening for the non-speech function of vegetative breathing; this relaxation excludes the glottal stop.

Utterance-internal speech truncation before correction is most effectively achieved by cutting off the air stream at the glottal valve; thus tensing of the vocal folds for a glottal stop would be the most natural process.

1.3 A database and processing tools for investigating glottalization phenomena in German

Two large phonetically labelled acoustic corpora of read and spontaneous speech have been compiled for German at IPDS Kiel, containing 31,382 and 37,777[1] running regular lexical words, respectively: the Kiel Corpus of Read/Spontaneous Speech (IPDS 1994, 1995, 1996, 1997a; Kohler *et al.* 1997). The transcription is basically linear segmental phonemic with componential additions (marking glottalization phenomena amongst others), using the SAMPA alphabet (Kohler *et al.* 1995). The read corpus and about one half of the spontaneous corpus have also been labelled prosodically using PROLAB (Kohler 1995b, 1997) based on the KIEL INTONATION MODEL (KIM) (Kohler 1997).

For signal analysis and labelling the software environment XASSP (IPDS 1997b) has been used. The signal and label files are distributed on CD-ROM: one for read speech and three for spontaneous speech so far.

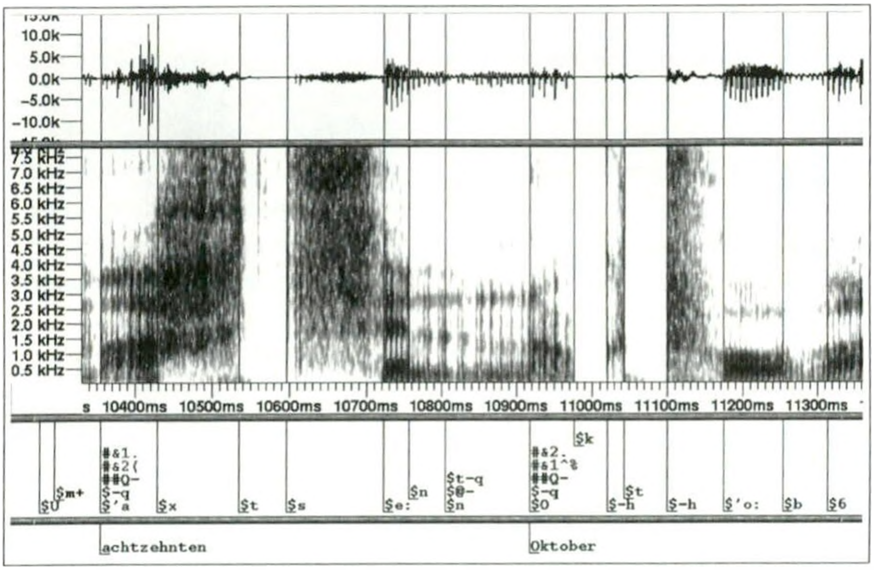


Figure 8. Plosive and vowel-related glottalization and phrase-final laryngealization in *achtzehnten Oktober*, Kiel Corpus of Spontaneous Speech, g083a003 KAK, male speaker; speech wave, spectrogram and SAMPA labels.

The database is increased and updated continually. From the label files lexicon-oriented databanks can be generated with the help of the data bank utilities KIELDAT (Pätzold 1997), which also contain frequently applied, standardized AWK retrieval tools (Aho *et al.* 1988). In addition, a library of AWK search scripts has been set up for a large number of phonetic questions, including glottalization phenomena. A wide array of phonation features related to their various linguistic functions have been examined in these two databases (see also Rodgers 1999), at the symbolic as well as the signal level. As regards the former, frequency distributions of the various phenomena have been established and compared for possible speaking style effects between read and spontaneous speech. This paper looks at signal manifestation and symbolic representation of plosive-related glottalization in the labelled Kiel databanks of read (R) and spontaneous (S) speech, and provides statistics on the occurrence of labelled glottalization phenomena in different plosive contexts, also in relation to unreduced plosive productions.

1.4 Perception experiments

In addition to the corpus analyses of plosive-related glottalization phenomena, this paper also discusses data from perception experiments with systematically spliced natural stimuli of sentence size, viz. *die könn(t)en uns abholen* 'they can/could collect us', *wir könn(t)en ihn fragen* 'we can/could ask him', *sie könn(t)en uns fragen* 'they can/could ask us'. On the basis of the production data found in the two large data bases of connected speech, sentences containing *können* or *könnten*, respectively, were constructed and presented orthographically to speakers for oral reproduction. Typical instances of /ə/ reduction with glottalization for *könnten* [kœnn̰n], of reduced *können* [kœnn], and of initial vowel glottalization in *ihn* were selected for stimulus generation, using the splicing technique in xassp to insert varied durations and vocal tract resonances of glottalization into different positions (initial, medial, final, total) of varied durations of the nasal. The factors to be tested in perception were the timing, the absolute and relative duration and the resonance of the glottalization, thus checking whether the patterns found in production are also relevant in perception (for details of method see Kohler 1999).

2. Plosive-related glottalization phenomena in German speech production

2.1 The state-of-the-art of research into the phenomenon

Plosive-related glottalization phenomena in German were first noticed in the acoustic and auditory processing and in the labelling of speech files within the Phondat (Kohler 1992) and later-on the Verbmobil project (Kohler *et al.* 1997). A systematic symbolic representation for glottalization was devised (Kohler *et al.* 1995) and applied to the data of the Kiel Corpus of Read/Spontaneous Speech (IPDS 1994, 1995, 1996, 1997a). Several studies of the phenomenon have since been presented on the basis of the connected speech data from these two projects (Kohler 1994, 1995a, 1996a,b; Kohler and Rehor 1996). The conditions of occurrence and the manifestation of plosive-related glottalization phenomena can be summarized as follows:

(1) glottalization: glottal stop and low-frequency glottal vibration

general conditions

- A simple glottal valve action is used to cut off the air stream for stop articulation, added to, or instead of, a more complex combination of supraglottal oral/velic closures.

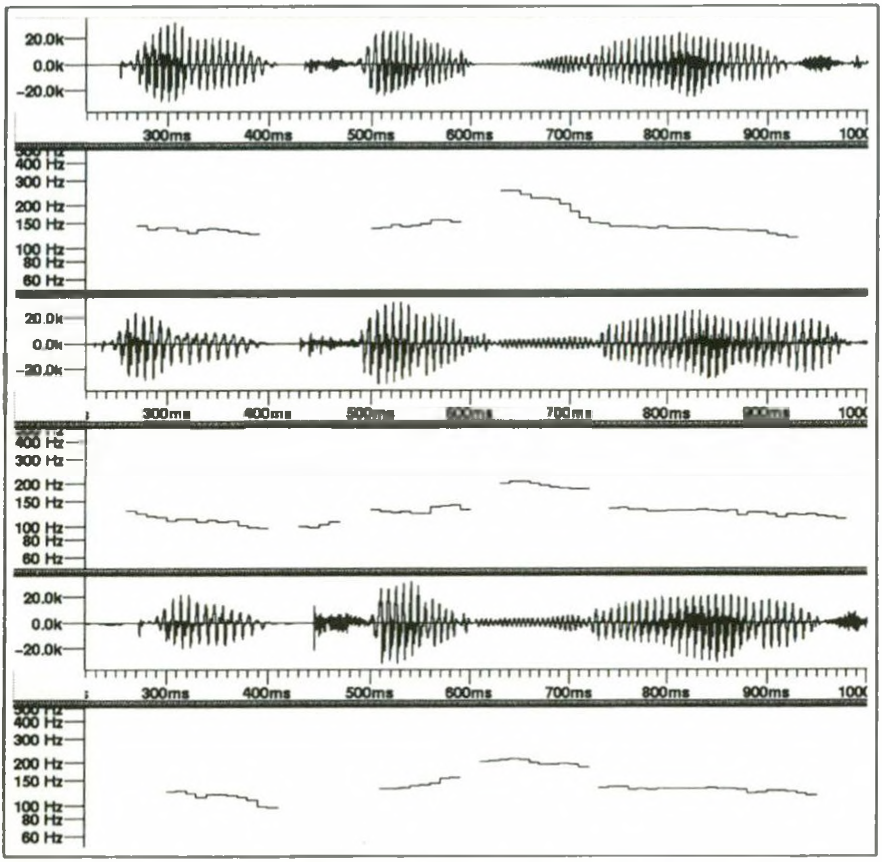


Figure 9. Speech waves and F0 traces in 3 repetitions of *dem* ***könnten*** *wir uns (anschließen)*, scripted lab speech, illustrating high-frequency glottalization for tensing; male speaker.

- The stop is not released into a vowel but is, in most cases, followed by another complete or partial oral occlusion - nasal, plosive or lateral.
- Irregular glottal pulsing instead of a glottal stop reduces, rather than blocks, the air stream. The frequency of this vibration differs from that of the (quasi)periodic environment; it is higher for tensing, lower for relaxation, the latter being typical, but Figure 9 shows several instances of the former.

specific contexts

(a) SONORANT – PLOSIVE – SONORANT (esp. NASAL)

- Glottalization occurs for fortis and lenis stops at all places of articulation, word-internally or across word boundaries.
- The word-internal sequence results from [ə]-elision before nasals/laterals of canonical forms.
- The oral closure in nasal – plosive and plosive – nasal sequences is adjusted to the plosive place of articulation throughout.
- This oral closure is accompanied by velic opening as the complete or partial interruption of the air stream is transferred to the glottal valve.
- The following examples of low-frequeny glottal vibration illustrate the various conditions: *könnten* [kœnn̰n], *Lampen* [lamm̰m], *halten* [hal̰n], *Stunden* [ʃtʊnn̰n], *sind noch* [zɪn̰ nɔx], instead of the more elaborated canonical pronunciations [kœnt^{h}ən], [lamp^{h}ən], [halt^{h}ən], [ʃtʊndən], [zɪnt nɔx]. Glottal stops are equally possible in these contexts.
- As regards the timing of glottalization there are four possible temporal alignments with the sonorant, e.g. /n/ in *könnten* (for further details see Kohler 1996a):
  medial, [nn̰n], is most common in all contexts
  final, [nn̰], is next frequent for lenis stops
  initial, [n̰n], is next frequent for fortis stops
  complete, [n̰n̰].
  Glottalization may also extend, or be shifted, into the preceding vowel (e.g. in Figure 7).

- With respect to the DURATION of glottalized nasal stretches, it has also been found to be quite variable (Kohler 1996a). On the other hand, when glottalized sonorants were compared with sonorants that had modal voice throughout, e.g. [kœnn̰n]vs.[kœnn], the former turned out to be consistently longer in a specially collected contextually comparable corpus of *könnten* and *können* sentences. They were read by three speakers (with 10 repetitions of the sentence set). The duration increase for *könnten* again varied a great deal from speaker to speaker, between averages of 30% and 60%.[2] So it may be assumed that, from the production point of view, a canonical plosive unit can be represented in the signal by a duration trace as well, at least in systematically elicited lab speech data.

(b) VOWEL – (FRICATIVE) FORTIS PLOSIVE – CONSONANT (esp. NASAL)

- There is a higher probability of glottally reinforced plosives (with velic raising) in this context than in context (a).
- In plosive – nasal sequences the same place adjustment occurs as in (a).
- In plosive – nasal sequences velic opening may occur very early after the oral occlusion, accompanied by glottal stop or low-frequency vibration.
- Examples for this context are *zweiten* [tsvaɪ̰(ʔ)n], *Leipzig* [laɪ̰ʔ͡ptsɪç], *hat nicht* [ha̰ʔnɪç].

(2) breathiness and breathy voice

- In the complete nasal context of (a), voiceless or breathy-voiced nasals instead of plosives are also possible, breathy-voiced especially for lenis; see Figures 2 and 3.
- This must be due to glottal (interarytenoidal) opening, which preserves the plosive phonation features, again combined with velic lowering, as required for the environment.
- Thus the modal-voice context of the nasal is still interrupted by different types of phonation, reflecting more complex plosive articulations.

(3) modal voice with(out) F0/amplitude modulation

- For lenis in the nasal context of (a), a further progression towards modal voice may be found, e.g. a reduction to [nn]in *einverstanden, Stunden*. For fortis this is only possible in unstressed function words, e.g. *könnten*, and elements of compounds, e.g. *-zehnten* in numerals; see Figure 10.
- This process may be complete, or there may be a weak trace of the plosive in the form of a medial amplitude and/or F0 dip in the nasal stretch; see Figure 11. So the speaker can still signal a break, albeit towards the low effort end of a reduction scale ranging from plosive to complete nasalization.

2.2 Results of the corpus analysis

2.2.1 Data search and data presentation. In addition to canonical phoneme-type transcriptions and the marking of word boundaries, the label files of the Kiel Corpus of Read/Spontaneous Speech contain symbolic information about /ə/ and plosive deletion, about aspiration, glottalization, breathy or breathy-voice or modal-voice nasalization of plosives, also about interchanges between the lenis and fortis categories and, indirectly, about nasal or lateral plosion (in the absence of any of the other plosive attribute markers). Specific AWK scripts were written to search the entire data base of the Kiel Corpus of Read/Spontaneous Speech for these features of plosive realization within words, containing one or two consecutive post-stress /ə/ + sonorant syllables, and also across word boundaries in the single-syllable type. As the prosodically labelled data files provide phrase boundary markers the occurrence of glottalization phenomena inside phrases or at their boundaries constitutes a further factor in this data bank search. It will help to answer the question of a possible link between plosive-related glottalization and its position in the utterance. Since all label files have the orthographic punctuation characters [.?!] as well as labels for pauses, breathing, laughing and various other paralinguistic sequential events, such phrase boundary searches can even be carried out with a high degree of validity on files without specific prosodic labels.

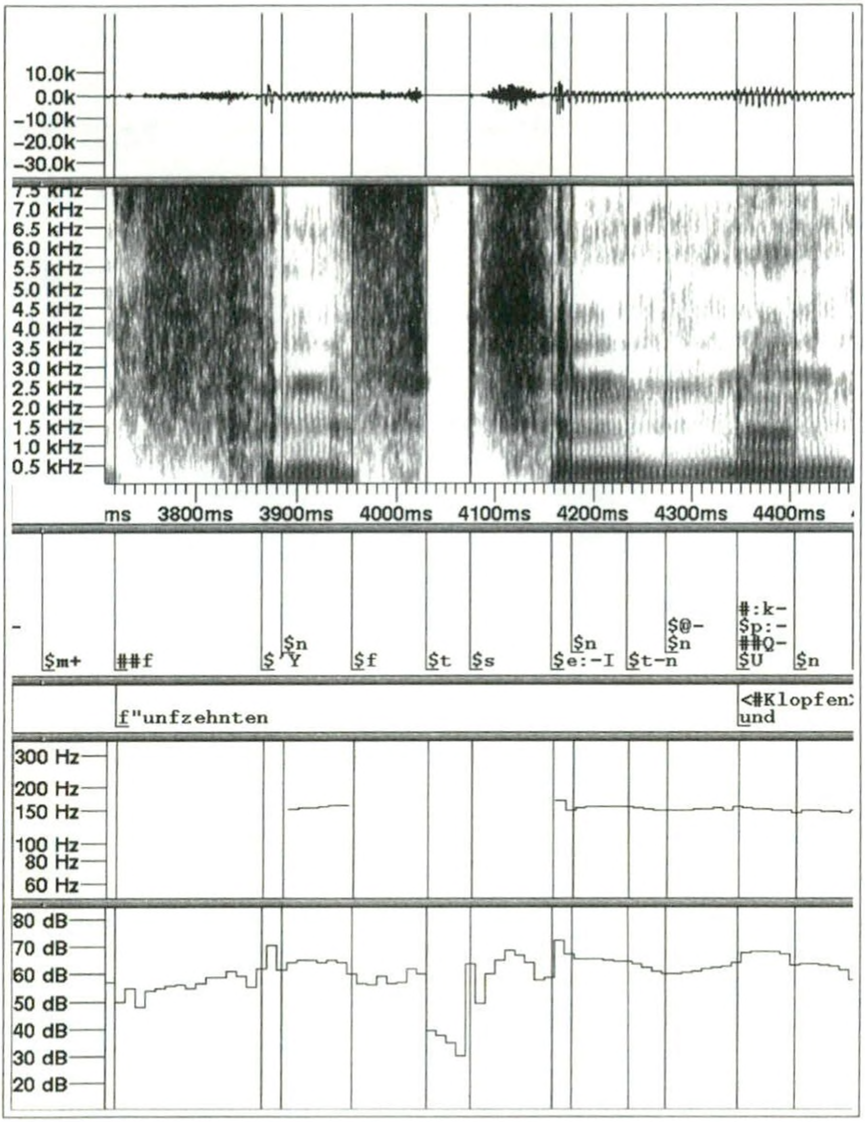


Figure 10. Amplitude and F0 dips in *-zehnten*, Kiel Corpus of Spontaneous Speech, g115a002 REK, male speaker; speech wave, spectrogram, SAMPA labels, fundamental frequency, and energy

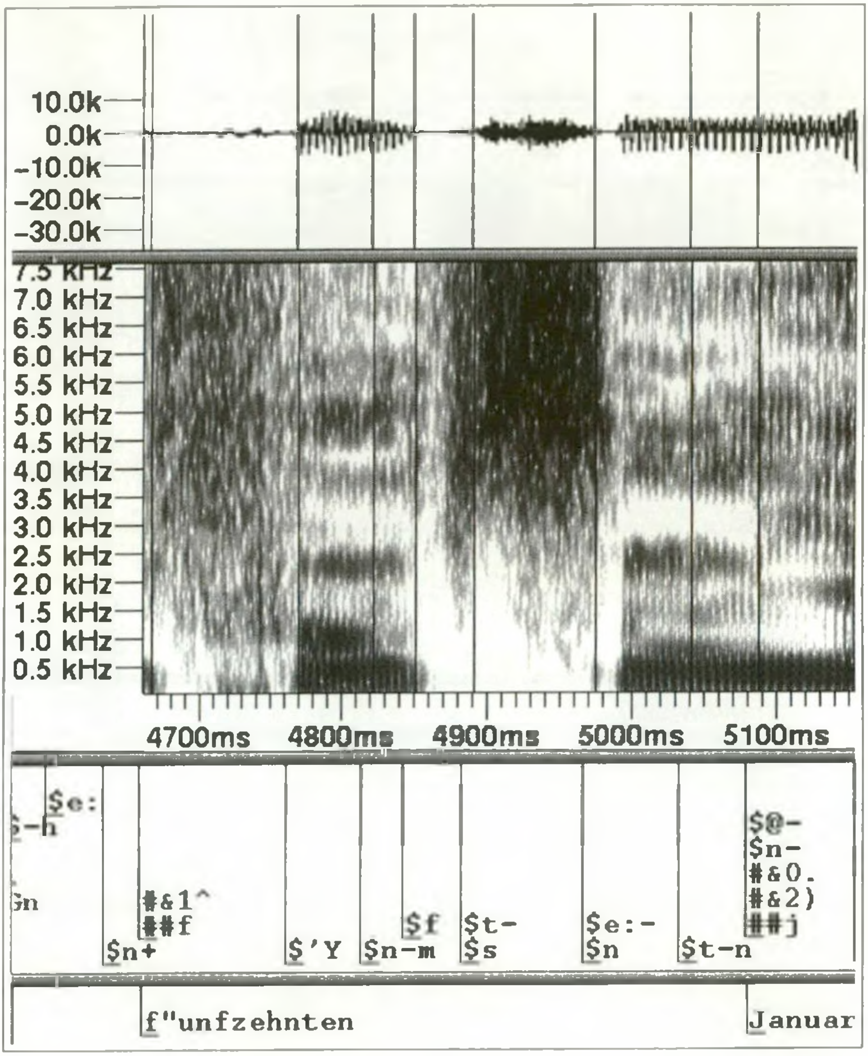


Figure 11. No plosive reflex in *-zehnten*, Kiel Corpus of Spontaneous Speech, g146a000 BAC, male speaker; speech wave, spectrogram, and SAMPA labels.

Table 1(a) presents the frequencies in the different categories of phonetic manifestation for the words with a single plosive + /ə/ + sonorant syllable following a sonorant. The realizations range along an elaborated/reduced scale from aspiration + schwa to just schwa or aspiration to nasal/lateral plosion to glottalization or nasal breath or modal-voice nasalization. The sonorants on either side of the canonical plosive are predominantly nasals; there are no cases with laterals on both sides. In the single syllable category with post-plosive lateral the following frequencies are found:

- in R there are 38 instances of (aspiration +) schwa, 52 of lateral plosion, 18 of plosive nasalization (17 with schwa), 2 of breathy nasal,
- in S 6 instances of lateral plosion;
- so glottalization does not occur in this context.

Words with pre-plosive lateral show the following distribution:

- in single syllables there are 156 cases of nasal plosion in R and 93 in S,
- 4 cases of glottalization in R (*gelten, stellten*) and 49 in S (*halten, sollten, wollten*),
- 5 cases of plosive nasalization (without schwa) in R (*Oldenburg*) and 5 in S (*halben, halten, sollten, folgendes*);
- in di-syllables S has 6 cases of nasal plosion in *folgenden*.

Table 1(b) presents the frequencies in the sequential patterns of schwa preservation/deletion in di-syllables. In Table 2 the frequency distributions for lenis and fortis plosives, which are conflated in Table 1(a), are separated.

Table 3 lists the frequencies of phrase-final and phrase-internal occurrences of items in four phonetic classes corresponding to those of Table 1a, where the data are conflated with regard to the phrase boundary factor. The two sets of Table 3 have been tested, separately for R and S, for an association between phrase boundary and phonetic manifestation of the canonical plosive syllables in a 2×4 χ^2. The test values are

10.3592 for R and 9.000 for S, which, with 3 d.f., is not significant at $p = .01$. This statistical proof suggests that the phonetic exponents — glottalization among others —are independent of the incidence of phrase boundaries. However, the data also show that the frequency distribution across the four classes is different in the two speaking styles: S favours the glottalization, R the more elaborated REST category, but they do so finally and internally in the phrase.

Table 4 provides the frequency distribution across the categories of phonetic realization for the canonical pattern vowel – (fricative) fortis plosive – /ə/ – sonorant. Again the sonorant is typically nasal.

Table 5 compares the frequencies for the presence and absence of glottalization across word boundaries before initial nasals and after sonorants, vowels or other segments preceding the word-final canonical plosive. There are no instances in the corpus where glottalization occurs before an initial lateral, and it is only in R that an example of this phonotactic structure occurs (*Haushalt lernen*). There are, however, a few cases with a lateral preceding the plosive; they have been incorporated in the table. The relative frequencies in each of the four contexts are based on the total number of occurrences in each of the two manifestation categories ±glottalization. They show that glottalization is most frequent after sonorants, much less so after vowels and negligible after other segments, and that this applies to both R and S in very similar proportions. The distribution of non-glottalized forms across the three contexts is, however, quite different from the distribution of glottalization, and it is also different between R and S.

Table 1. Frequencies of glottalization phenomena in the canonical pattern sonorant – plosive –/ə/ – sonorant in read (R) and spontaneous (S) speech, set against other realizations; (a) one /ə/syllable (b) two /ə/ syllables in succession

	R		S	
1 syll	**abs**	**%**	**abs**	**%**
total	479	100.0	874	100.0
−schwa	425	88.7	866	99.1
glott	125	26.1	461	52.7
nas breath	4	0.8	76	8.7
nas	48	10.0	53	6.1
nas/lat plos	224	46.8	272	31.1
asp	24	5.0	4	0.5
+schwa	2	0.4	0	0.0
asp +schwa	52	10.9	8	0.9

(a)

	R		S	
2 syll	**abs**	**%**	**abs**	**%**
total	16	100	25	100
−schwa +schwa	12	60	10	40
−schwa −schwa	0	0	15	60
+schwa +schwa	4	40	0	0

(b)

Table 2. Frequencies of glottalization phenomena in the canonical pattern sonorant – plosive – /ə/ – sonorant of monosyllables in read (R) and spontaneous (S) speech, for /ptk/ (1) and /bdg/ (2), set against other realizations

	R				S			
	abs		%		abs		%	
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
total	273	206	100.0	100.0	733	141	100.0	100.0
−schwa	234	191	85.8	92.7	725	141	98.8	100.0
glott	63	62	23.1	30.1	389	72	53.1	51.1
nas breath	0	4	0.0	1.9	50	26	6.8	18.4
nas	4	44	1.5	21.4	37	16	5.0	11.3
nas/lat plos	143	81	52.4	39.3	245	27	33.4	19.1
asp	24	0	8.8	0.0	4	0	0.5	0.0
+schwa	0	2	0.0	1.0	0	0	0.0	0.0
asp + schwa	39	13	14.3	6.3	8	0	1.1	0.0

Table 3. Frequencies of prosodic boundaries occuring after items in the phonetic classes of Table 1a; nas/lat plos, asp (+schwa), and +schwa have been combined to rest. Numbers in brackets are the fequencies of phrase-internal occurrences of the 4 classes; both numbers in each abs field add up to the sums of phrase-internal and phrase-final occurences listed in corresponding classes of Table 1a.

	R		S	
1 syll	**abs**	**%**	**abs**	**%**
total	140(339)	100.0(100.0)	207(667)	100.0(100.0)
glott	26(99)	18.6(29.2)	110(351)	53.1(52.6)
nas breath	3(1)	2.1(0.3)	21(55)	10.2(8.2)
nas	12(36)	8.6(10.6)	6(47)	2.9(7.1)
rest	99(203))	70.7(59.9))	70(214))	33.8(32.1))

Table 4. Frequencies of glottalization phenomena in the canonical pattern vowel – (fricative) fortis plosive – /ə/ – sonorant in read (R) and spontaneous (S) speech, set against other realizations.

	R		S	
	abs	**%**	**abs**	**%**
total	524	100.0	1069	100.0
−schwa	483	92.2	1053	98.5
glott	9	1.7	68	6.4
nas/lat plos	426	81.3	878	82.1
asp	26	5.0	10	0.9
vd nas/lat plos	15	2.9	14	1.3
/t/ del after /s/	7	1.3	80	7.5
/t/ del in *guten*	0	0.0	3	0.3
vd plos +schwa	0	0.0	1	0.1
asp +schwa	41	7.8	15	1.4

Table 5. Frequencies of glottalization (1) and of its absence (2) across word boundaries before initial nasal and after sonorants, vowels or other segments preceding the word-final canonical plosive in read (R) and spontaneous (S) speech.

	R				S			
	abs		**%**		**abs**		**%**	
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
total before nasal	87	614	100.0	100.0	36	497	100.0	100.0
after sonorants	67	83	77.0	13.5	26	64	72.2	12.9
laterals	1	6	1.2	1.0	5	7	13.9	1.4
after vowels	18	403	20.7	65.6	9	148	25.0	29.8
after other segments	2	128	2.3	20.9	1	285	2.8	57.3

2.2.2 Discussion of the results

1. Pattern (a): sonorant – plosive – /ə/ – sonorant

/ə/ realization is rare in either corpus, but is even less frequent in S than in R (0.9% vs. 11.3%). But the decisive difference between the two speaking styles is the proportion of plosives vs. glottalization phenomena (glottalization + breathy nasalization) and modal nasalization:

R 63.1% plosives 26.1% glottaliz 36.9% glottaliz phen + nasaliz
S 32.5% plosives 52.7% glottaliz 67.5% glottaliz phen + nasaliz

This still holds for fortis and lenis plosives separately and points to a greater degree of articulatory reduction in S vs. R.

fortis
R 14.3% /ə/ 75.5% plosives 23.1% glottaliz 24.5% glottaliz phen + nasaliz
S 1.1%/ə/ 35.0% plosives 53.1% glottaliz 64.9% glottaliz phen + nasaliz
lenis
R 7.3%/ə/ 46.6% plosives 30.1% glottaliz 53.4% glottaliz phen + nasaliz
S 0.0%/ə/ 19.1% plosives 51.1% glottaliz 80.8% glottaliz phen + nasaliz

The data comparison for fortis and lenis in each speaking style shows an increase of /ə/ deletion and a substantial increase of plosive reduction for lenis, due to stop nasalization. This supports the hypothesis that in a nasal context, the shorter and weaker lenis plosive articulations lose their stop character achieved by velic raising more readily irrespective of speaking style.

In R, sequences of two /ə/ syllables always keep the second /ə/ and in 40% of the cases also the first; in S the first /ə/ is never preserved, the second only in 40% of the cases. Although the absolute frequencies are rather small, these data again point to more elaborated articulation in read than in spontaneous speech.

The realization of /ə/ syllables in words occurring before prosodic boundaries shows comparable distributions across four phonetic categories along the reduced/elaborated scale as phrase-internal syllables within each speaking style. This supports the independence of plosive-related glottalization phenomena from their position in the prosodic phrase. But in R 2/3 of the syllables are realized with plosives, whereas in S 2/3 exhibit glottalization phenomena. Since these proportions also apply to the manifestation inside prosodic phrases in each speaking style, they underline the greater degree of plosive reduction in spontaneous as against read speech.

2. Pattern(b): vowel – (fricative) fortis plosive – /ə/ – sonorant
/ə/ realization is again rare in either corpus, but there are again more deletions in S. In both corpora nasal/lateral plosion is the predominant pattern with ca. 80%.

Glottalization is rare, but more frequent in S, i.e. the frequency of glottalization is completely different for the two segmental patterns in either speaking style.

3. Glottalization across word boundaries
It occurs in both speaking styles before a nasal at the beginning of the next word and is most frequent in Pattern (a), after sonorants, predominantly nasals, which provides ca. 75% of the cases in both R and S. Although the context patterns after vowels and after other segments are represented by a great deal more data than Pattern (a) in both speaking styles (with reversed rank orderings of vowels and other segments in R and S), the instances of glottalization are concentrated on the bilateral sonorant, i.e. mainly nasal, context.

2.2.3 Explaining the data with reference to general principles of speech production. The analysis and statistical assessment of plosive-related glottalization phenomena in two extensive annotated acoustic corpora of German have been presented here to buttress the state-of-the-art account given in 2.1 with quantitative data from a representative data base of a sufficiently large number of speakers of Standard Northern German. We are now in a position to draw some conclusions for speech production.

In both contextual patterns for plosive production – (a) and (b), two steps can be postulated for the simplification of the articulatory program:

(1) the elimination of a central oral opening-closing gesture, resulting in nasal or lateral plosion,
(2) the elimination of velic raising during the oral occlusion and the transfer of air stream control to the glottis, resulting in glottalization phenomena.

In a bilateral nasal context of Pattern (a), (2) eliminates the need for a synchronization of velic control with other vocal tract components; the velum can remain lowered in the entire sequence, but the listener still receives a signal break for a canonical plosive through a glottal stop, glottalization or some other change in phonation. So articulatory reorganization takes place, with the same communicative function.

The statistical data support this view. The frequency distribution of plosive-nasal realizations across word boundaries (in 2.2.2.3) as well as the scarceness of glottalization word internally in Pattern (b) (see 2.2.2.2) show that the (homorganic) nasal context is particularly conducive to the occurrence of glottalization. This quantitative empirical fact fits in with the argument that this contextual pattern provides the most natural environment for articulatory economy through reorganization of stop production: glottal control can take over the function of air stream interference from velic control, allowing all other supraglottal settings – oral occlusion, place of articulation and velic lowering – to stay the same as needed for the nasal environment. Moreover, reducing the extent of velic movement and giving greater flexibility to its synchronization with other articulatory gestures accords very well with a sluggish articulator.

The temporal indeterminacy of velic action is further heightened by a temporal flexibility of phonation changes, as found in the extremely variable position and duration of glottalization within a sonorant (see 2.1). Although the duration of glottalized as against modal-voice sonorants can be longer this increase also varies a great deal from speaker to speaker (see 2.1). So in view of this enormous temporal variability in connected, and especially in spontaneous speech, it is doubtful whether the longer duration of glottalized sonorants is a generally established production pattern, and even more doubtful whether it plays an important role in speech communication (see 3.)

In the short closure of lenis stops, this flexible timing of the velum triggers an even greater reduction of its movement, resulting in complete assimilation to modal-voice nasality (see 2.2.2.1). In all the modifications of plosive + nasal syllables, found in the data base, the demands on articulator coordination are reduced; this helps to ease production whenever called for by context of situation. In particular, unscripted dialogue speech, as against a reading style, sets a frame for greater articulatory imprecision; so there are more articulatory reductions of the types described under this condition (see 2.2.2.1).

3. Plosive-related glottalization phenomena in German speech perception

3.1 Some hypotheses

The corpus analysis has shown that nasal glottalization is a consistent and prominent production pattern for canonical nasal + plosive + nasal syllables in read and spontaneous speech in German. It contrasts with completely modal-voice nasals. The realization of this sonorant glottalization was found to vary in the following four factors:

- position of the glottalized section within the nasals – medial, initial, final, total
- total duration of glottalized nasals, compared with that of modal-voiced nasals
- duration of the glottalized section within nasals
- vocal tract resonance of the glottalized section differentiating plosive-related from vowel-related glottalization.

The question that now has to be asked is how German listeners process the variability in these factors for the recognition of utterance-embedded words containing glottalization or modal-voice features. The hypotheses, derived from the production data, and to be tested in perception experiments, are:

(1) the consistent opposition pattern of presence vs. absence of glottalization found in German speech production is mapped onto speech perception,
(2) the indeterminacy of temporal position of glottalization within the nasal is reflected by perceptual irrelevance,
(3) the increased total duration of glottalized vs. modal-voice nasals is perceptually irrelevant,
(4) the duration of the glottalized section has a perceptual effect if it transgresses a threshold,
(5) vocal tract resonances are perceptually relevant to separate plosive-related from vowel-related glottalization.

Two experiments were carried out by the author (Kohler, 1999), a third experiment under the author's supervision by a student (M. Hein)[3] . The method used is sketched in 1.4 and described in more detail in Kohler (1999). All the experiments test hypothesis (1). Experiment 1 adds hypotheses (2) and (3), Experiment 2 hypotheses (4) and (5), Experiment 3 hypotheses (2), (3) and (4). The test of hypothesis (3) and its interrelation with the other hypotheses still requires a more elaborate and more stringent experimental design. The results referring to it are only preliminary.

3.2 Experiment 1: Temporal position of glottalization and nasal duration

3.2.1 Stimuli. There are eight stimuli in this experiment, based on the utterances *die könn(t)en uns abholen (kab)*, produced by a male speaker (KJK) without vowel-related glottalization.

kab1 is an original *können* utterance with a modal-voice nasal of 105ms;

in ***kab2*** the nasal of *kab1* was lengthened to 120 ms by period doubling;

in ***kab3*** the nasal of *kab1* was shortened to 75ms by excising single periods;

in ***kab4*** the final 75ms of the nasal in *kab2* were replaced by glottalization taken from an original *könnten* utterance;

in ***kab5*** the initial 70ms of the nasal in *kab2* were replaced by glottalization;

in ***kab6*** the medial 65ms of the nasal in *kab2* were replaced by glottalization, with 25ms of modal voice at the beginning;

in ***kab7*** the complete 120ms of the nasal in *kab2* were replaced by glottalization;

kab8 contains the original *könnten*, whose glottalization was used for stimulus generation, spliced into the same sentence frame as the other stimuli; the duration of the nasal was 187ms, with 81ms of medial glottalization.

Stimuli **kab2,4,5,6,7** have the same total utterance and nasal consonant durations; they differ with regard to the factors ±glottalization and position of glottalization within the nasal. Stimuli **kab1,3,8** introduce the factor 'nasal duration'; **kab8** combines a longer nasal with a similar duration of medial glottalization as stimulus **kab6**.

3.2.2 Results. Table 6 presents the results of *können* vs. *könnten* identification in a formal listening test (8 stimuli × 10 repetitions × 23 listeners).

All stimuli that contain glottalization in the nasal of at least 65ms, irrespective of its position and the total length of the nasal are uniquely identified as *könnten (kab4,5,6,7,8)*. All stimuli that have only modal voice in the nasal, irrespective of the nasal duration, are uniquely identified as *können*.

3.3 Experiment 2: Vocal tract resonance of glottalization

3.3.1 Stimuli. There are 9 stimuli in this experiment, based on the utterances *wir könn(t)en ihn fragen (kfr)*, produced by a male speaker (KJK).

kfr1 is an original *können* utterance with a nasal of 105ms (mostly modal voice but 2 peri-ods of nasal glottalization at the end), followed by a 60ms [i] glottalization (see Figure 6 (bottom));

kfr2 is derived from *kfr1* by deletion of the entire glottalized section (vowel and nasal) and a slight lengthening of the modal-voice nasal to 111ms;

in ***kfr3*** the nasal of *kfr2* is lengthened to 172ms;

in ***kfr4*** the entire glottalized section of *kfr1* is replaced by nasal glottalization taken from an original *könnten* utterance (see Figure 6 (top)), resulting in 115ms of modal-voice followed by 60ms of glottalization in a nasal of 175ms;

in ***kfr5*** the nasal glottalization of *kfr4* is extended to 150ms within the 175ms nasal;

in ***kfr6*** the nasal glottalization of *kfr4* is extended to the total length of a 172ms nasal;

Table 6. Absolute frequencies in the 2 response categories of Experiments 1 and 2; N=230
Stim kab1-3 with modal-voice nasal (kab1 = original *können*,
kab2/3 = lengthened/shortened)
Stim kab4-7 with glottalized nasal (final, initial, medial, complete)
Stim kab8 = original *könnten*;
Stim kfr1-3 with modal-voice nasal
kfr1 = original *können*, modal-voice nasal + [i] glottalization
kfr2/3 = modal-voice nasal lengthened/shortened
Stim kfr4-6 with final nasal glottalization (increasing length)
Stim kfr7 with final nasal glottalization + [i] glottalization
Stim kfr8 with shortened modal-voice nasal + lengthened [i] glottalization
Stim kfr9 = original *könnten* with medial glottalization

Stim	*können*	*könnten*	Stim	*können*	*könnten*
kab1	230	0	kfr1	222	8
kab2	230	0	kfr2	230	0
kab3	229	1	kfr3	230	0
kab4	3	227	kfr4	3	227
kab5	1	229	kfr5	0	230
kab6	0	230	kfr6	2	228
kab7	1	229	kfr7	65	165
kab8	0	230	kfr8	220	10
			kfr9	0	230

in ***kfr7*** the modal-voice nasal of *kfr4* is cut back to 60ms, followed by 90ms of nasal glottal-ization, in turn followed by 60ms of [i] glottalization;

in ***kfr8*** the modal-voice nasal of *kfr1* is cut back to 60ms followed by an extended section of 120ms of [i] glottalization;

kfr9 is another original utterance *wir könnten* ihn spliced into the frame before *fragen* of *kfr1* to regularize the sentence prosody; here the nasal is 205ms with 115ms of medial glottalization (ending in a glottal stop), after 40ms and before 50ms of modal voice, without [i] glottalization.

Stimuli ***kfr1,3,4,5,6,8*** have approximately the same duration up to the onset of modal [i], ranging between 165ms (*kfr1*) and 180ms (*kfr8*). They differ with regard to the presence of [i] or nasal glottalization or with regard to their absence. This is combined with increasing durations of nasal glottalization within the same total length of the nasal in ***kfr4,5,6*** (60ms, 150ms, 172ms) or with increasing durations of [i] glottalization in ***kfr3,1,8*** (0ms, 60ms, 120ms). Nasal glottalization is final in ***kfr4,5,6***. This contrasts with medial glottalization and a longer nasal duration in ***kfr9***. In ***kfr2,3*** the modal-voice nasal is varied in its duration. Finally, ***kfr7*** combines nasal and [i] glottalizations in sequence.

3.3.2 Results. Table 6 presents the results of *können* vs. *könnten* identification in a formal listening test (9 stimuli × 10 repetitions × 23 listeners). All stimuli that contain nasal, but not [i] glottalization are uniquely identified as *könnten* (*kfr4,5,6,9*), and as in Experiment 1, this is again irrespective of the duration or position of glottalization or the total length of the nasal. A nasal glottalization duration of at least 60ms is clearly on the *könnten* side of the threshold, no matter what the total length of the nasal is. All stimuli that contain [i], but no, or very short (ca. 20ms), nasal glottalization are uniquely identified as *können* (*kfr1,8*), its length being again irrelevant. The same also applies to complete modal-voice nasals (*kfr2,3*), irrespective of their duration. However, when nasal and [i] glottalizations are contiguous and both are at least 60ms long, judgement is no longer unique, but *könnten* predominates.

3.4 Experiment 3: Temporal position and duration of glottalization

3.4.1 Stimuli for Experiment 3. There are 14 stimuli in this experiment, based on the utterances *sie können uns abholen/könnten uns fragen* (*kabfr*), produced by a female speaker (SH). The signal portion from the beginning of the stop to the beginning of the fricative in *können uns* was excised from *sie können uns fragen* and spliced into the equivalent position in *sie könnten uns abholen*, thus producing *könn(t)en uns* in the same sentence frame, neither having vowel-related glottalization.

kabfr1 is original *können* with a modal-voice nasal of 104ms;

kabfr2, kabfr3 were derived from *kabfr1* by lengthening and shortening its nasal to 154ms and 54ms, respectively;

for ***kabfr4, kabfr5, kabfr6*** 19ms of nasal glottalization from the *könnten* stimulus were spliced into the nasal of *kabfr1* initially, medially and finally, with a complementary shortening of modal voice to the same total nasal duration of 104ms;

for ***kabfr7, kabfr8, kabfr9*** the same stimulus manipulations were carried out with 37ms of glottalization;

for ***kabfr10, kabfr11, kabfr12*** the same stimulus manipulations were carried out with 57ms of glottalization;

in ***kabfr13*** the 37ms-glottalization was copied 3 times (111ms) to replace the entire modal-voice nasal;

kabfr14 is original *könnten* with 37ms of medial nasal glottalization and a total nasal duration of 220ms.

Stimuli ***kabfr1,4–13*** have the same total nasal durations. They differ in the temporal position and the duration of glottalization inside the nasal. Stimuli ***kabfr1,2,3*** vary the duration of the modal-voice nasal. Stimuli ***kabfr8,14*** contrast the same duration of medial nasal glottalization in a shorter and a longer nasal.

3.4.2 Results. Table 7 presents the results of *können* vs. *könnten* identification in a formal listening test (14 stimuli × 10 repetitions × 10 listeners).

The two-way comparison of the responses to the 3 glottalization durations in each of the 3 sonorant-internal positions — *kabfr4,7,10* vs. *kabfr5,8,11* vs. *kabfr6,9,12* — shows that there is an interaction between these two factors. In each position the number of *könnten* answers increases with glottalization duration, but in different proportions for the three positions. The weakest position is final, followed by initial. For the longest durations, initial (*kabfr10*), medial (*kabfr11*) and complete (*kabfr13*) glottalization practically equalize above 90% *könnten*, but the final position still produces 30% *können* responses. This result differs from the one in Experiment 1. However, since there the final glottalization duration was 30% longer, it is very likely that we are dealing with a duration threshold beyond 60ms for the final position, whereas for the other two positions it is lower, and lowest for medial. As *kabfr7* and *kabfr14* have the same length of medial glottalization their different *könnten* frequencies may point to a nasal duration effect which becomes relevant when glottalization duration is small. Lack of glottalization is again a clear cue for *können* perception in all nasal durations.

3.5 Discussion

Of the initially postulated hypotheses (1), (4) and (5) have clearly been confirmed. The linguistic contrast between glottalization and modal voice, consistently found in plosive-related production data in German, at least of the North German variety, has its counterpart in perception data. There is a duration threshold in the perception of glottalization, and vocal tract resonances are relevant for the perceptual separation of plosive and vowel-related glottalization. But these two factors interact with each other and with the factor of hypothesis (2).

Table 7. Absolute frequencies in the 2 response categories of Experiment 3; N=100
Stim kabfr1-3 with modal-voice nasal (kabfr1 = original *können*,
kabfr2/3 = lengthened/shortened)
Stim kabfr4-6 with short glottalization in the nasal (initial, medial, final)
Stim kabfr7-9 with longer glottalization in the nasal (initial, medial, final)
Stim kabfr10-12 with longest glottalization in the nasal (initial, medial, final)
Stim kabfr13 with complete glottalization in the nasal
Stim kabfr14 = original *könnten* with medial nasal glottalization

Stim	*können*	*könnten*	Stim	*können*	*könnten*
kabfr1	99	1	kabfr8	19	81
kabfr2	92	8	kabfr9	70	30
kabfr3	99	1	kabfr10	5	95
kabfr4	53	47	kabfr11	9	91
kabfr5	34	66	kabfr12	31	69
kabfr6	98	2	kabfr13	6	94
kabfr7	14	86	kabfr14	0	100

The initial, medial or final positioning of glottalization within a nasal is only irrelevant for plosive-related perception when its duration transgresses a threshold, which is different in each of these positions, and is highest finally. A value of more than 60ms seems to be necessary to trigger a plosive-related percept there, in the context before a word-initial vowel at any rate. So a successful auditory discrimination of spectral properties of glottalized stretches connected with plosive or vowel productions at word boundaries would also seem to require a minimum duration. That would explain the weakness of this effect in Experiment 3 but the very strong effect in Experiment 2, and it also explains the much more efficient signalling power of glottalization in medial position.

There are indications in the results of Experiment 3 that hypothesis (3) is also dependent on hypothesis (4): the increased total duration of nasals may only be indiscriminate for plosive-related perception if the duration of glottalization is above threshold. If glottalization is too short it seems to get auditorily enhanced by a long phonation contrast (Diehl *et al.* 1990). This would mean that a deviation from modal voice can be made perceptually salient either by lengthening its duration above threshold, or - when it is too short - by enhancing it through lengthening its phonatory environment.

4. Conclusion

This paper has knit together the analysis of production and perception data on a phenomenon of the phonetics of German that has only recently been observed: plosive-related glottalization. It has been presented as an array of regular and consistent phonetic manifestations of a phonological structure. It has also been the aim to show that the production patterns of glottalization find their close parallel in perception and that the phonetic feature therefore plays an important role in speech communication. It escaped notice for so long because phoneticians and phonologists have been preoccupied with citation form pronunciations of lexical entries and with their segmental representations. But the increasing interest in connected, more specifically spontaneous speech data bases has made it mandatory for researchers to enter into the phonetics and phonology above the word in real-life communication, and it is in this domain that glottalization phenomena abound. In dealing with such phrase-level features it also becomes necessary to develop a new paradigm for speech analysis that moves away from a strictly linear phonemic framework towards a componential analysis (Kohler 1999) to accommodate the temporal indeterminacies of speech production and perception successfully. This paper also wishes to set an example of dealing with phonetic data in this way, for an insightful explanation of observed speech behaviour.

From this general phonetic and linguistic point of view, it is now a great task for future research to investigate glottalization phenomena and their communicative functions in a large number of phonetically and phonologically diverse languages. What I would like to see is a comprehensive study of vowel, plosive, syllable and utterance-related glottalization phenomena across languages to arrive at phrase-level typologies and universals of phonation and of its coordination with supraglottal articulation under different conditions of communication. We can already draw on a substantial corpus of descriptions; we need to pool this knowledge, expand it considerably and integrate it into a coherent descriptive and explanatory cross-language frame.

With her comprehensive investigation into the Danish stød over many decades, Eli Fischer-Jørgensen has already contributed towards this goal more than any other scholar. Her work has been a source of inspiration for my own research in this area. It triggered the question "Is there a stød in German?" I think I can now give an answer. Danish *vennen* (definite form of *ven* 'friend') is [vɛnn̰n], besides emphatic [vɛnʔn], which coincides phonetically with the very common realizations of German *wenden* 'to turn', having a glottalized nasal or glottal stop inside the nasal. So from the phonatory point of view German has a stød. And American English has one as well, for example in the pronunciation of the name *Fenton*. The distributions of this phonetic feature and their phonological functions are, of course, completely different. Let's pick up Eli's example and find out more about glottalization phenomena in human speech and language!

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Notes

1 In this word count of the 117 dialogues of spontaneous speech, the following items were excluded: hesitation particles, neologisms, slips of the tongue, word-internal truncations and false starts, and stretches difficult or impossible to identify.

2 These data were collected in an experimental phonetics course for advanced students at IPDS Kiel in the summer semester of 1999 by J. Beckmann.

3 In an experimental phonetics course for advanced students at IPDS Kiel in the summer semester of 1999.

Linking linguistic contrasts to reality: The case of VOT

Peter Ladefoged and Taehong Cho

In the early days of acoustic phonetics Eli Fischer-Jørgensen (1954) described a number of important properties of stop consonants, including the fact that the length of the aspiration in voiceless stops (Voice Onset Time, or VOT, as it was later termed) varied with place of articulation. Cho and Ladefoged (1999) summarize several factors underlying this universal tendency, showing how it may depend on aerodynamic circumstances, the mass and mobility of different articulators, temporal adjustment between the closure duration and VOT, and perceptual concerns. These factors are given different weights in different languages, resulting in variations across languages in the way contrasts in VOT are manifested.

This paper is based on the data reported in Cho and Ladefoged (1999). It will discuss the extent to which the phonological inventory of a language affects the VOT, and conclude by discussing how a phonological description of a single language can make explicit statements about the physical manifestation of VOT in that language, noting how it differs or is the same as that in other languages. We will not consider within languages variations in VOT due to place or articulation or other factors. It is sufficient for our purposes to consider VOT only in voiceless velar stops in a number of different languages.

Previous discussions of cross-linguistic variations in VOT (e.g. Lisker & Abramson 1964, Keating 1984) have been hampered by not being able to refer to a large body of data that had been collected in accordance with the same protocol. When comparing the phonetic properties of different languages it is important to collect data from a number of speakers of each language, so that any individual bias is discounted, and to analyze the data in the same way, so that differences in recording techniques and measurement procedures do not affect the results. We were fortunate to have access to a body of data that fulfilled these prerequisites.

The data we used consisted of measurements ofVOT in 18 languages. For the last 8 years Peter Ladefoged and Ian Maddieson have been the Principal Investigators of a National Science Foundation sponsored project to study the phonetic structures of endangered languages. (This project is continuing for a further three year period under the sole direction of Ian Maddieson.) Endangered languages are no different from any other languages in their possible phonetic structures. These languages are endangered in that they are losing speakers, usually for socio-economic reasons that have no linguistic biases. Consequently a sample of the world's languages consisting solely of languages spoken by communities that are disappearing could theoretically be representative of the world's languages as a whole. Of course, as Maddieson (1997a) and others have pointed out, there are enormous problems in getting a valid sample of languages that is truly representative of the 6,703 (Grimes 1999) current languages in the world (not to mention the further problems of extending this sample to cover all human languages that ever have been or ever could be). The 18 languages that are used in the present work fail completely as a representative sample of possible languages. But they are diverse enough to be at least indicative of the range of VOT that can be found.

The 18 languages in the data set represent 12 different language families as shown in Table 1. Most of the languages are spoken by a comparatively small number of speakers, but Navajo and Apache are fairly widely spoken. Navajo is not an endangered language, but it was investigated in the same way as the other languages. Jalapa Mazatec is also not dying rapidly. It is spoken by nearly all the inhabitants of Jalapa de Diaz in Mexico, including the children. It is endangered in the sense that it is changing rapidly due to the influence of Spanish. Many distinctions are no longer made by younger speakers. Scottish Gaelic may be spoken by 70,000 people, as we have been told, but it is clearly an endangered language, spoken by very few young people. Eastern and Western Aleut are closely related, but they have a number of phonological differences.

Table 1. Languages in the data set.

LANGUAGE	FAMILY	LOCATION
Aleut (Eastern)	Eskimo-Aleut	Alaska, U.S.A.
Aleut (Western)	Eskimo-Aleut	Alaska, U.S.A.
Apache	Athabaskan	Arizona, U.S.A.
Banawá	Arawan	Northern Brazil
Bowiri	Niger-Congo	Ghana
Chickasaw	Muskogean	Oklahoma, U.S.A.
Dahalo	Cushitic	Kenya
Defaka	Niger-Congo	Nigeria
Gaelic	Indo-European	Scotland, U.K.
Hupa	Athabaskan	California, U.S.A
Jalapa Mazatec	Otomanguean	Mexico
Khonoma Angami	Tibeto-Burman	Nagaland, India
Montana Salish	Salishan	Montana, U.S.A.
Navajo	Athabaskan	New Mexico, U.S.A.
Tlingit	Athabaskan	Alaska, U.S.A.
Tsou	Austronesian	Taiwan
Wari'	Chapacuran	Northern Brazil
Yapese	Austronesian	Western Pacific

The recordings of these 18 languages were made in the field in a standardized way by one or other of the two Principal Investigators, Peter Ladefoged and Ian Maddieson, with the exception of the Hupa data, which were recorded by Matthew Gordon, at that time a graduate student in the UCLA Phonetics Lab. Material illustrating the full range of segmental contrasts in each language was recorded, but in this paper we will refer only to the data on voiceless unaspirated and voiceless aspirated velar stops. These stops were always recorded in initial position in citation forms of contrasting words before a non-high vowel. It is arguable that this is not the most appropriate data in that it does not reflect natural utterances in the languages. We thought, however, that it was preferable to ensure unity of style across languages, even at the expense of naturalness.

Several speakers of each language were recorded using high quality equipment. All the speakers were adult native speakers who used the language in their daily life. As noted above, most of the languages investigated are moribund (the children no longer speak them), but all our speakers were completely fluent. The recordings were all analyzed by Research Associates in the UCLA Phonetics Lab in the same way (for details see Cho and Ladefoged, 1999). The differences between languages that emerged are almost certainly not artifacts of the slight differences in the circumstances in which the recordings were made, nor are they due to variations in the measurement techniques of the graduate students who worked on this project, all of whom were closely supervised and trained in the same way. We can conclude that the data reflect real differences between languages.

Figure 1 shows the mean VOT of the velar stops in these 18 languages. If a language contrasts aspirated and unaspirated velar stops, both values are shown, so that there are 25 columns of mean values. There is a very wide range of values, going from 20 ms for the Khonoma Angami voiceless unaspirated stops to 154 ms for the Navajo aspirated stops. The lower of these figures is not unexpected; voiceless velar stops are known to have some voicing lag, so it is no surprise that the lowest value recorded in the data set is significantly greater than zero. But, to those unfamiliar with Navajo, the value of 154 ms for aspirated velar stops may seem excessive – almost as if it were an artifact. It is not. As listeners to the language can attest, aspiration is a very salient feature of Navajo speech.

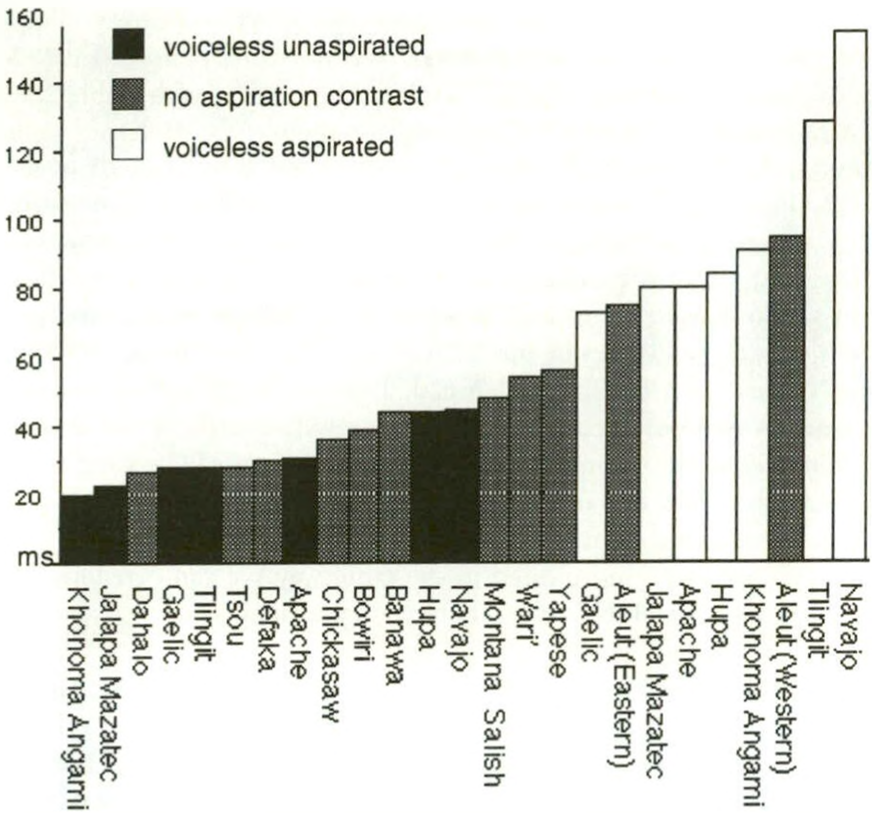

Figure 1. Mean VOTs (ms) for voiceless velar stops in 18 languages. (Values for voiced velar stops are not shown.)

Before discussing the data in detail, we must consider the set of oppositions that occurs among these velar stops in each language. The fact that in some languages there is only a single velar stop, while in others there are two, and in yet others three, might be expected to influence the VOT chosen by each language. If there is no need to make a perceptual distinction between two sounds, then one might expect a language to use the simplest articulatory gesture, what Docherty (1992) has called the low-cost option. This simplest gesture – whatever it is – is presumably the same for all human beings. So one might expect all languages that have only one velar stop to use the same gesture. When there is more than one voiceless velar stop, then each of them must be kept distinct and something other than the low-cost option will have to be used. It is important, therefore, to consider the phonological oppositions. The contrasts within each language are shown in Table 2. We have omitted labialized velars, considering them to be irrelevant to the present discussion of VOT. But we have included information on ejectives, as these sounds are perceptually similar to velar stops that are distinguished simply by VOT. None of the languages in the sample has distinctions due to variations in phonation type, such as creaky voice or breathy voice. The symbols used are those chosen by the authors of the individual studies.

Table 2. The contrasting velar stops (not including labialized stops) that occur in each of the 18 languages.

Language	Contrasting velar stops	Source
Aleut (Eastern)	**k**	Cho et al. 1997
Aleut (Western)	**k**	Cho et al. 1997
Apache	**k, kʰ, k'**	Gordon et al. 2000
Banawá	**k**	Ladefoged et al. 1997
Bowiri	**k, g**	Maddieson p.c.
Chickasaw	**k**	Gordon et. al. 1997
Dahalo	**k, g**	Maddieson et al. 1993
Defaka	**k, g**	Shryock, et al. 1996
Gaelic	**k, kʰ**	Ladefoged et al. 1997
Hupa	**k, kʰ, k'**	Gordon, 1996
Jalapa Mazatec	**k, kʰ**	Silverman et al. 1995
Khonoma Angami	**k, g**	Blankenship et al. 1993
Montana Salish	**k, k'**	Flemming et al. 1994
Navajo	**k, kʰ, k'**	McDonough & Ladefoged 1993
Tlingit	**k, kʰ, k'**	Maddieson et al. 1996
Tsou	**k**	Wright & Ladefoged 1997
Wari'	**k**	MacEachern et al. 1997
Yapese	**k, k', g**	Maddieson 1997b

There are six languages in the set that have only one velar stop. In none of them is this stop voiced, so, quite understandably from a phonological point of view, the authors of the original studies have represented each of these stops by the symbol **k**. But from a phonetic point of view, these stops vary considerably. Some might well be considered phonetically aspirated stops, and the others unaspirated. Both forms of Aleut have stops that are among the most aspirated in the set. The other four languages that have only a single velar stop, Banawá, Chickasaw, Tsou and Wari', vary in their choice of VOT, Tsou being among the lower group and Wari' among the higher. None of these six languages needs to make a perceptual distinction between two sounds, and they might all be expected to use the simplest articulatory gesture. But the data show that they do not necessarily choose the same simplest, low-cost, articulation.

There are only four languages, Bowiri, Dahalo, Defaka and Khonoma Angami, that have what those with a European bias might consider to be the typical velar contrasts, **k** vs **g**. A fifth, Yapese, has this contrast plus an ejective. We do not have adequate data on the voiced stops in these five languages (except that we know that they all have some voicing during the stop closure), so we cannot say which of them are more like French, with a contrast between a fully voiced stop and a voiceless unaspirated stop, and which more like English, with a contrast between a partly voiced stop and an aspirated stop.

In our pursuit of the distinction between voiceless unaspirated and aspirated stops, we can consider all 11 languages that have a single voiceless velar stop that has, from a phonetic point of view, to be called voiceless unaspirated or aspirated. When describing these languages we do not need to make the distinction for phonological reasons, but we must, within the usual techniques of phonetic description, say that these stops fall into the one phonetic category or the other. The VOT's for these 11 languages are represented by the gray columns in Figure 1. Where should we draw the line for the phonetic boundary between voiceless unaspirated stops and aspirated stops? If we look at the data in Figure 1 it might appear as if we could draw it after Banawá. But if we remove the distraction of the data from languages that contrast voiceless unaspirated and aspirated stops, and look at languages that have just one voiceless stop, as in Figure 2, the answer is not so obvious. There is a steady increase in VOT, and no obvious way of dividing the data into two phonetic categories until we get to Eastern and Western Aleut, both of which clearly have aspirated stops. The difference between Banawá and Montana Salish, the dividing line suggested by the data in Figure 1, is smaller than that between Banawá and Bowiri, and that between Montana Salish and Wari'. There is a smooth increase in VOT, and we can make only an arbitrary decision about which languages have voiceless unaspirated stops, and which have aspirated stops.

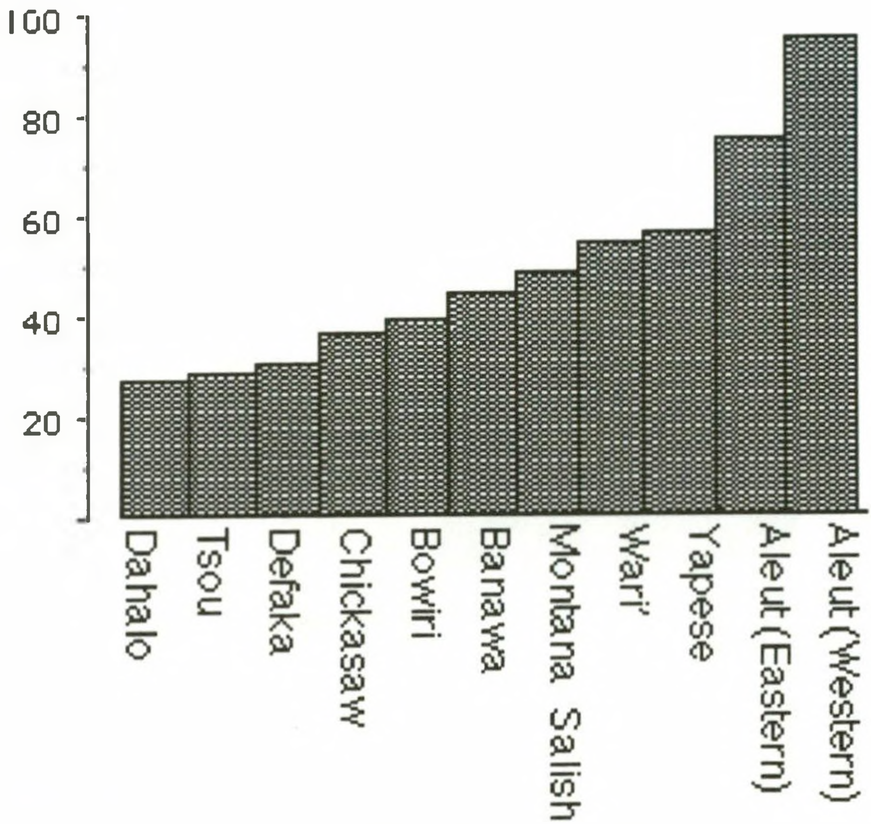

Figure 2. The 11 languages in the sample that do not distinguish voiceless unaspirated and aspirated stops.

Now consider the 7 languages in the sample that contrast voiceless unaspirated and aspirated stops, shown in Figure 3. We noted earlier that when there is no need to make a perceptual distinction we might expect that languages will choose the low-cost option, and make the simplest articulation. This expectation turned out to be wrong. Here, where there is a need to make a perceptual distinction between similar sounds, one might expect that languages would maximize the perceptual difference between them. But, as in the previous case, this expectation is not met. Languages do not behave in this way. Some languages make a large difference, others do not. Hupa has a difference of only 40 ms between voiceless unaspirated and aspirated stops. This is less than half Tlingit's 100 ms.

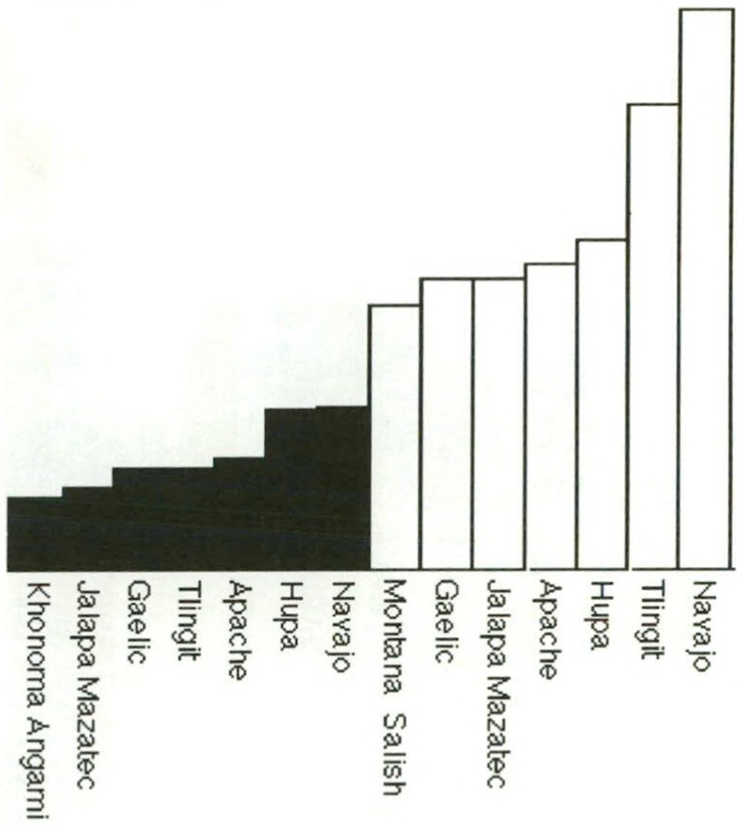

Figure 3. The 7 languages in the sample that distinguish voiceless unaspirated and aspirated stops.

There are six languages that have ejectives. Apache, Hupa, Montana Salish, Navajo and Tlingit contrast **k, k', k^h**. Yapese contrasts **k, k', g** and Montana Salish has just **k, k'**. These languages are interesting in that they may use VOT as a helping feature (Stevens, Keyser & Kawasaki, 1986) to further the distinction between ejectives and other stops. There is a tendency for this to happen, as can be seen from the data in Figure 4, in which the shading has been arranged so as to make it easier to compare languages. In every language except Hupa the ejectives are clearly distinguished from the other stops by VOT.

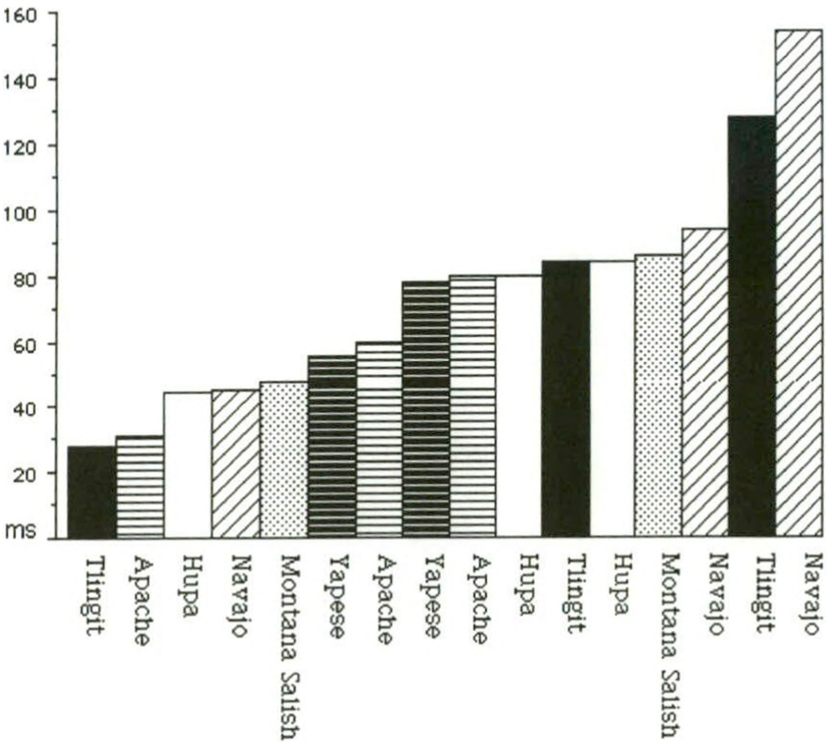

Figure 4. The 6 languages in the sample that have ejectives. Each language has been given a different shading so as to make it easy to compare the ejectives with the other stops in the language.

We will now assess the data as a whole, and consider how phonological statements about each language can be related to observable VOT differences. We presume that phonological descriptions will need to distinguish at least three possibilities [voiced], [voiceless unaspirated] and [aspirated]. We have considered only the [voiceless unaspirated] and [aspirated] categories in this paper, partly because we do not have data on voiced stops, and partly because we do not know of any claims that different degrees of negative VOT are phonologically contrastive. However, languages vary in the amount of voicing that can occur in a phonologically voiced stop, and any mechanism that we propose for the realization of phonologically voiceless stops in terms of physical phonetic variables should apply in a similar way to phonologically voiced stops.

How should the three possibilities {voiced, voiceless unaspirated, aspirated} be realized? Because we want a variable that will be constant within a language across different places of articulation, we propose making phonetic specifications not in terms of the directly observable acoustic measure, VOT, but in terms of an underlying physiological measure. We suggest that there is a phonetic parameter, which we will call Articulatory VOT, definable in terms of the difference in time between the initiation of the articulatory gesture responsible for the release of a closure and the initiation of the laryngeal gesture responsible for vocal fold vibration. We think it likely that speakers aim for a certain timing difference between articulatory and glottal gestures irrespective of the articulatory gesture involved. This is the low-cost option suggested by Docherty (1992). Differences in VOT within a language are usually the inevitable consequence of the physiological movements and the aerodynamic forces that occur at different places of articulation and in different syntagmatic contexts. Cho and Ladefoged (1999), however, found a few cases in which a single VOT target cannot account for all the observed variations in VOT within a language. Sometimes there may be variations in VOT ascribable to aerodynamic causes (e.g. the variations due to place of articulation in unaspirated stops) that a language may choose to use in other circumstances (e.g. as an aid to the perception of places of articulation of aspirated stops in which different aerodynamic forces occur and would, unless prevented, have produced a different acoustic effect).

Even if we specify VOT in terms of an underlying physiological parameter, our data show that there is a great deal of between language variation. Moreover, it is impossible to predict the differences between languages from knowledge of the phonological contrasts within a language. It is not the case that if a language lacks a contrast between **k** and **kʰ** it will have the simplest possible VOT, with a value between the modal value for **k** and that for **kʰ**. Nor is it the case that if a language does have a contrast between **k** and **kʰ** will it make that contrast with a larger than usual VOT for **kʰ** and a smaller one for **k**, so as to make sure that the difference is easy to hear. Nor does the VOT in ejectives have any simple relation to the VOT of other phonological contrasts. We propose, as in Cho and Ladefoged (1999), that each language chooses a modal VOT value for each of the categories [voiced], [voiceless unaspirated] and [voiceless aspirated] that are specified in the phonology. The statement of these values is the link between phonology and measurable phonetic parameters. A phonological description of a language that does not include statements of this kind is incomplete.

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Hearing the Polish sibilants [s ś š]: Phonetic and auditory judgments

Leigh Lisker

1. Introduction

While fricative consonants are usually lumped together with stops as »true« consonants, they resemble both the stops and other segment types in their perceptual properties. As in the case of the stops, some place information is provided by transitional shifts in formant patterns adjacent to the interval of constriction, but unlike the stops, much place information is also provided by acoustic properties of the sound emitted during the constriction. Moreover, at least some of the fricatives seem to be continuously variable in "color," more like vowels than stops.[1] Certain experiments reported by K. S. Harris (1958) indicate that for English [sʃfθ] the contributions of noise intervals and transitions to perception are variable, the noises being of overwhelming importance for the "strident" consonants [s] and [ʃ], and transitions playing a greater role in the case of the less noisy [f] and [θ]. The different perceptual weightings of noise and transition seem readily explained by the intensity relations between the two. Of course, a spectrographic look at the syllables /sɑ/ and /šɑ/ shows them as differing markedly in transitions, just as the /f/ and /θ/ noises show spectral differences. One motive for initiating the study reported here was to see whether, for English-speaking listeners, the relation between noise and transition cues to the English fricatives holds more generally for this class of phonetic segments, even those drawn from a language such as Polish, which is rather richer in such segments than is English, particularly in regard to sibilants. Where English has [s] and [š], Polish has three: [s], [š] and [ś] (described as post-dental, palato-alveolar and alveolo-palatal, or more tersely as simply dental, alveolar and palatal (Jassem 1964). The first two are said to be very like English [s] and [š] (Shenker 1973), although the third also sounds pretty much like English [š] to English speakers. But before addressing the question of how and on what basis English-speaking listeners might categorize the Polish sounds, let us look at three of their visible transforms.

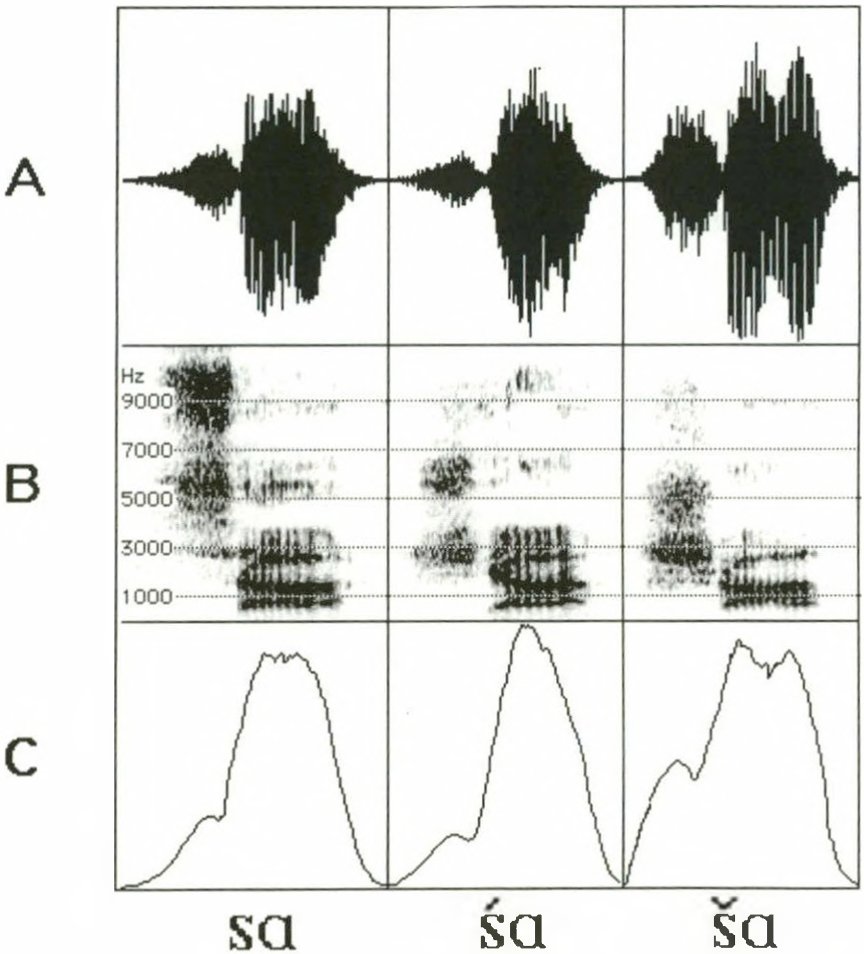

Figure 1. Acoustic displays of representative tokens of Polish syllables [sɑ], [śɑ] and [šɑ]: (A) waveforms, (B) spectrograms, and (C) amplitude profiles.

2. Some simple acoustic observations

In Figure 1 we see pressure waveforms, spectrograms, and amplitude contours of representative tokens of the three nonsense syllables [sɑ], [śɑ] and [šɑ][2] pronounced by an adult male speaker of standard Warsaw Polish. Four tokens of each syllable type were produced in isolation in randomized order and recorded in a suitably shielded sound booth. These syllables were presented for identification to two native speakers of Polish, whose responses showed that each syllable was identified exactly as the speaker had intended. A cursory examination of the spectrograms suggests at least two visual (acoustic) classifications of the three syllables,– one on the basis of frequency characteristics of the noise spectra, the other based on the shape of the second formant transition. From the representative averaged spectra of the three noises (Figure 2), it appears that [s] has a major concentration of energy in the

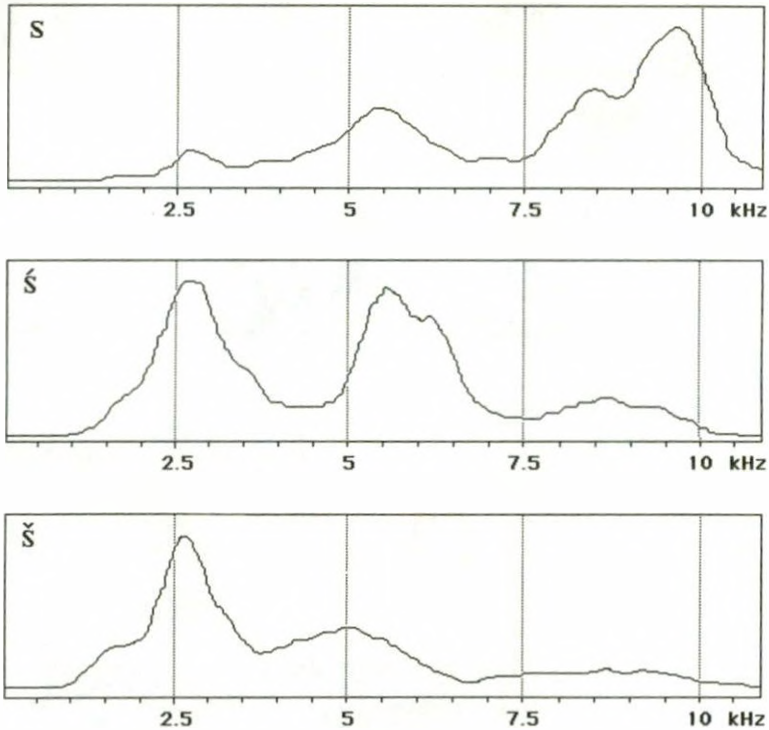

Figure 2. Spectra of representative [s], [ś] and [š] fricative noises averaged over their entire durations.

neighborhood of 9 kHz., with little below 5 kHz, while in both [š] and [ś] energy peaks are found at about 6 kHz and lower. Spectrographically, the [śɑ] syllable shows an F2 vocalic transition that begins at a considerably higher frequency than do those in either [sɑ] or [šɑ]. F2 transitions of [sɑ] and [šɑ] look remarkably alike, despite the recognized fact that the two categories differ in place of articulation, and that the second formant transition is often said to be a most important cue to this sort of difference.[3] (There are other differences to be seen. For one, both the spectrograms and the waveforms suggest that the three noises might have characteristically rather different amplitudes relative to the following vowels: [s] < [ś] < [š] (but see Strevens 1960). A closer look at the transitional patterns suggests the possibility of perceptually significant differences in the other formants, the third and perhaps the first, fourth, and even higher ones.)

3. Phonetic labeling tests

3.1 Procedures

Because classification by eye is no substitute for one by ear, several kinds of perceptual tests were carried out, the stimuli being presented at a comfortable level by loudspeaker in a sound-proof studio. First of all, an informal pilot test of five phonetically naive American English speakers fully bore out the expectation that Polish [s] would be equated with English [s], and that both the Polish alveolar (or palato-alveolar) [š] and palatal (or alveolo-palatal) [ś] would be identified largely with English [š].[4] More serious testing was thereafter confined to a dozen English speakers with some degree of linguistic training, but no previous experience of Polish or its alveolar-palatal shibilant contrast. After a brief initial exposure to a randomized sequence composed of one token of each of the three syllable types, where listeners were provided with feedback as to the correctness of their judgments, they were then presented with randomly ordered sets of stimuli derived from four tokens of each type, with an interstimulus interval of four seconds between each stimulus (each heard twice in immediate succession, and with eight exposures of each token). Three tests were carried out, with different orders of presentation for different subsets of listeners. In one test the stimuli consisted of the isolated noise intervals, in a second the post-noise intervals alone, while in the third the stimuli were the syllables as recorded.

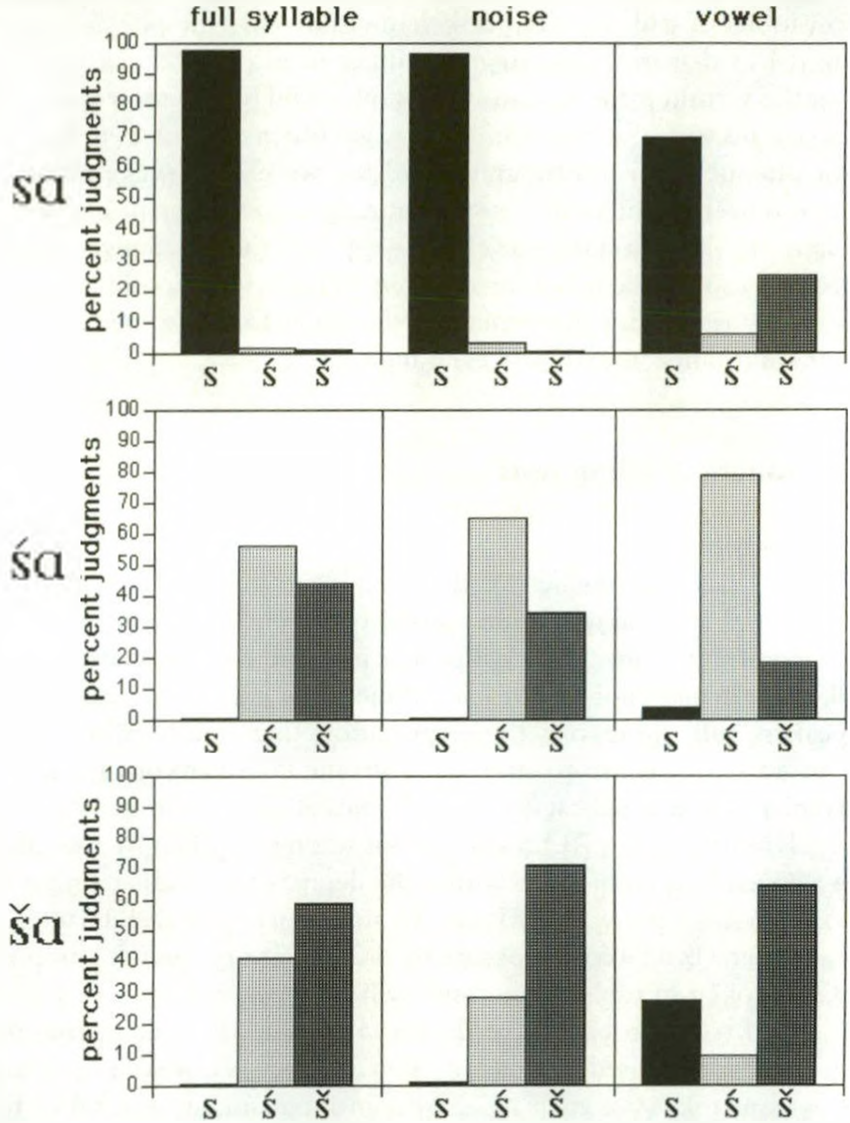

Figure 3. Mean labeling responses of 10 listeners to [sɑ], [śɑ] and [šɑ] syllables and their noise and vocalic residues presented separately. A total of 320 judgments (10 Ss × 32 trials) was recorded for each stimulus type.

3.2 Test results

Figure 3 represents the averaged responses for the three tests.[5] Identifications of the three CV stimuli were much as expected: [sɑ] was clearly distinct from both [śɑ] and [šɑ], but the latter two were not nearly as well separated. Thus the slight preference for ś as against š responses in the labeling of the [śɑ] stimuli (56% vs 44%) was not statistically significant (by one sample t-test: $t = .802$; $p = .44$). The slightly greater tendency to report [šɑ] as š rather than ś, 59% vs 41%, was also non-significant ($t = 1.279$; $p = .23$). Moreover, comparison of the responses to the two syllables by paired t-test revealed no significant difference in response patterns ($F(1,9) = 2.1$, $p = .16$). A similar comparison of the responses to the isolated shibilant noises yielded rather different values ($F(1,9) = 12.7$, $p = .0002$), indicating a considerably enhanced ability of our listeners to separate the two. Of the third set of stimuli, in which the vocalic intervals were presented alone, a comparison of responses to those originally preceded by the alveolo-palatal [ś] vs those originally preceded by [š], showed the greatest degree of resolution ($t = 44.1$, $p < .0001$).

4. Auditory difference judgments

In a recently advanced version of the motor theory of speech perception by Liberman and Mattingly (1985), it was suggested that the listener interprets the acoustic signal directly as "intended" articulatory gestures, with no intermediate stage in which its auditory qualities are subjected to cognitive evaluation. The classical case again is that of the stop consonant as cued by formant transitions, whose movements up or down in frequency cannot normally be perceived in any auditorily plausible way,– a transition is not perceived as a shift in pitch or pitches, but as a vocal tract movement to or from closure at a particular place. Since during the interval in which the vocal tract assumes a shape characteristic of a fricative an intelligible acoustic signal **is** produced (so that in this respect it is more like a vowel than a stop), I thought it worthwhile to learn, by means of further experiments, whether the Polish fricative-vowel syllables could be as well or even better separated on the basis of purely auditory judgments than in terms of phonetic labelings. In the experiments described below I confined the stimulus set to the two Polish shibilant-vowel syllables.

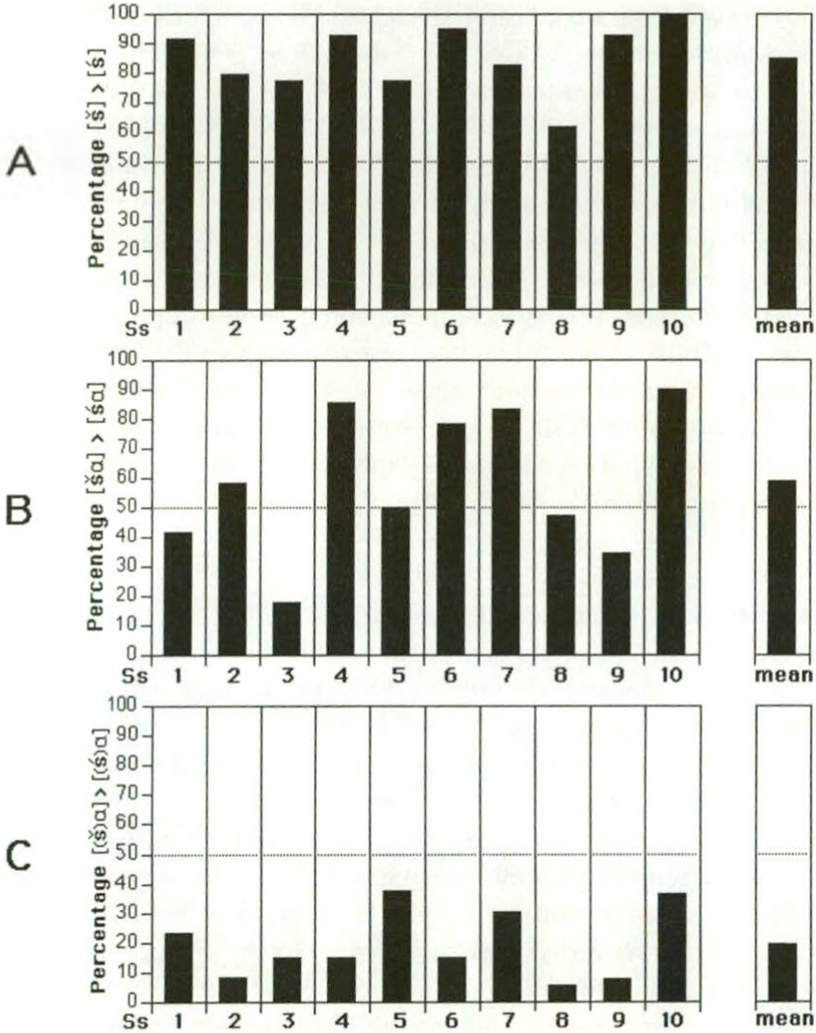

Figure 4. Comparative loudness judgments provided by 10 Ss, each of whom gave a total of 96 responses for each comparison. (A) mean percentage of judgments that isolated [š] noise was louder than [ś] noice. (B) mean percentage of judgments that noise onsets of [ša] syllables were louder than those of [śa], and (C) mean percentage of judgments that residual vowels of [ša] had louder onsets than those of [ś].

4.1 Relative loudness judgments

In one set of tests the listeners' task was to judge the relative loudness of the palato-alveolar as against the alveolo-palatal noises. The task involves the paired comparison of each of the four tokens of the palato-alveolar with each of the four tokens of the alveolo-palatal noises. In one of these tests the vocalic intervals were deleted from the original fricative-vowel syllables. The responses elicited by the isolated noises are shown in panel A of Figure 4, from which it appears that for every one of the ten listeners the palato-alveolar noise [š] was more often than not reported to be louder, a result that might be anticipated from a comparison of both the waveforms and the amplitude curves shown in Figure 1. The mean percentage of judgments favoring [š] as louder (85 %) departs significantly from random ($t = 9.5$, $p < .0001$). In a related test listeners were asked to compare these noises in their original contexts. Here the results (panel B) are very different; only five of the ten listeners reported the same noise to be the louder one, the other five either went the other way or showed no preference. (By one-sample t-test, the mean percent judgment reporting [š] as louder (58.5 %) is not significantly different from random: $t = 1.10$, $p = .30$.) The same comparison test was applied to the post-fricative intervals, listeners being asked to decide which one of a vowel pair had the louder onset. From panel C it appears that every one of the ten listeners heard the vowels extracted from [šɑ] as having weaker onsets (less loud) than those derived from [śɑ], again a result very different from random ($t = 8.14$, $p < .0001$).

4.2 Comparative pitch judgments

Another set of tests, involving the same paired comparisons, asked for relative pitch judgments. Figure 5 shows that for nine of the ten listeners the alveolo-palatal noises ([ś]), both in and out of their original vocalic contexts, had the higher pitch. Again, there were contextually related differences. In the case of the full syllables (panel A) 68 % of the judgments reported [śɑ] as having higher-pitched onsets, and by single sample t-test this score differed significantly from random ($t = 2.4$, $p = .037$). For the isolated shibilant noises (panel B) the mean percentage of judgments favoring [ś] as higher in pitch was 84.6 %, for which t =

4.2 and p = .002. Moreover, the post-/ś/ signals in isolation (panel C) were also judged (79.8 %) to begin with the higher pitch (t = 9.6, p < .0001).

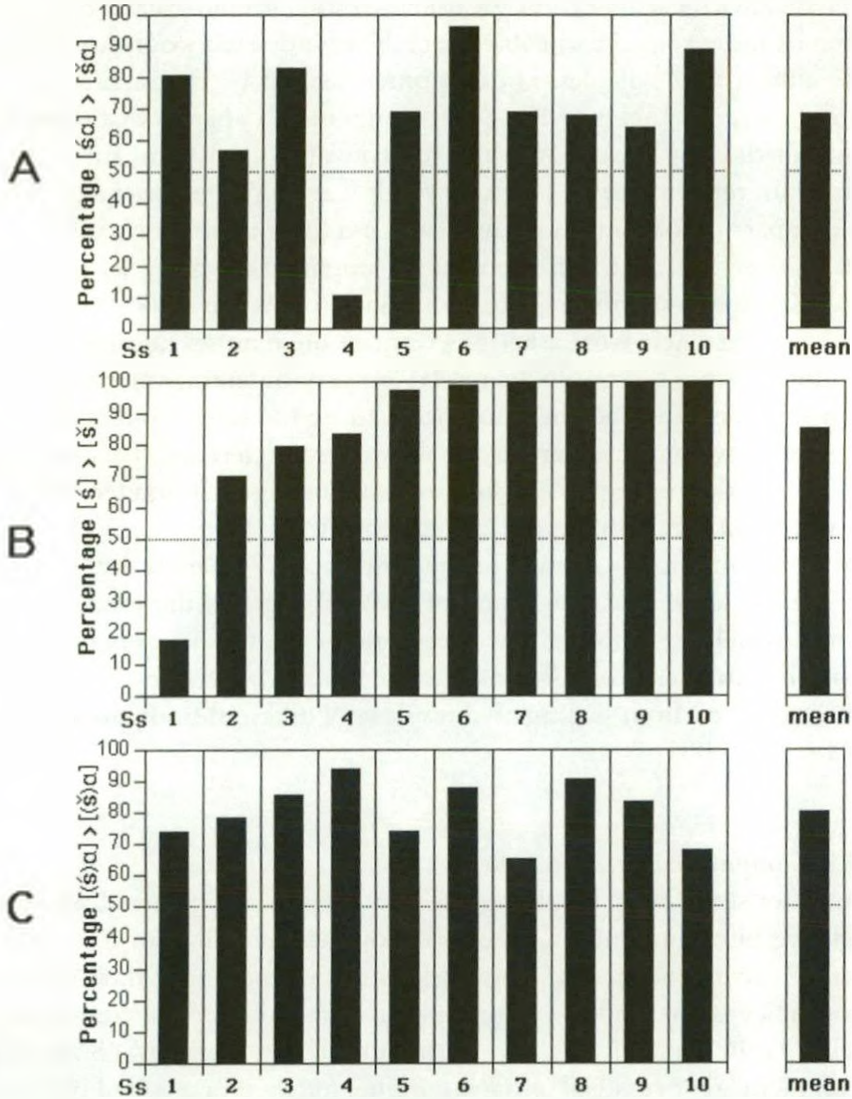

Figure 5. Comparative pitch judgments of 10 Ss, each of whom recorded 96 judgments per comparison. (A) judgments of full syllables, (B) judgments of isolated fricative noises, and (C) judgments of onsets of post-fricative residues.

5. Conclusions

From the identification tests it is clear that the Polish syllable [sa], whatever its phonetic differences from English [sa] might be, was readily identified as sa, but that test subjects did not reliably separate [śa] from [ša]. Their ability to distinguish [sa] from the other two appears to be largely a matter of identifying the [s]-noise, although the post-[s] signal may also have contributed something to its identification. But in the case of [śa] vs [ša] the failure to apply the ś and š labels consistently is not matched by a similar inability to separate either the noise or the vocalic components of the two syllables, when these were presented separately. The distributions of labeling judgments of both the isolated [ś] and [š] noises show a significant bias in favor of the correct responses, while the post-[š] and post-[ś] intervals were even more successfully identified. It is not immediately obvious why the two shibilant noises should be better identified when the following vowels with their information-bearing transitions have been deleted, or why deleting the initial shibilant noises should yield residues that were even better separated perceptually. To be sure, the observation that in English there is no phonological contrast like that of the Polish shibilant distinction must have relevance to the finding that English-speaking listeners fail to sort the Polish syllables [śa] and [ša] into distinct categories, as does the fact that both shibilants may be identified more or less equally (?) with English [š]. These two facts, when taken together, might be taken to serve as an adequate explanation of our listeners' failure to distinguish between the [śa] and [ša] syllables (cf. Best 1995). However, given the absence of an [ś] – [š] distinction in English, how do we then explain their success in labeling the isolated [ś] and [š] noises? Is it plausible to suggest that these signals (though not the full syllables, and surely not the isolated vowels[6]) were perceived psychoacoustically, i.e., that despite the ostensibly phonetic nature of the labels applied to them, the so-called speech mode of perception (Liberman and Mattingly 1985) was not brought into play in the performance of the labeling task required? In order to advance such an argument it would seem wise to find other evidence to support the view that isolated fricative noises are less speechlike than either the vocalic intervals or the full CV syllables. Perhaps the failure to separate the full syllables on the basis of fricative loudness is more prosaically explained by the fact that while the [š] noise was found to be louder than the [ś] noise, the post-[š] vowel was judged to have a weaker onset than the post-[ś] vowel, and in comparing the full syllables listeners were unable to focus attention strictly on the noise onsets. Moreover, in the case of the pitch judgments, the fact that the syllable [śɑ] was uniformly heard to begin at a higher pitch than [šɑ] is perhaps to be accounted for by the fact that **both** the isolated [ś] noise **and** the post-[ś] vowel onsets had the higher pitch.

Even if it is supposed that in their loudness and pitch judgments listeners were making psychoacoustic rather than phonetic evaluations of [šɑ] and [śɑ] and their components, it is still not clear that this forces us to accept the view that in the process of perceiving speech **as speech** there is a purely auditory stage. For it might reasonably be claimed that fricative noises, particularly in isolation, are no longer unequivocally speech, i.e immediately identified as the outputs of a human vocal tract in particular articulatory configurations, and are therefore amenable to the same psychoauditory processing as any other nonspeech acoustic signals. Of course, we have to be careful in trying to draw a sharp line between phonetic and auditory processing, since after all some phonetic distinctions drawn, e.g the one between "strident" and "nonstrident" fricatives and affricates that many phonologists draw (Chomsky and Halle 1968: 29) would suggest that auditory criteria **can** serve in phonetic classification, though one might wonder whether what the linguist is doing here has any connection with the usual processes of speech perception. The fact that the ś and š noises were more successfully separated on the basis of loudness when presented in isolation than when given in a speechlike context might be construed as evidence for the claim that processing acoustic signals as speech is very different from their auditory evaluation.[7] At the same time, however, we cannot at present deny absolutely that the auditory properties of pitch and loudness play any role in the phonetic classification of these fricative consonants, perhaps particularly by listeners for whom the difference is not a feature of their native language.

Acknowledgment

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Notes

1 Thus fricatives compared across different languages, though similarly spelled in IPA transcription, may be auditorily distinguished. For example, "[ʃ]" might be said to stand for somewhat different sounds and articulations in English, French, German, Polish and Russian.

2 In IPA transcription these Polish fricatives are represented as [sɕʃ]. The symbols ś š were used instead of ɕʃ by our subjects because they were found to be more legible as handwritten test responses.

3 Delattre (1965) points out transition differences between English and French [s], which he attributes to differences in tongue position and shaping. Perhaps (?) Polish [s] is more like the French.

4. However, there is no way of knowing from these data whether listeners would fail to distinguish between Polish [s] and English [s], or between Polish [š] and English [š].

5. The responses of two subjects had to be eliminated from consideration because they reported, and their responses suggested, that they had switched the symbols for the palatoalveolar and the alveolo-palatal fricatives in the course of testing.

6. Under direct questioning, three very experienced linguist-phoneticians who unerringly identified the post-ś signals as against the other two, agreed that the first were **phonetically** distinguishable by the presence of an initial "y" glide.

7 Ladefoged made a similar point in questioning whether estimates of the loudness of isolated vowels were to be taken as judgements of 'heard speech' or of 'meaningless noises' (Ladefoged 1967, p. 39).

Accessibility and activation

Jacob L. Mey

tilegnet
i taknemmelighed og venskab
den mest tilgængelige af alle mine lærere
og med sine halvfems
super-aktiv som altid:
Eli

accessibility

accessibility is a quality of the mind
not of words or sentences
accessible is an open heart
one that listens and beats in unison

learning is by access given
a good teacher is an accessible teacher
one who shows where she got her ideas
in order to share them better with you

teaching is by access granted
reaching into the minds of the learners
accessibility is open understanding
actively removing all obstacles

accessible is being close:
close to oneself, close to others
close in openings, open in closings
accessible is being active
active in beginning, active in ending
living in access, active in living

always and everywhere

Various authors have raised the question how to determine the *accessibility* of a particular item in a stretch of text. Accessibility can roughly be described as the ease with which we, in a certain piece of text, establish the *reference* that determines a particular noun, pronoun (personal or relative), verb subject, and so on. Similarly, the general problem of securing reference of phoric phenomena (including anaphora and cataphora) can be defined in terms of accessibility, according to these authors (see especially Ariel 1992; Gundel & al. 1993).

Both Gundel and her colleagues and Ariel operate with the notion of *degrees* of accessibility, according to which certain items rank higher than others on a scale of co-textual identifiability; that is, some items in the text are easier to identify than others, when we look at the text environment surrounding them. The emphasis here is on those lexical items that can be identified in the *surface* structure of a sentence (such as noun phrases, pronouns, and so on). More *deeper*-lying textual questions (such as the problem whose 'voice' we are hearing in a certain stretch of text; see Mey 1999: chapter 5) are not taken into consideration in these authors' theoretical framework.

Furthermore, the textual features that do enter into consideration are conceived of as *linearly* ordered in the text according to the *prius ac posterius* principle (thus, in a language such as English, subjects are normally before their predicates, adjectives before their nouns; anaphoric and cataphoric references have a different co-textual orientation, and so on), whereas the ordering of *preference* is hierarchical along a scale of accessibility, with the number of scalar degrees ranking from 1 through 6 to 10.

This approach does not allow for a text being 'in motion': that is, the accessibilities are considered to crucially exist at one particular moment of analysis, and the time dimension (as manifested in the development of a narrative) is not taken into account. The underlying rationale here is that, in principle, the Saussurean tenet of the linearity of the signifier (1916:170) does not permit taking into account the possibility of accessing two signifying units at the same time (as in prolepsis) or of collapsing or anticipating different signifiers (as in spoonerisms). Both tendencies are exemplified in the immortal expression created by a certain Fr. Battle, an Episcopalian priest taking a University of Texas undergraduate syntax course back in the sixties who, when asked to present to the class a 'structural description' of Biblical Hebrew, came up with what he named a 'scriptural destruction' of the language.

By no coincidence, any discussion of *linearity* itself, seen as a matter of accessing the text, bases itself also firmly on scriptural grounds. Not only in the stricter sense, in which the word is said to represent the Word of God, the Divine *lógos*, recapitulating the beginning and end of everything, as epitomized in the first and last letters of the alphabet: 'Alpha and Omega', but also in more superficial ways; as an instance, consider activities such as counting by way of letters (as in Greek, Hebrew, and other languages). Deep or superficial, the principle distinguishes itself by the disregard it inspires for possible other ways of thinking, ways that could offer us a different take on the question of linearity: a non-linear approach, maybe even a 'principle of non-linearity'.

In the study and teaching of reading, the controversy between a linear, 'letter by letter' approach, as contrasted to a 'holistic' method (which takes in larger units at a glance; most certainly the favored technique of normally advanced readers) still rages in grade school PTA meetings and teacher coffee rooms. Compare to this that already thirty years ago, the French linguist and pedagogue Victor Henry argued (in a little known article; my reference is due to Hutton 1999:127) that even at the phonemic level, linearity has to be rejected in principle. For Henry, time does not 'fly like an arrow':

> … le temps est plutôt conçu … comme un contenant universel, un milieu indéfini, qu'une ligne est absolument incapable de figurer. (Henry 1970:88)

Evidently, on the level of *langue*, where the sign joins signified and signifier, the apperception of linguistic units does not follow the time pattern of phonetics, prescribed by the *parole*-based constraints of the articulatory process ('one cannot say two words at a time', maintains Saussure). Rather, we are dealing with a 'block apperception' (Henry 1970:92), more or less in the sense of a Gestalt, where units do not only overlap, but are produced and perceived simultaneously in psychological reality, albeit staggered in real (i.e. physical) time.

In another approach to the same problem, suggested by Hajičová (1997), time is considered as creating a further dimension, so to speak, one that is orthogonal to what is basically a linear production of linguistic units. Such a temporal 'depth' is part of a functional model of text representation within the general framework of the Prague School's 'topic-focus'-articulation. Hajičová defines a process of 'activation', by which certain textual items are brought forward, activated, as 'topics' to be 'focused' on; subsequently, these items are allowed to fade out again, in accordance with the development of a particular narrative, or stretch of narrative.

In this way, the *dynamics* of text production and interpretation can be accounted for (at least to a certain degree): what the text is 'about', and what items are 'accessible', at any given point of textual space and time, need not always be the same, subject to a law of constant identity. As we read on, the text may shift before our very eyes: its focus may change or its topics vary. Interesting examples of such shifting (where the text's voices are 'undone', the text 'unvoiced') are found in such modern authors as Julio Cortázar (e.g. 1976) or Kazuo Ishiguro (1996; cf. Mey 1999, chapter 7.3).

One problem which Hajičová's model shares with earlier representations is that its emphasis, too, is on *single* items, not on entire stretches of text. Moreover, only noun phrases and nouns are considered; the crucial role of verbs in producing text cohesion is not taken into account. Still, the activation of an item (its being brought to the center of attention), and hence its accessibility (in terms of identifiability of reference) are correctly considered from the viewpoint of the dynamic flow of the text as it unfolds in narrative, rather than from a fixed observation point on a line, linearly proceeding in Saussure's 'synchronic' dimension. But even though Hajičová thus correctly assesses accessibility as not being a static, but rather a dynamic concept, exhibiting a variation of degrees depending on what happens in the (co-)text surrounding it, she still leaves out the wider (textual and contextual) implications that are always present in the narrative.

Stressing and generalizing the dynamic aspects of Hajičova's notion of 'activation' (as opposed to the static concept of 'accessibility') will allow us to include the total context of narrativity as being 'activated'. This extension of the notion carries with it the advantage of enabling us not only to properly model the readerly activity that is at the basis of the processes of establishing reference, anaphora, and the other intra-textual connections; it also allows us to take into account the entire situation in which the reader is placed, and his or her *activation as a reader*, by considering such readerly activities to be instantiations of the 'pragmatic act of reading', as I have defined it elsewhere (Mey 1999, chapter 10.4.3; Mey 2000, chapter 9.5).

In a general perspective, too, the entire scene on which the various actors come and deliver their speech, and from which they retreat again into the backdrop of 'de-activation' (a metaphor suggested by Eva Hajičová in personal communication) is more easily established within the framework of 'pragmatic acts' or *pragmemes* (Mey 2000, chapter 8.4.2). What is required for such a perspective to be valid depends, in the final consideration, on the *situation* (not just the immediate *co-text*, but also the *con-text*, as it is usually understood). For this reason, an approach which in principle, and explicitly, considers the situational determination of the text by taking the entire textual situation as its point of departure, has better chances of delivering a satisfactory account of the various factors that play into the understanding of a text, than one that restricts itself to one of the established, more syntactically oriented frames of analysis (including the earlier mentioned, venerable notions of 'topic' and 'focus').

In the following example, the pragmatic act of 'referring' is made possible only through reference to such a total context.

[A woman, Jean, is talking to her married daughter who has come to her to discuss a relationship she is considering having with another man].

'It will pass,' Jean said. 'Everyone gets the fidgets, it's usually about forty but perhaps you are having them early. Don't give him biscuit dear, or he asks all visitors.'
'He'd better have that bit, he's licked it—'
Jean shooed the terrier into his basket and came back to say, ...
(Joanna Trollope, *The Choir*, p. 186)

In this excerpt, the references to 'him' and 'he' are unclear initially, since they do not make sense in a narrowly defined co-text. Even so, the entire situation is one in which one may expect a dog to turn up and ask for biscuits. In fact, two pages earlier the author has told us that Jean »had a dog, a garden, a bridge four and an old school friend to go on holiday with to the Scilly Isles« (*ibid.*, p. 185). However, that information remains below the surface, so to speak, encapsulated in the total situation in which the conversation takes place. Rather than talking about a 'cataphoric' reference, therefore (which would be a regular, linguistic way of explaining the third singular masculine pronouns in the excerpt: as referring to an item in the text which follows, rather than precedes, the reference), I prefer to appeal to the entire context in which the conversation takes place, as well as to our general understanding of that situation. Such an understanding actively calls forth the image of two people having tea and a conversation; what happens next is entirely normal and expected in that situation: some companion animal comes up to the table and begs to join, if not in the conversation, at least in the meal.

In reading, as in all textual activity, the importance of the user aspect of 'co-creation' is paramount (see Mey 1999, chapter 10.4.3.2). It is our readerly user competence which activates or deactivates the items that have been introduced into the narrative at a certain point, and thus explains, rather than presupposes, the referential mechanisms that are at work throughout the text. The pragmemic approach, which explicitly builds on the activation of the user in the situation as one of the components of the pragmatic act (the other one being the co(n)-text), is therefore eminently suited to explain the readerly co-creation that characterizes the activity of reading. Features like 'world view' (Hajičová's 'stock of shared [situation or] dialogue knowledge'; 1997:15,17), translate, within this framework, into the *affordances* (Mey 2000:405-406) that are available to the individual reader at any given instant of the reading process. These features and affordances are not confined to the text as such, or to an isolated speech act, but take the whole gamut of reader activation into account.

The notion of 'pragmatic act' (or 'pragmeme'; Mey 2000, chapter 8.3) does not do away with time-honored concepts such as 'speech act', or 'topic' and 'focus'; applied to *reading*, it organizes the contributions of these notions to our understanding of the reading process, by pointing out how they collaborate, under the direction of an active reader, to help create the text as it is being understood in a concrete, worldly, and readerly relevant, context, and thus, in an extended use of the term, make the entire text more *accessible* to the *active* (and activated) reader.

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Durational phenomena in an apocopating dialect

Peter Molbæk Hansen

1. Introduction

The investigation reported in the present paper was carried out some 20 years ago when I was engaged in the phonology and phonetics of West Danish dialects. For various reasons the material has never been published before, but I think the results are of interest both to Danish dialectology and to diachronic phonology/phonetics.

2. Background

The Jutlandic apocope, i.e. the deletion of word final unstressed vowels, probably via reduction to shwa, is generally assumed to have taken place in the so-called Older Middle Danish period of Danish language history (Skautrup 1944:224 ff). Judging from modern Jutlandic dialects the apocope does not seem to have caused a general merger between words of pairs such as *hav* 'sea' – *have* 'garden', *kan* 'can' – *kande* 'jug', *hest* 'horse' – *heste* 'horses', etc. which can be assumed to have formed minimal pairs before the apocope, the only (phonological) difference being presence vs. absence of shwa. Such words still form contrastive pairs in (conservative) Standard Danish, and for ease of presentation such potentially minimally distinct words are henceforth rendered in Standard Danish orthography in cases where phonetic detail is not essential. In what follows Old Danish monosyllabic words which were not affected by apocope (and which are still monosyllabic) will be referred to as type I words, and words becoming one syllable shorter (in most cases monosyllabic) thanks to the apocope will be referred to as type II words. There is considerable variation in the treatment of type II words in modern Jutlandic dialects. Ringgaard (1958a), Nielsen (1959), and Fischer-Jørgensen (1982 with references) give detailed descriptions of the various reflexes of type II words in the Jutlandic dialects. But I will briefly state the most relevant facts here.

In the Eastern Jutlandic dialects there is now complete merger between potentially minimally distinct words of the two types in question in cases where a short stressed vowel is followed by one or more obstruents: *drik* '(a) drink' = *drikke* '(to) drink', *lap* '(a) patch' = *lappe* '(to) patch', *let* 'easy' = *lette* '(to) ease', *kys* '(a) kiss' = *kysse* '(to) kiss'. In this group of dialects (spoken in the central and northern parts of East Jutland, i.e. the districts around the towns Århus and Randers, and the eastern part of Himmerland south and southeast of Ålborg) there has been a tendency, however, to form plurals of nouns like *stok* 'stick'with the suffix *-er*, (phonetically now [ʌ]) instead of the inherited suffix *-e* (now long since apocopated), so that merger between singular and plural forms is avoided in this morphological context, cf. Standard Danish *stok* 'stick' – *stokke* 'sticks'. (see e.g. Lyngby (Bjerrum 1942)).

In West Jutland and the western parts of Himmerland the merger in this type of words (short vowel + obstruent) is only complete in words in which the postvocalic obstruent is an unvoiced fricative (f or s). In words with short vowels followed by stops a particular glottal modification "West Jutlandic stød" has developed in type II words, so that *stok* and *stokke* etc. are still commutable in these dialects. In West Jutlandic the West Jutlandic stød also distinguishes words like *hjælpe* 'to help', *banke* 'to knock' from the corresponding old monosyllables *hjælp* 'help', *bank* 'knock' (imperative). i.e. in words with a sonorant or a semivowel between the short vowel and the stop (Ringgaard 1960).

In North Jutland (Vendsyssel) vowel lengthening has generally taken place in type II words with originally short vowel regardless of their segmental buildup.

In central East Jutlandic dialects type II words with difthongs and short vowel followed by a single sonorant are also reported (by Jensen 1944) to be indistinguishable from their old monosyllabic type I counterparts in cases where the latter are stødless in these dialects: *kan* 'can' = *kande* 'jug', *vej* 'road' = *veje* 'roads', *hav* 'sea' = *have* 'garden'. This is also reported to be the case in words where the voiced phase (diphthong or short vowel + sonorant consonant) is followed by one or more obstruents as in *hest* 'horse' – *heste* 'horses', *hjælp* 'help' – *hjælpe* 'to help'.

In this respect Himmerlandic as spoken in the 19th century according to K. J. Lyngby (Bjerrum 1942) has an intermediate position between western and eastern dialects: It goes with the western dialects of Jutland in maintaining the difference between the two word types in all cases involving a diphthong or a short vowel + a sonorant consonant (and in the western part of the region by maintaining the difference also in cases involving a short vowel + a stop), but it goes with the eastern dialects of Jutland in merging the two word types in other cases, i.e. in cases involving a short vowel + an unvoiced fricative, (and in the eastern part of the region in merging the two types also in cases involving short vowel + stop).

According to the literature on Jutlandic dialects this state of affairs was true of the "classic dialect period" (as I call the period represented by dialect speaking persons typically born one or two decades before 1900) so meticulously investigated and described by Danish dialectologists in the mid 20th century (Jensen 1944, Ejskjær 1954, Ringgaard 1960, Jul Nielsen 1968, and others). The facts of the classic period can be exemplified schematically as in table 1 (not taking the northern and northwestern dialects into account).

In Himmerland the situation at the time of the investigation (in 1979) seems to have been in a flux. I regard my first language as representative of a south eastern variety of Himmerlandic (without West Jutlandic stød). In this dialect as spoken by my own generation (I was born in 1946) there was no longer any length distinction between words of the relevant types involving a diphthong or a short vowel +

	W	WH	EH	CE
kys – kysse				
[	g̊ʰys	g̊ʰys	g̊ʰys	g̊ʰys]
[	g̊ʰys	g̊ʰys	g̊ʰys	g̊ʰys]
stok – stokke				
[	sd̥ʌg̊	sd̥ʌg̊	sd̥ʌg̊	sd̥ʌg̊]
[	sd̥ʌˑg̊	sd̥ʌˑg̊	sd̥ʌg̊(ʌ)	sd̥ʌg̊(ʌ)]
let – lette				
[	lɛd̥	lɛd̥	lɛd̥	lɛd̥]
[	lɛˑd̥	lɛˑd̥	lɛd̥	lɛd̥]
hvalp – hvalpe				
[	hʷalb̥	hʷalb̥	hʷalb̥	hʷalb̥]
[	hʷalˑb̥	hʷal:b̥	hʷal:b̥	hʷalb̥(ʌ)]
vej – veje				
[	vɛj	vɛj	vɛj	vɛj]
[	vɛj:	vɛj:	vɛj:	vɛj]
kan – kande				
[	g̊ʰan	g̊ʰan	g̊ʰan	g̊ʰan]
[	g̊ʰan:	g̊ʰan:	g̊ʰan:	g̊ʰan]

Table 1. W = West Jutlandic, WH = West Himmerlandic, EH = East Himmerlandic, CE = Central East Jutlandic.

a sonorant consonant (henceforth I will refer to these types of structures as the VP (voiced part)), so in this respect my native dialect goes with the central East Jutlandic dialects. But I was made aware of the length distinction by several persons born in the first two decades of the 20th century who claimed to make this distinction and who demonstrated it orally to me (quoting a few minimal pairs) in a convincing way.

Since the distinction between the two types of words was quite alive in the speech of people only 20–40 years older than me, and since this was in line with the reports of K. J. Lyngby on the state of affairs in

Eastern Himmerlandic of the mid nineteenth century, the following questions seemed to me of interest:

1. What are the acoustic-phonetic properties of the distinction? Is it basically a lengthening of the postvocalic sonorant consonant (including the last part of a diphthong) as described by other dialectologists for other dialects with this distinction? Or are tonal characteristics involved? (cf. that K. J. Lyngby referred to type II words as having RULLENDE TONEHOLD = 'rolling intonation'.

2. Is the distinction subject to contextual restrictions? One might, for instance, imagine that the distinction was possible only in words where the VP was word final, i.e. in pairs like. *vej – veje*, *kan – kande*, but not in pairs like *hvalp – hvalpe*, *hest – heste*.

3. Is the distinction subject to lexical/grammatical restrictions? One might, for instance, imagine that the distinction was only used in certain morphological contexts where its functional load was considerable, e.g. in singular vs. plural of nouns like *stok* 'stick', *kat* 'cat',but that type II was not used in e.g. infinitive forms like *bande* '(to) swear' which originate from apocopated words but do not normally have type I counterparts, cf. that imperatives with stød basis, e.g. *band!* 'swear!' have stød in this dialect just like the corresponding forms in Standard Danish.

4. What is the phonetic difference between type II words and genuine disyllabic words of the same segmental structure (henceforth referred to as type III words)? Cf. triads like *kan* 'can' (verb) – *kande* 'jug' – *kanden* 'the jug' (in which the written d is mute, and the [ə] represented by the written e is apocopated in type II and totally assimilated to n in type III) and *saks* 'pair of scissors' – *sakse* 'pairs of scissors' -*saves* 'is sawed' (the letter sequence spelled *ak* is pronounced as a diphthong. [ɑu̯]). This question is of some interest to the typology of phonetic/phonological change of the (prosodic) kind in question, and also to a comparison with the ongoing apocope-like change in modern Standard Copenhagen Danish, which is called shwa assimilation by Brink and Lund (1975). If shwa assimilation will shortly lead (or in

some varieties of Copenhagen Danish already has lead) to a complete merger of words like *kande* 'jug' – *kanden* 'the jug', as claimed by Brink & Lund (1975 vol. I:202), then the mechanism must be different from the apocope of the Jutlandic dialects where type II and type III words seem to have been kept distinct after the apocope for 6 or 7 centuries. Grønnum and Basbøll (forthcoming) show that there is a clear difference in Standard Danish (in the duration of the nasal) between *dame* and *damen* and betweeen *længe* and *længen*, but in *damen* and *længen* the nasal phase reflects a sequence of two heterorganic nasal consonants, at least at a morphophonemic level, which is not the case with *kanden*.

In order to investigate these questions the experiment reported in the following sections was carried out.

3. Material, subjects, and recordings

3.1 Material

The material chosen was the following words grouped in 5 series. The phonetic transcriptions reflect my own pronunciation, i.e. one in which type I and type II words with identical segmental structure are not distinguished.

SERIES 1 (VP unsegmentable (diphthongal) and word final):
Type I *lag* 'layer' [ˈlɑu̯]
Type II *lave* '(to) make' [ˈlɑu̯]

SERIES 2 (VP segmentable and word final):
Type I *kan* 'can' [ˈg̊ʰan]
Type II,1 *kande* 'jug' [ˈg̊ʰan]
Type II,2 *bande* '(to) swear' [ˈb̥an]
Type III *kanden* 'the jug' [ˈg̊ʰann̩]

SERIES 3 (VP followed by a stop):
Type I *hvalp* 'puppy' [ˈhʷalb̥]
Type II *hvalpe* 'puppies' [ˈhʷalb̥]

SERIES 4 (VP followed by a fricative):
Type I *saks* 'pair of scissors' ['sɑu̯̽s]
Type II *sakse* 'pairs of scissors' ['sɑu̯̽s]
Type III *saves* 'is sawed' ['sɑu̯̽əs]

SERIES 5 (VP followed by fricative + stop):
Type I *hest* 'horse' ['hɛi̯̽sd̥]
Type II,1 *heste* 'horses' ['hɛi̯̽sd̥]
Type II,2 *bedste* 'best' (definite form) ['b̥ɛi̯̽sd̥]

3.2 Subjects

The (now deceased) subjects were:
MMH, male, born 1902.
AVH, male, born 1909.
TH, female, born 1913, married to AVH.

They all spoke Himmerlandic as their native and daily language. MMH had the West Himmerlandic feature of West Jutlandic stød in type II words with short vowel + stop. AVH and TH were clearly representative of East Himmerlandic in this respect. This difference was not thought to influence their treatment of the test words since these did not include the type short vowel + stop.

3.3 Recordings

The test words were placed in plausible test sentences where they would appear under main (non-focal) stress, and care was taken to design the phonetic context of each test word in such a way that an acoustic segmentation would be possible. The recordings were done in the following way: I read each sentence aloud in my own pronunciation, and the subject repeated the sentence. This procedure was thought to be satisfactory, given the fact that there is no (standardized) way of rendering dialects in orthography. The danger that subjects would (unconsciously) emulate my pronunciation (and thus deviate from their own pronunciation habits) turned out to be non-existent. The results clearly show that all subjects used their own language in the relevant prosodic respects (i.e. that they made distinctions not made by me, cf. section 3.1). Each subject produced the list of sentences (including distractor sentences) 5 times: forwards – backwards – forwards – backwards – forwards. The test material produced thus consisted of 14 × 5 × 3 = 210 recordings of test words. A semi-professional UHER cassette tape recorder was used, and the recordings were done in a drawing room which was acoustically reasonably well suited for the purpose (carpets and curtains).

4. Acoustic measurements

The following mingographic recordings of the signal were obtained:

1. A logarithmic intensity curve, HP-filtered at 500 Hz. Purpose: segmentation of single segments.

2. The positive half-wave of of a duplex oscillogram BP-filtered in a band corresponding to the subject's F0-range. Purpose: segmentation of voiced phases.

3. The negative half-wave of a duplex oscillogram. i.e. in reality a linear intensity curve, HP-filtered at 2000 Hz. Purpose: support of segmentation of single segments.

4. An F0-curve with input BP-filtered in a band corresponding to the subject's F0-range.

On the basis of the mingographic recordings the following measurements were done:

A. The duration of the word (in all test words).
B. The duration of the voiced part of the rhyme (in all test words).
C. The duration of the rhyme (in all test words).
D. The duration of postvocalic s (in ['sɑu̯s] I, ['sɑu̯s] II, ['sɑu̯əs] III, ['hɛi̯sd̥] I, ['hɛi̯sd̥] II, and ['b̥ɛi̯sd̥] II).
E. The duration of the closure of the final stops (in ['hʷalb̥] I, ['hʷalb̥] II, ['hɛi̯sd̥] I, ['hɛi̯sd̥] II, ['b̥ɛi̯sd̥] II).

F.The durations of [l] and [n] ([nn̥]) (in [ˈhʷalb̥] I, [ˈhʷalb̥] II, [ˈg̊ʰan] I, [ˈg̊ʰan] II, [ˈb̥an] II, [ˈg̊ʰann̥] III)
G.The durational distance from vowel onset to the first minimum in F0 (in all test words recorded by MMH and AVH).
H.The durational distance from vowel onset to the first maximum in F0 (always later than the first minimum; in all test words recorded by MMH and AVH).
I.F0 in Hz at the minimum and the maximum points

The accuracy of duration measurements was 1 cs.The accuracy of F0 measurements was 2 Hz.

5. Results

For each durational parameter the average, standard deviation and-standard deviation in % of the average were calculated for each subject, and statistical significance of the differences between corresponding parameters in the two word types likewise.

The dispersion of the data for each parameter for the same subject and the same intended word showed clear tendencies:

For almost all words the dispersion was least on the total duration of the word. In all words the standard deviation of the total word duration is less than 10% of the average.This is probably an effect of the well known tendency to compensate for unintended lengthenings or shortenings of early segments in a word by shortening and lengthening later segments (see e.g. Fischer-Jørgensen 1982).

The dispersion is also relatively small for the duration of the rhyme.

The dispersion is also small for those parameters which constitute an unsegmentable VP, i.e. the diphthongs [ˈɑu̯]and [ˈɛʎ̯].

The dispersion is largest for the parameters pertaining to single segments: vowels, l, n, s, and the stops. The segmentable VPs, i.e. the VPs of the words with [al] and [an], show a somewhat larger dispersion than the diphthongal VPs, but less than the single segment parameters. As for the difference between type I and type II the following statement holds: For all subjects at least one of the following parameters of a type I word is significantly shorter than the corresponding parameter of the corresponding type II word:

1. The total duration of the VP; or 2. The duration of the vowel; or 3. The duration of the voiced postvocalic consonant.

In the following subsections each series is treated separately.

5.1 *hvalp – hvalpe*

All three subjects show the same pattern (the female subject TH who is also the youngest to a somewhat lesser degree than the two male subjects): The VP is systematically longer in *hvalpe* than in *hvalp.* But the individual subjects distribute the extra duration in different ways: AVH puts most of the extra duration on the consonant, whereas MMH distributes the extra duration more evenly on the vowel and the consonant. AVH's average lengthening of the VP is 4.2 cs with 1.4 cs on [a] and 2.8 cs on [l]. MMH's average lengthening is 5.2 cs with 3.2 cs on [a] and only 2.0 cs on [l]. TH's average lengthening is only 2.1 cs with 1.7 cs on [a] and 0.4 cs on [l]. MMH has no significant difference between the total durations of the two words. This is due to a negative correlation between the duration of the VP and the duration of the p-closure. The average durations in cs of the VPs are as follows:

	hvalp	*hvalpe*
AVH	21.8	26.0
MMH	15.2	20.4
TH	12.9	15.0

5.2 *lag – lave*

The diphthongal phase is on the average longer in *lave* than in *lag* for all three subjects. The average lengthenings are 3.8 cs, 3.8 cs, and 4 cs for AVH, MMH and TH respectively. The average durations in cs of the VPs are as follows:

	lag	*lave*
AVH	18.2	22.0
MMH	17.2	21.0
TH	15.8	19.8

5.3 saks – sakse – saves

All three subjects show a clear distinction between the disyllabic type III word *saves* and the two other words, the VP being systematically considerably longer in *saves*. The difference between *saks* and *sakse* is rather clear for AVH, less clear for MMH and TH. For AVH the duration is systematically longer in *sakse*. MMH and TH show some overlapping both between the duration ofVP I and VP II and between the duration of [s] I and [s] II. But on the average the VP is a bit longer and [s] a bit shorter in type II, so that the total duration of the rhyme is almost the same in the two word types. In other words, both MMH and TH show the same tendency as MMH shows in *hvalp – hvalpe*, viz. that the extra duration of the VP is taken from the final obstruent. The average lengthenings of the VP are 4.0 cs, 2.4 cs cs, and 2.5 cs for AVH, MMH and TH respectively. The average durations in cs of the VPs are as follows:

	saks	*sakse*	*saves*
AVH	17.8	21.8	29.4
MMH	16.8	19.2	25.0
TH	12.5	15.0	20.8

5.4 kan – kande – bande – kanden

The disyllabic type III word *kanden* is clearly considerably longer than the two other words. The average lengthening of the VP of *kande* as compared wit the VP of *kan* is as follows: For AVH: 5.8 cs with only 1.6 cs on [a] and 4.2 cs on [n]; for MMH: 4.0 cs with 2.2 cs on the [a] and 1.8 cs on [n]; for TH: 6.5 cs with only 1.8cs on [a] and 4.7 cs on [n]. It is clear that *bande* goes with *kande* rather than with *kan*. This should be expected if there has been no lexical/morphological interference (cf. question 3 in section 2) since both *kande* and *bande* are apocopated words. The average durations in cs of the VPs are as follows:

	kan	*kande*	*bande*	*kanden*
AVH	18.8	24.6	23.8	34.6
MMH	15.8	19.8	19.4	30.2
TH	12.0	18.5	20.0	30.4

5.5 hest – heste – bedste

The type II word *heste* is clearly longer than the type I word *hest* for all three subjects. (AVH's recording of *bedste* was discarded due to mispronunciation (the word was not fully stressed)). All three subjects show some overlapping both between the duration of VP I and VP II and between the duration of [sd̥] I and [sd̥] II, but on the average the VP is a bit longer and [sd̥] a bit shorter in type II, so that the total duration of the rhyme is almost the same. In other words, the treatment of these words is comparable to that of *saks – sakse*: cf. section 5.3: The extra duration of the VP is taken from the final obstruent(s). The average lengthenings of the VP are 5.6 cs, 4.8 cs, and 3.6 cs for AVH, MMH and TH respectively. The word *bedste* seems to group with *hest* rather than with *heste* as it ought to. This is obvious for TH in particular. This may be due to special treatment of superlatives. The average durations in cs of the VPs are as follows:

	hest	*heste*	*bedste*
AVH	19.4	25.0	-
MMH	15.0	19.8	16.8
TH	10.4	14.0	10.4

5.6 Graphical displays of durations

Figs. 1-3 shows the durational characteristicsof each word for each subject.

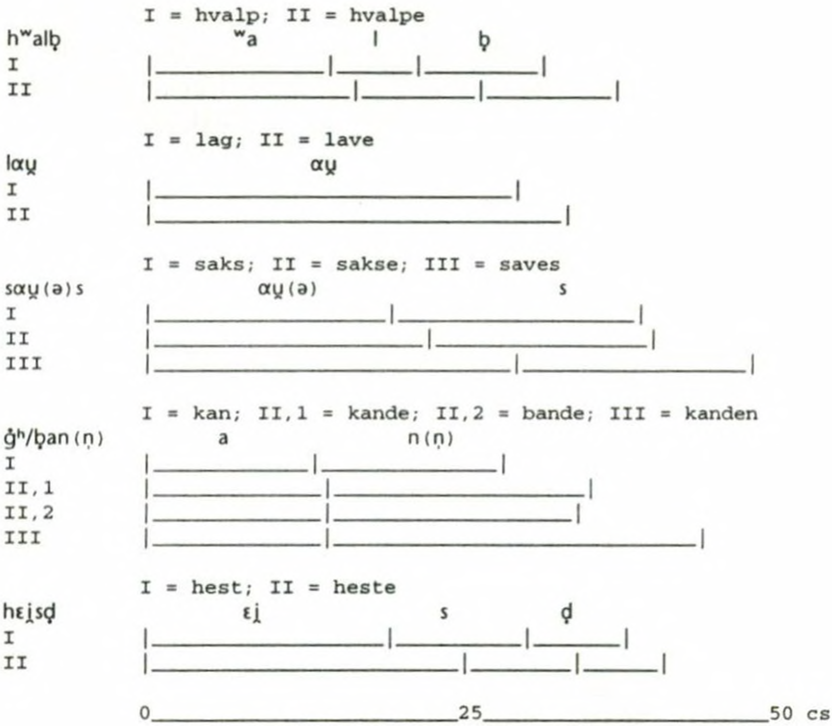


Fig. 1 Durations for subject AVH

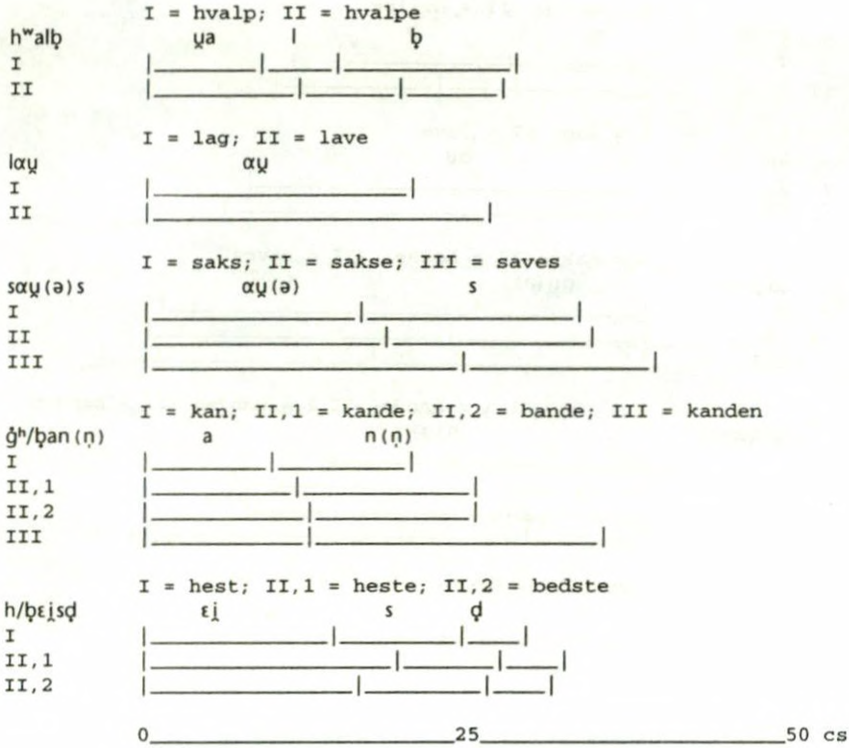
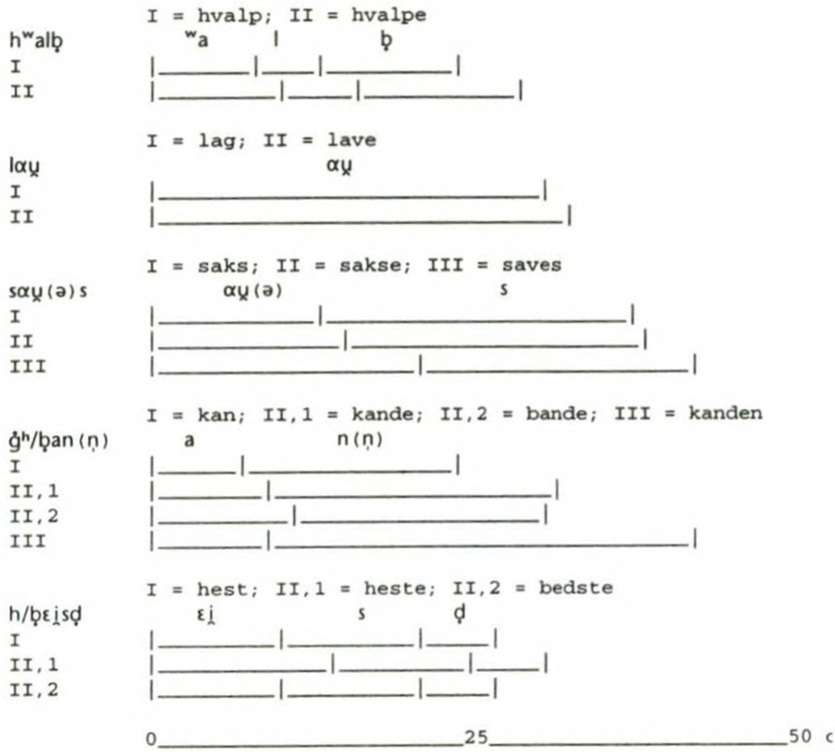


Fig. 2 Durations for subject MMH



6. F0-measurements

F0 in Himmerlandic words shares with Copenhagen Danish the "hammocklike" falling-rising-falling contour with a trough near the beginning of the vowel of a stressed syllable, cf. e.g. (Grønnum 1992). Measurements of F0 at the first minimum after vowel onset and at the following maximum, and measurements of the timing of these two points in relation to the segmental structure were carried out. These measurements showed no significant difference between the three word types, and I will not comment further on them here. But it should be noted that this finding is in line with the facts of Standard Danish (Grønnum 1992).

7. Conclusion

The main results of the (old) investigation reported here are the following:

1. Old Danish disyllabic words apocopated in Jutlandic dialects in medieval times were still distinguishable from corresponding old monosyllabic words with identical segmental structure in the speech of Himmerlanders born in the beginning of this century in words with a stressed diphthong or with a short stressed vowel followed by a voiced consonant ([l] or [n]).

2. The distinction is maintained independently of the presence or absence of obstruents after the voiced phase.

3. The distinction is one of duration, the apocopated words being systematically longer than the old monosyllables.

4. The distribution of the extra duration of apocopated words of the relevant structure varies between subjects, at least in cases where the voiced phase of a stressed syllable can be segmented, as in words with [al] and [an]. Either most of the extra duration is placed on the postvocalic voiced consonant, or it is distributed more evenly over the vowel and the consonant.

5. No systematic difference exists between the F0-contours of the two types of word. Thus, unless this phenomenon is of recent age, Lyngby's RULLENDE TONEHOLD seems to cover just the longer duration of type II words.

6. In cases where the voiced phase of old apocopated words of the type in question is followed by one or more obstruents there seems to be a negative correlation between the duration of the voiced phase and the duration of the obstruent(s), so that the total durations of the (rhymes of the) two types of word may show considerable overlap.

7. Genuine disyllabic words with a segmental structure (almost) identical with the segmental structure of apocopated words were clearly

and systematically distinguishable from (phonetically considerably longer than) apocopated words. This is also true of the speech of younger speakers of the dialect.

8. The data suggest that at least apocopated infinitive forms follow the same durational pattern as other apocopated words, although they do not typically form minimal pairs with corresponding monosyllables.

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Acoustic VC transitions correlate with degree of perceptual confusion of place contrast in Hindi

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1. Introduction

Speech sounds must be (a) different from their neighboring sounds (a syntagmatic requirement) and (b) different from all the other sounds that might have appeared in the same context (a paradigmatic requirement). Common cross-language sound patterns manifesting such constraints suggest that they arise from physical phonetic factors, the only thing common to all languages. For example, for a syntagmatic constraint, in English (and many other languages (Kawasaki 1982; Ohala & Kawasaki-Fukumori 1997)) in native vocabulary the labial-velar approximant [w] fails to occur as C2 in syllable initial consonant clusters where C1 is [labial]. This is presumably motivated by the fact that the consonantal transitions from a labial consonant create a formant trajectory that is too similar to that of a [w] to be reliably differentiated from it. Thus, although /w/ is otherwise paradigmatically distinct from other approximants that can appear in C2 position, i.e., /j l r/, it is syntagmatically too close to other labials. Similar acoustic-perceptual factors account for paradigmatic phonological constraints. For example, distinctive pharyngealization in Arabic is manifested more easily on coronal consonants than labial or velar (in other words, pharyngealization's distinctive lowering of F2 is not as easily detectable on segments like labials and back velars that already have a low F2 (Ohala 1985)). Thus by most analyses of Arabic, only coronals exhibit distinctive pharyngealization (Ghazeli 1977). The acoustic-perceptual constraints on speech sounds' distinctiveness impacts on a number of issues.

First, how capacious is the 'phonological space'?[1] From cross-language studies it is possible to derive a notion of the "usual" or modal number of contrasts one can expect in certain features (Maddieson 1984). For example, vowel height typically has three contrasts and VOT typically has two. Fewer or more contrasts than these are possible but if more than the modal number are used one expects some "cost", e.g., in the production domain where tighter control of relevant phonetic parameters may be required (thus requiring no extra cost at the perceptual level) or in the perceptual domain where the cost may be more confusion between the relevant sounds (and thus implying no extra cost at the level of production). (See also Zipf 1935; Lindblom & Maddieson 1988; Lindblom 1984, 1989.)

Second, the fact that the set of multiple acoustic cues differentiating most features may be different in different environments would predict that there should be context-specific constraints on features. For example, stop bursts contain important cues for their place of articulation (Fischer-Jørgensen 1954) but for aerodynamic reasons they only have bursts upon their release, not on their onset. The presence of these cues only upon release may explain in part why CV syllables are more common than VC (J. Ohala 1995) and why stop place is often neutralized in coda position or why medial heterorganic stop clusters yield a stop (geminate or singleton) that has the place of the C2, the stop that had the release, e.g., Late Latin /nokto/ > Italian /not:e/ 'night' (Ohala 1990). Ohala (1975) and Ohala and Ohala (1993) speculated that the reason why there are often more place contrasts among nasals in post-rather than pre-vocalic position (contrary to the pattern for obstruents) is because nasals have greater velopharyngeal opening post-than pre-vocalically, and since the strength of the spectral differences differentiating nasals by place depend on the degree of nasal-oral coupling. (See also Ohala & Kawasaki 1984, Ohala 1992, Ohala & Kawasaki-Fukumori 1997.)

One might suppose that paradigmatic and syntagmatic similarity would especially be a problem in languages that supported a relatively large number of contrasts. Hindi, for example, has 34 consonant distinctions, not counting singleton (short) vs. geminate (long) contrasts. Among stops (including affricates) it has four laryngeal distinctions (voiced, voiceless, voiceless aspirated, and breathy-voiced) and five place distinctions (labial, dental, retroflex, palatal, velar) (M. Ohala 1994). Table 1 lists the segments of Hindi and Table 2 presents a minimal set showing the five place contrasts in coda position.

p	t	ʈ	t͡ʃ	k	
pʰ	tʰ	ʈʰ	t͡ʃʰ	kʰ	
b	d	ɖ	dʒ	g	
b̤	d̤	ɖ̤	d͡ʒ̤	g̈	
f	s		ʃ		
	z				
m	n			ŋ	
ʋ			j		h
	ɾ	ʈʈ̈			
	l				

Table 1. Consonant inventory of Hindi (excluding geminates).

pip	*pus*
pit̪	*yellow*
piʈ	*beat (verb)*
pitʃ	*raised garden row*
pik	*spit (betel juice)*

Table 2. Hindi words (and their English translations) showing contrast of five places of articulation in stops in coda position.

Hindi thus presents opportunities to explore this issue along with a related issue brought up by a recent claim of Steriade (1997) regarding the context where retroflex place distinction is most robust. Steriade starts with the view, similar to that of Ohala & Kawasaki (1984) and Ohala & Kawasaki-Fukumori (1997), that contrasts are "...permitted (or licensed) in positions that are high on a scale of perceptibility."

Most of her arguments are based on neutralization of certain laryngeal contrasts but, referring to a study by Dave (1977), she also considers the case of retroflexes and indicates that since the VC transitions of retroflexes are more prominent than their CV transitions, the position that should show more neutralization involving retroflexion is the onset (CV) position (i.e. word-initial or post-consonantally). (This is in contrast to other segment types where CV cues are said to be more prominent than VC.) Anderson (1997) finds support for Steriade's claims based on perceptual data from Western Arrernte intervocalic dental/alveolar/retroflex contrasts. She found that the vowel preceding the retroflex shows the most prominent formant transitions and these formant transitions increase correct identification more than is the case with alveolar stops.

The VC (rather than CV) context is, perhaps, an ideal testing ground for an investigation of the costs of accommodating more than the usual number of place contrasts because there are circumstances where the set of differentiating cues could be quite impoverished. The place of the C in a VC context has some cues at its onset, namely from the VC formant transitions, as well as from its offset, namely the release burst. However, in many cases the stops at least may be unreleased.

Thus if the 'cost' attached to this higher-than-modal number of place contrasts is paid in tighter control at the production level, one would expect to find lesser overlap of these place-cueing transitions. On the other hand, if the cost is paid in the perceptual domain one might expect a high level of confusion between these place contrasts.

If Steriade's hypothesis is correct one might expect better differentiation of retroflexion (vis-à-vis the other places of articulation) from the transitions alone in the VC context, both in production and perception.

We should first consider the evidence on the relative capacity of VC transitions to convey place distinctions in stops. In fact, the evidence from prior studies is mixed on this point. Sussman, Bessell, Dalston, & Majors (1997) found the locus equations (F2 value at the consonantal transition vs. F2 of the adjacent vowel) to be more variable in VC than in CV position. They review literature also showing that VC transitions afford poorer differentiation than CV transitions: Ahmed & Agrawal (1969) which, significantly, also dealt with Hindi, and Redford and Diehl (1999). The results of Wang & Bilger (1973) showed no overall difference in this regard between CV and VC contexts. On the other hand a number of earlier studies did show VC place cues more reliable perceptually than those at CV: Sharf & Hemeyer (1972), Sharf & Beiter (1974), and Ohde & Sharf (1977) found VC place cues more reliable than CV, even when played backwards, i.e., when they then appeared as CV transitions. They reject hypotheses that this result was obtained due to auditory constraints or listeners' experience, and rather advocated a theory that there was inherently more information on place in VC transitions.

Greenberg (1995) cites neurophysiological studies of neurons in the auditory cortex showing that with many neurons the response is greater for onset of a stimulus rather than its offset and speculates that this may account for the greater incidence and greater variety of syllable onsets rather than codas in languages of the world.

Studies involving the creation of medial heteroganic stop clusters through splicing, e.g., splicing the first half of [apa] and the second half of [aka] to yield the heterorganic medial cluster [apka], show that, in general, when the medial closure duration is kept short, listeners hear a single consonant, not a cluster, and the place cues are taken from the C2 consonant, i.e., the one that had the CV transitions (Dorman, Raphael, & Liberman 1979; Repp 1976, 1977a, 1977b, 1978; Fujimura, Macchi, & Streeter 1978; Ohala 1990; Beddor & Evans-Romaine 1995; Streeter & Nigro 1979). Wang (1959) demonstrated much the same by combining post-vocalic VC transitions with final stop releases from other stops. (These lab-based perceptual results mirror, in part, the sound changes exemplified by the Late Latin to Italian change of medial -C1C2- clusters to -C2C2- geminates, mentioned above.)

Reinforcing the above finding that place cues at stop release overshadow those in the VC transition are the findings of Householder

(1956) and Malécot (1958) that there are fewer errors in place judgements when final stops are released than when they are not.

In pursuing the above questions, we sought first to determine whether the VC transitions leading into the five different places of articulation in Hindi were sufficiently distinct. This is described in study 1. Then we sought to determine the perceptual distinctiveness of the place of these coda stops, both with their releases and without. This is described in study 2.

2. Study 1

In order to determine the character of the VC transitions leading into the 5 places of articulation in Hindi we did the following study. The specific questions addressed were: (a) Are these places cued similarly in different vocalic environments? (b) Are the five places of articulation well differentiated by formant transitions alone, i.e. without the benefit of stop or affricate releases? (c) Are the formant patterns characteristic of place similar to those found in other languages?

2.1 Method

Ten male native speakers of Standard Hindi were recorded uttering syllables of the form /pVC/ where V = one of the following vowels [i ɪ ɛ u ʊ a] and C = a voiced or voiceless (unaspirated) stop that was bilabial, dental, retroflex, palatal, or velar. (Again, the palatal stop is actually a palato-alveolar affricate.) These words occasionally happened to be real words; although most were nonsense words. The test words were read in one of two different random orders in the frame [vo___aja] 'he___came'. The utterances were recorded using high quality analog portable equipment and subsequently band-pass filtered at 68 Hz to 7.8 kHz and digitized at 16.7 kHz.[2] The analysis of the recordings from three talkers was done with the aid of waveform and LPC spectral displays produced by the CSRE™ speech analysis software and related programs. The VC formant transitions (the last 100 msec of the vowel) were extracted by the CSRE™ LPC-based formant tracking algorithm. The results presented in Figure 1 are for the most part based on 9 tokens (but never less than 7) per utterance (3 tokens × 3 speakers).

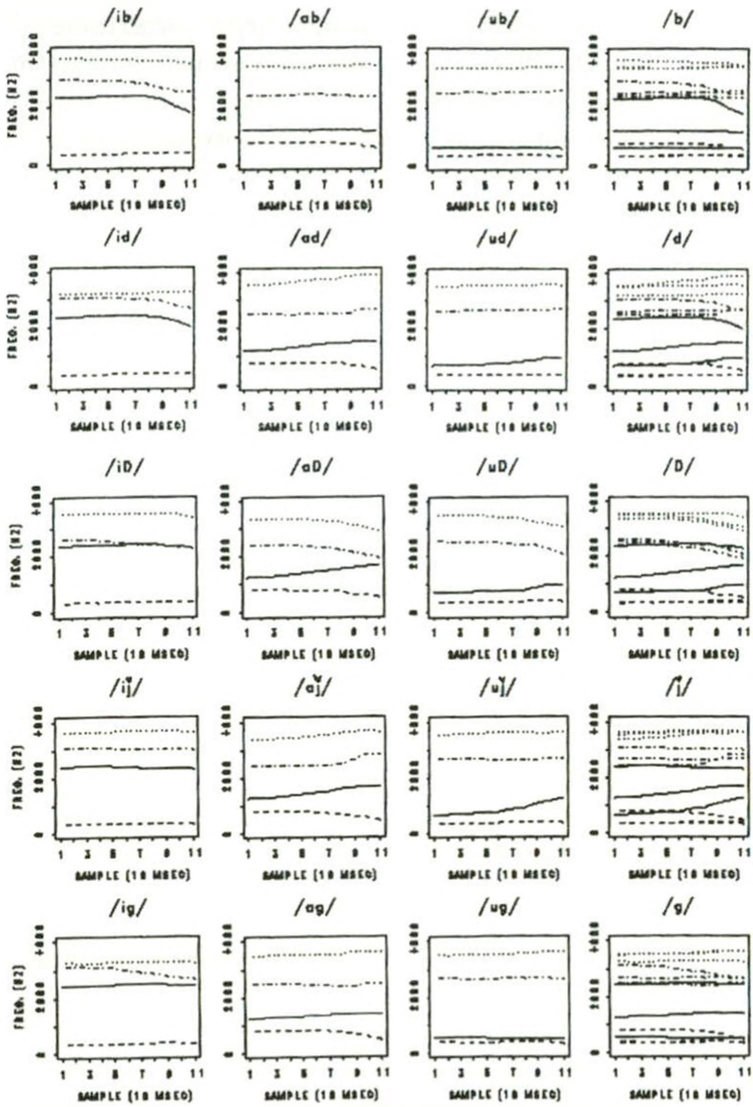

Figure 1. Formant tracks of various VC sequences in Hindi. Dashed line: F1, solid line: F2, dashdot line: F3, dotted line: F4. The symbol [D] stands for a retroflex stop. Rows: different places of articulation (labial, dental, retroflex, palatal, velar); Colums: different vowels (i, a, u); the last column superimposes the formant tracks from all three vowels. See text for furter details.

2.2 Results

Figure 1 gives a graphical summary of the averaged formant tracks for three vowels [i a u] before 5 different places of voiced stop (or affricate). (The results for [ɪ ʊ ɑ] were in general similar to those of [i u a] respectively and the patterns for [ɛ ɔ] were in general interpolated between those shown here, e.g., the pattern for [ɛ] is approximately in between those for [i] and [a]. Also, although the formant tracks for voiceless consonants are not given, they were similar to those of the voiced consonants.)

Some of the formant patterns conform to expectations (based on patterns seen in other languages):

- Labials show a lowering of F2 and F3 – except after back vowels where F2 and F3 were essentially flat.

- Dentals show a transition that ends in a mid-frequency region between about 1000 to 2000 Hz.

- Palatals show an elevated F2 and F3.

- Place distinctions are most different in the environment of the open vowel [a]; they show similarities and thus potential neutralization in the environment of the high vowels [i] and [u].

Some patterns of the transitions, however, are not expected, at least based on what has been previously reported for other languages:

- Although the velar stop shows some convergence of F2 and F3 in the environment of [i], it does not show this expected pattern after [a].

- The retroflex does show convergence of F2 and F3 in all vocalic environments.

There is also a considerable amount of overlap. Thus many transitions were visually quite similar in specific vowel contexts. Specifically the following were similar:

- Labials and dentals have similar transitions after [i].
- Retroflexes and velars have similar transitions after [i].
- Dentals and palatals are similar after [a] and [u].
- Labials and velars are similar after [u].
- Dentals and velars are similar after [a].

It is also interesting to note therefore that acoustic cues for place are highly variable and context dependent – even in a language with a crowded segment inventory.

The question arises: are there other parameters which carry the necessary place cues or are these places in fact highly confusable with their differentiation requiring a stop release with its rich place cues present? A perception experiment was designed to elucidate these issues.

3. Study 2

In this study we sought to determine how well the place of the five stops could be perceptually differentiated both with and without the final release burst.

Method

Stimuli: The recorded stimuli used was from the same data-base as the one mentioned above except one of the three speakers was different. (This was because one of the speakers from the first study often released his final stops into the vowel of the following word. Thus another speaker whose stop releases could be better isolated was selected.) In order to keep the size of the word list manageable only three vowels were used. Thus the stimuli was of the form /pVC/ where V = [i a u] and C = a voiceless unaspirated stop that was bilabial, dental, retroflex, palatal, or velar. The resulting tokens were of the sort [puk], [pap], [pitʃ], etc. (In the first study the final stops were voiced. Voiceless stops were used here because it facilitated the isolation of the final stop release. We don't believe the voicing of the final stops would have any significant effect on the overall trends in the results.) The data, digitized at 16 kHz after low-pass filtering at 8 kHz, were further processed to yield two versions of each word type: the "whole word" version, and a gated version that excluded the signal after the halfway point in the silence of the final stop, i.e., excluding the final burst. No part of the frame sentence was included. Thus the stimulus list contained 90 items: 3 vowels × 5 stops × 2 conditions × 3 subjects = 90. This 90 item word list was randomized and recorded on a tape with an interstimulus of 4 s. After every 5 tokens a 10 second gap was given (to allow subjects to find their way in case they lost their place on the answer sheet – although none did). Preceding the 90 item word list was a 10 item practice session to familiarize the subjects with the way the stimuli would sound, how long they would have to respond, and with the way they were to mark their answer sheet which gave the candidate answers in the Devanagari script. These 10 tokens were similar to the words for the main test except they were prepared from /pVC/ tokens where the C was voiced. Five were in the "whole word" format and 5 in the gated format. For these, too, there was a 4 s. gap between tokens. Between the 10 tokens of the practice session and the tokens of the main test there was a 20 second gap. This test was administered over headphones via a high-quality portable tape playback system in 21 subjects' homes in India.

Subjects and Procedures: The subjects were between the ages of 13-60; they could all read the Devanagari orthography. They were paid for their participation. They were provided with an answer sheet which listed the five final consonants [k tʃ ʈ t̪ p] in the Devanagari orthography for each of the 90 items of the test session as well as the practice session. The instructions to the subjects given orally in Hindi were as follows: The purpose of this experiment is to examine the intelligibility of speech in noisy conditions. You will be hearing words some of which are real words and some nonsense words. Some of the words will sound quite clear, for others the end might not be so clear. You should listen carefully and circle on the answer sheet the consonant that you think the word ends with. You **must** circle one consonant (and only one consonant) for each item even if you have to guess at what it is. There will be 4 second gaps between each item and longer gaps after every 5 items in order to help you find your place. We will start with a practice session in order for you to get used to the format. After the practice session if there were no questions we proceeded with the main test.

3.2. Results

i-gated	p	t̪	ʈ	tʃ	k	i-whole	p	t̪	ʈ	tʃ	k
p	90.5	7.9	0.0	0.0	1.6		95.2	4.8	0.0	0.0	0.0
t̪	54.0	36.5	6.3	0.0	1.6		4.8	71.4	23.8	0.0	0.0
ʈ	19.0	39.7	36.5	1.6	3.2		1.6	0.0	92.1	4.8	1.6
tʃ	20.6	39.7	11.1	11.1	17.5		0.0	1.6	17.5	76.2	4.8
k	3.2	11.1	0.0	0.0	81.0		0.0	0.0	0.0	0.0	95.2

Table 3. Confusion matrix (in percent) for /iC/; left: with release gated; right: with release intact. Correct response along diagonal.

u-gated	p	t̪	ʈ	tʃ	k	u-whole	p	t̪	ʈ	tʃ	k
p	92.1	6.3	0.0	0.0	1.6		84.1	6.3	9.5	0.0	0.0
t̪	3.2	90.5	4.8	1.6	0.0		31.7	65.1	3.2	0.0	0.0
ʈ	9.5	17.5	66.7	4.8	1.6		0.0	0.0	95.2	4.8	0.0
tʃ	3.2	50.8	3.2	38.1	4.8		0.0	0.0	0.0	95.2	4.8
k	49.2	0.0	3.2	1.6	42.9		1.6	0.0	1.6	0.0	92.1

Table 4. Confusion matrix (in percent) for /uC/; left: with release gated; right: with release intact. Correct response along diagonal.

a-gated	p	t̪	ʈ	tʃ	k	a-whole	p	t̪	ʈ	tʃ	k
p	92.1	4.8	0.0	1.6	1.6		93.7	4.8	1.6	0.0	0.0
t̪	9.5	81.0	6.3	0.0	1.6		0.0	90.5	9.5	0.0	0.0
ʈ	1.6	6.3	87.3	4.8	0.0		0.0	0.0	95.2	4.8	0.0
tʃ	3.2	54.0	7.9	25.4	9.5		0.0	0.0	0.0	95.2	4.8
k	3.2	19.0	0.0	0.0	73.0		0.0	0.0	0.0	0.0	95.2

Table 5. Confusion matrix (in percent) for /aC/; left: with release gated; right: with release intact. Correct response along diagonal.

The results are given in Tables 3-5 in the form of confusion matrices (in per cent).[3] The results from the gated condition are on the left and those from the whole word condition on the right. The original consonant categories are listed on the leftmost column and the response categories on the top row. Thus in Table 3, the intersection of the /ṭ/ row and the /p/ column (on the left side) shows that 54% of the responses to the gated /ṭ/ were /p/.

4. Discussion

Overall, the rate of correct place identification was 63% when the release burst was gated out but 86% for the whole word condition (χ^2 = 41.5, df = 1, p< .001). Only in the case of /pu/ and /ṭu/ were the identification scores less in the whole word condition than in the gated. The rate of 63% is far above chance but it amounts to greater than 1 error for every 3 stimuli. The stimuli here represent careful "laboratory" speech; one may guess that casual connected speech would have a much lower rate of correct identification of place were these sequences presented in isolation. Insofar as connected speech is intelligible, one must credit this to higher order redundancies, e.g., at the lexical, grammatical, semantic, pragmatic levels. We do not know what an "acceptable" level of intelligibility should be in a redundancy-free context such that communication will succeed in ordinary redundant situations.

The 37% errors in the gated stimuli were not distributed evenly. The /a/ context had the least errors (72% correct), then the /u/ context (66%) and the /i/ context had the most errors (51%). This difference is significant (χ^2 = 11.4, df = 2, p<.01) The major particular confusions in the gated condition, in descending order, were the following:

it̪	>	ip	54%
atʃ	>	at̪	54%
utʃ	>	ut̪	50.8%
uk	>	up	49.2%
itʃ	>	it̪	39.7%
iʈ	>	it̪	39.7%
itʃ	>	ip	20.6%
iʈ	>	ip	19%
ak	>	at̪	19%
uʈ	>	ut̪	17.5%

Understandably, the palatal stop (the affricate) is very poorly identified without its affricated release. It is most often confused with the dental stop. Confusion between /p/ and /t̪/ after /i/ is high as has previously been found by others (Plauché, Delogu, & Ohala 1997; Winitz, Scheib, & Reeds 1972) studying CV sequences, although in our data the direction of the confusion is the reverse from these earlier studies where it was the sequence /pi/ most often confused with /t̪i/. The confusion between /k/ and /p/ after /u/ is high and this, too, parallels previous findings (Winitz, Scheib, & Reeds 1972) (although in their case the confusion was largely symmetrical). From the listing above one sees that the most common responses in the errors were /p/ and /t̪/.

This asymmetry in the errors may be due to listeners expecting to hear a burst and, when they didn't, deducing that the stops must have had very low intensity bursts that were inaudible. Listeners presumably know from experience that /p/ and /t̪/, among all the stops, have the weakest bursts (due to the fact that they, unlike stops at the other places of articulation, have little or no downstream resonator serving to reinforce and amplify the noise burst). In general, the greater percentage of correct responses for the labial and dental place may reflect a kind of response bias because labial or dental were also the most common erroneous responses for the other places.

Of the five noted similarities in the shape of formant transitions from study 1, four of them corresponded to high rates of confusion in the present study, namely, labial and dentals after /i/, dentals and palatals after /a/ and /u/, labials and velars after /u/, and velars and dentals after /a/. An expected confusion between retroflexes and velars after /i/ did not manifest itself – possibly because the retroflexes, unlike the velars, tended to induce a characteristically low F3 throughout the preceding vowel.

There was also some confusions that were not predicted, at least based on a visual examination of the formant transitions, namely, palatals and retroflexes were confused with both dentals and labials after /i/ and retroflexes were confused with dentals after /u/.

Over all three vocalic environments, the rank order of percent correct identification of place was, from more to less: labial (91.6%), dental (69.3%), velar (65.6%), retroflex (63.5%), and palatal (24.9%).

The degree to which place perception was improved, on average, by the addition of the final stop release varied considerably:

palatals	64%
retroflex	31%
velar	29%
dental	6.3%
labial	– .57%

This ranking is roughly in the same order as the typical prominence and robustness of the releases of these stops. The palatal (affricate) is known to have an intense characteristic fricative release and the back-articulated velar and the retroflex stops would also tend to have relatively intense bursts by virtue of their having downstream resonators to amplify their sound.

Regarding Steriade's (1997) claim: it is true that the retroflex has robust VC transitions after [a], and corresponding to this the percent correct identification in the gated conditions was a high 87.3%. However, after [i] this is not true: the transitions are less robust (Dave 1977; M. Ohala 1995) and the rate of correct identification was only 36.5%. Thus claims about the robustness of the retroflex place distinction in

VC context need to take into consideration the nature of the V. Additionally, another factor may have to be taken into account in evaluating the relative salience of retroflexes' cues in some VC positions. It is possible that via sound change the presence of a syllable final retroflex consonant has yielded a different preceding vowel, e.g., in Dave's (1977) study the /ə/ before a retroflex may no longer be the same as the /ə/ before other consonant places. The data presented by Dave (1977) for Gujarati retroflexes suggests, for example, that the preceding vowel itself, not just the transitions, may differ from the same vowel before dentals. Similarly, in the history of English a post-vocalic /r/ has had major influences on preceding vowels (Dobson 1968). One example is that after metathesis changed *brid* to 'bird' the vowel underwent lowering and centralization. (We cite this as an example of how a consonantal context can influence the phonological quality of vowels. It is not necessarily directly relevant to retroflexes' influence since the original /r/ in English may not have been retroflex.) If such a vowel change is involved, the identification of final retroflexes may in some cases be helped by a correlated difference in vowel quality, not just by the consonantal transitions per se.

Additionally, the results obtained after [i] would not have been predicted on the basis of examining the formant transitions. Anderson's (1995) results that post-alveolars were identified correctly more often in intervocalic position than word-initial may not necessarily show that these sounds' VC transitions are better cues to that place than the CV transitions; it could simply mean that the combination of VC and CV cues (since both are present intervocalically) are better than CV cues by themselves.

One final note of caution: although it seems reasonable to think that VC intervocalically (the position reported on by Anderson (1997), Dave (1977) and Steriade (1997) and VC in final position (used in the present study) would behave similarly for formant transitions and how they are perceived, this might not be so and still needs to be examined.

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Notes

1 We use the term 'space' as a convenient metaphor but do not endorse many of the concepts associated with it (J. Ohala 1997).

2 The recordings were made in New Delhi, India, in the Language Laboratory of the Jawahar Lal Nehru University.

3 The rows occasionally add up to more or less than 100% due to round-off error.

The properties of the vocal-tract walls help to shape several phonetic distinctions in language

Kenneth N. Stevens

1. Introduction

The articulatory and acoustic attributes of vowels and consonants are usually classified in terms of the configurations and movements of the various articulators that are used to produce these segments, together with the acoustic consequences of these movements. The model is that of an acoustic tube with a time-varying shape, excited by different kinds of sound sources (Fant 1960). Little attention is usually paid to the role played by the properties of the walls of the vocal tract in shaping the sound pattern (but see Boersma 1998). Models of speech production that take these properties into account reveal that the acoustic and perceptual manifestations of some classes of segments are very much dependent on the properties of the vocal-tract walls. These include the direct effects of the vocal-tract surface properties on acoustic propagation in the vocal tract and the effects on acoustic sources that arise from influences of the yielding walls on the pressures and flows in the tract.

In this paper we review several phonetic contrasts which have acoustic correlates that depend on the fact that the vocal tract has yielding walls. We discuss two ways in which yielding walls of the vocal tract can have an influence on the sound: (1) for vowels and sonorant consonants, for which the supraglottal pressure remains at atmospheric pressure and the acoustic mass and resistance of the walls affect the frequency and bandwidth of the first formant frequency; (2) during the constricted interval for obstruent consonants, when the intraoral pressure causes a displacement of the vocal-tract walls both at the consonantal constriction and upstream from the constriction, influencing the properties of both fricative and stop consonants. Some of the effects of the walls have been discussed elsewhere, and some, as far as we know, have not previously been noted.

2. Physical characteristics of vocal-tract walls

The walls of the vocal tract include the tongue surface, the pharyngeal walls, and the hard and soft palate surfaces. Each of these components has somewhat different mechanical characteristics. The total surface area of these walls has been estimated to be about 100 cm^2 for an adult speaker. No direct measurements have been made of the mechanical impedance of these surfaces within the vocal tract, over a range of frequencies. However, measurements of the impedance of other skin surfaces of the body have been made (Ishizaka et al. 1975; Wodicka et al. 1993), and it has been assumed that these data can be used to approximate the impedance of a substantial part of the vocal tract surfaces. Also, the impedance in the audio frequency range (100-300 Hz) can be inferred from acoustic data on the first formant frequency when a closure or narrow constriction is made in the oral cavity (Fant 1972). These and other methods (e.g. Rothenberg 1968), have led to a model of the mechanical impedance of the vocal tract walls as a compliance C_s, a mass M_s, and a resistance R_s in series. Average values of these elements (per unit area) have been estimated to be

C_s = 1.0 x 10^{-5} to 3.0 x 10^{-5} cm^3/dyne
M_s = 1.0 to 2.0 gm/cm^2
R_s = 800 to 2000 dyne-s/cm^3.

It is noted that at high frequencies (above about 50 Hz), the acoustic mass dominates the impedance, whereas at low frequencies (below about 20 Hz), the acoustic compliance is dominant. These two ranges correspond to the two classes of influence of vocal-tract walls described below in Sections 3 and 4, respectively.

For the value of the wall compliance C_s given above, the outward displacement of the vocal tract walls when there is an intraoral pressure of 8 cm H_2O during an obstruent consonant is in the range 0.8 to 2.4

mm. As will be shown later in this paper, this displacement can have a significant effect on the size of the vocal-tract constriction for a fricative consonant and on the time course of the change in constriction size near the instant of release for a stop consonant.

The surfaces of the nasal cavity have properties that are quite different from those of the vocal tract proper. The principal difference is the large surface area due to a number of undulations and conchae. Examination of the cross-section at a point within the nasal cavity shows that the circumference is three to five times greater than it would be if the cross-section were circular (Bjuggren and Fant 1964; Dang et al. 1994). As discussed later, this large surface area has consequences for the acoustic properties of nasal vowels and consonants.

3. Influence of vocal-tract walls on acoustic characteristics of vowels and sonorant consonants

Fant (1972) pointed out that the propagation of sound in the vocal tract must take into account the impedance of the walls, particularly at low frequencies. The first formant is shifted upward in frequency relative to its expected value if the vocal-tract walls were rigid. In this frequency range, the impedance of the vocal-tract walls can be approximated as an acoustic mass in series with a resistance. If a closure were formed in the oral cavity to produce a stop consonant, the first-formant frequency decreases to about 180 Hz, rather than to zero frequency as predicted for hard-walled tubes (Fant 1972).

When the tongue body is raised to a relatively high position to form a narrowing in the oral cavity, the frequency F1 of the first formant decreases. Figure 1 shows the calculated relation between F1 and the cross-sectional area A_c of the constriction for a simple model whose dimensions approximate those of the vowel /i/. The figure displays the relation between F1 and A_c when hard walls are assumed (dashed line), as well as for the condition where the mass of the walls is taken into account (solid line). The minimum cross-sectional area appropriate for vowels is around 0.2 to 0.3 cm^2. When the constriction size is smaller than this, the reaction of the vocal tract on the acoustic source at the

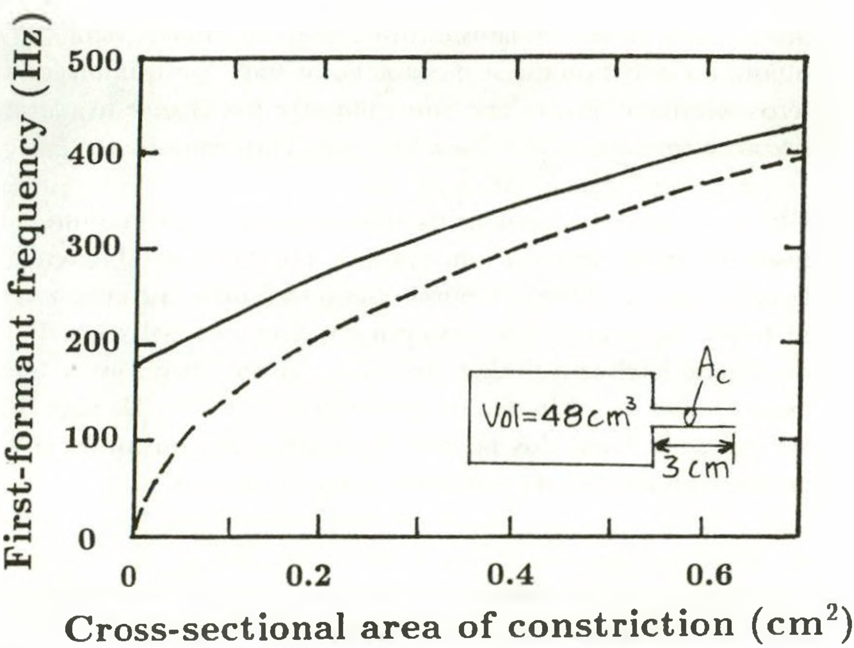

Figure 1. Calculated relation between the first-formant frequency and the cross-sectional area A_c of the constriction for an idealized resonator shape as shown. A simple lumped element resonator is assumed. The dashed line is calculated based on the assumption of hard walls. The solid line assumes yielding walls as discussed in the text.

glottis becomes large and the amplitude of the source is reduced relative to its amplitude for a more open vocal tract. The amplitude is also reduced because some of the energy of the glottal source is diverted to the walls rather than being radiated from the mouth opening. This reduced amplitude compromises the status of a sound produced with such a narrow constriction as a vowel, which is generally considered to be defined acoustically as having a peak in amplitude. Thus the lowest frequency that can occur for a high vowel (i.e. a vowel produced with a narrowing in the oral cavity) is in the range 270-300 Hz. For most speakers, this is above the frequency of the first harmonic of the glottal source, so that the spectrum and waveform of the vowel can show evidence of the first formant frequency. In the absence of the influence of the vocal-tract walls, the minimum F1 for a high vowel would be lower, and acoustic evidence for the first formant frequency would be more obscure.

In the vicinity of this range of constriction sizes corresponding to a high vowel, Fig.1 shows that the sensitivity of F1 to small changes in the cross-sectional area of the constriction is less than it would be if hard walls were assumed for the vocal tract. Thus, in order to achieve a low F1 in a range appropriate for a high vowel, the precision that is required for adjusting the size of the constriction formed by the raised tongue body in proximity to the palate is less than it would have been if the vocal-tract walls were hard. In a sense, then, the impedance of the vocal-tract walls causes less severe articulatory requirements for the production of high vowels.

The nasal vowels and consonants are another class of sonorant segments for which the surface characteristics of the airways have a large influence on the acoustic properties of the filter that shapes the glottal source. This large mucosal surface in the nasal passages gives rise to substantial acoustic losses, especially at low frequencies in the first formant range. A consequence is that when a vowel is produced with a velopharyngeal opening, the bandwidth of the first formant increases and the amplitude of the spectral prominence corresponding to this formant decreases. The contrast between a nasalized and a nonnasal vowel is illustrated by the spectra in Fig.2. The less prominent first-formant peak is evident in the nasalized vowel. This flattening of the spectrum at low frequencies is known to be a primary perceptual cue for vowel nasalization (Maeda 1982), whether the nasalization is distinctive in the language or whether it is a consequence of a following nasal consonant.

In the case of a nasal consonant, which is produced with complete closure in the oral cavity, the acoustic losses in the nasal cavity also cause an increased bandwidth of the lowest resonance, and contribute to a reduced low-frequency amplitude during the nasal murmur. This reduced amplitude helps to enhance the acoustic and perceptual contrast between the consonant and the vowel. That is, the acoustic correlates of the consonantal feature of the nasal segment are strengthened.

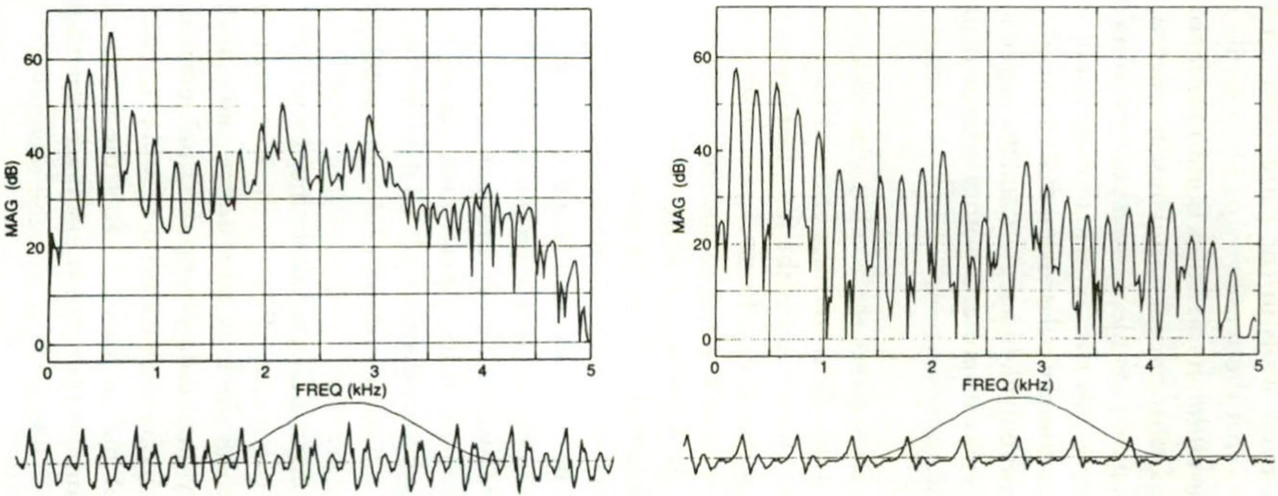

Figure 2. Spectra sampled in a nonnasal vowel (left) and a nasalized vowel (right) produced by a female English speaker. The waveform is shown below each spectrum. The nonnasal vowel is in the word **bet** and the nasalized vowel is in the word **bend**. The attribute of interest is the widened first-formant bandwidth for the nasalized vowel, presumably a consequence of the greater acoustic losses at the walls of the nasal. (Adapted from Stevens 1998.)

4. Influence of vocal-tract walls in the production of obstruent consonants

During the closure interval for an obstruent consonant, there is an increase in pressure behind the constriction that is formed by the primary articulator, and a consequent decrease in the transglottal pressure. The decrease in transglottal pressure can lead to cessation of vocal-fold vibration. The minimum transglottal pressure that can maintain vocal-fold vibration depends on the degree of glottal adduction or abduction and on the vocal-fold stiffness, and can be in the range 2-5 cm H_2O for the kinds of glottal configurations used in producing obstruent consonants (Hirose et al. 1985). The rate at which the intraoral pressure increases when a constriction is formed for an obstruent consonant that follows a vowel or a sonorant consonant is influenced strongly by the stiffness of the vocal-tract walls behind the constriction. There is evidence that this stiffness can be manipulated by a speaker (Svirksy et al. 1997). When a voiced stop consonant is produced, the stiffness of the walls is decreased, permitting a greater expansion of the volume of the airway behind the constriction, and hence an extended time interval over which the transglottal pressure remains high, airflow continues through the glottis, and vocal-fold vibration is maintained. For a voiceless stop consonant, there is an increased stiffness of the walls, leading to a more rapid pressure buildup, and a more rapid cessation of vocal-fold vibration. Thus the stiffness of the vocal-tract walls plays an important role (along with other factors) in facilitating the voicing distinction for obstruent consonants. Other factors include active adjustment of the vocal-tract volume during the consonantal interval (Perkell 1969; Westbury 1983).

The stiffness of the surfaces of the tongue and lips also appears to influence the adjustment of the constriction size during the production of fricative consonants. The increased pressure behind the consonantal constriction creates a force on the surface of the articulator that is forming the constriction. This force is in a direction that displaces the articulator away from its opposing surface and therefore increases the cross-sectional area of the constriction relative to the area it would have if there were no increased pressure upstream from the constriction. However, an increased cross-sectional area leads to greater airflow, and a consequent reduction of the force on the walls in the region of the constriction. Thus there is a balancing process between the adducting and abducting forces on the surfaces. The result is that the maintenance of a particular constriction size does not require precise control of the articulator positioning and shape. It can be shown that there is an optimum constriction size (in relation to the glottal opening) that maximizes the intensity of the frication noise for a fricative consonant (Stevens 1998), and the interaction between aerodynamic forces and the yielding walls in the vicinity of the constriction facilitates the achievement of this optimum condition.

During the closure interval for a stop consonant, the active articulator (usually the lips, the tongue blade, or the tongue dorsum) is pressed against an opposing surface that remains largely passive. The pressure behind the constriction builds up, and reaches a value that is equal to or less than the subglottal pressure depending on whether the consonant is voiceless or voiced. This raised pressure immediately upstream from the constriction creates a force on the articulator surface, and, because this surface has a finite stiffness, there is an additional displacement of the surface. The situation is illustrated schematically in Fig.3 for the case of an alveolar consonant. A midsagittal shape for such a stop consonant is given in Fig.3a. The dashed lines in Fig.3b show the hypothetical shape of the tongue blade pressed against the hard palate if there had been no increased intraoral pressure, and the solid lines show how this shape would be modified by the forces on the surface due to the pressure. As the tongue blade is displaced downward by active muscle forces in preparation for the consonant release, the shape changes from that in panel 1 to panel 4. The condition in panel 2 exists just prior to the time the tongue blade surface breaks contact with the palate. As shown in panels 3 and 4, the pressure-induced force causes the articulator to break contact with its opposing surface earlier than if there had been no increased intraoral pressure. As soon as contact is broken, air begins to flow through the constriction, and the separating force due to the intraoral pressure decreases. The consequence is a brief slowing of the rate of movement of the articulator surface. The surface then continues its motion along a path it would have taken had there been no increased intraoral pressure for the stop. The cross-sectional area of the constriction as a function of time is displayed as the solid line in Fig.3c. The dashed line near a time of 0 milliseconds indicates the area change that would occur if there had been no increased pressure, for example for a nasal consonant.

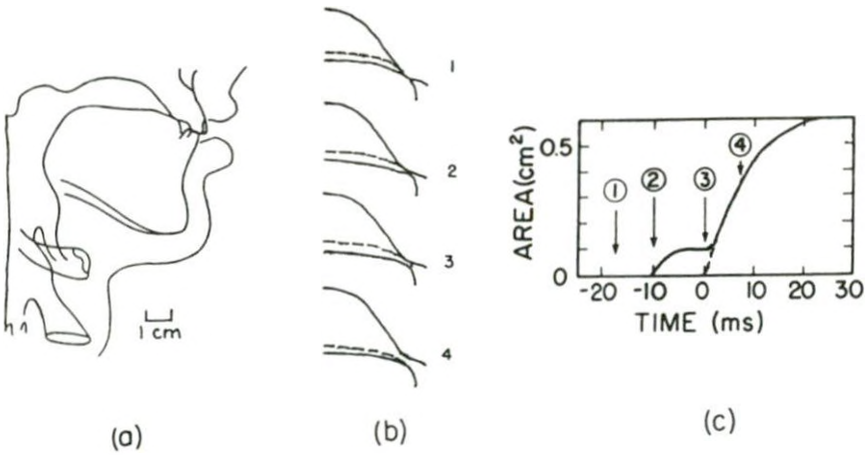

Figure 3(a). Midsagittal configuration for an alveolar stop consonant (from Perkell 1969). (b). A series of schematized shapes of the tongue blade as the release occurs for the consonant. The dashed line in each panel shows the contour of the tongue blade if there were no increased pressure behind the constriction, and the solid line gives the estimated tongue-blade shape if the effect of the pressure is included. (c). Schematization of the cross-sectional area versus time at the consonant release when the effect of the pressure is included (solid line), and when there is no increased intraoral pressure (dashed line). The labeled arrows indicate the points in time corresponding to the panels in (b). (Adapted from Stevens 1998.)

This path taken by the cross-sectional area of the constriction at a stop consonant release has consequences for the acoustic events at the consonant release. During the brief interval when the area increase is delayed, the decrease in intraoral pressure is delayed. Since the transglottal pressure remains low during this interval, the onset of full glottal vibration is delayed. In this time interval there is rapid flow of air through the constriction, creating a burst of frication noise that precedes the onset of full voicing. The duration of the initial plateau in the area increase in Fig.3c depends on the configuration of the articulatory structures that is producing the stop consonant. The duration of the plateau in area is influenced by the degree of tapering of the articulator immediately posterior to the closure. This duration can be as short as 5 milliseconds for a labial release, and can be 20 milliseconds or longer for a velar release. These durations are apparent in the length of the burst that occurs at the consonant release.

The temporal and spectral properties of the bursts at stop-consonant releases have been studied extensively by Eli Fischer-Jørgensen, beginning as early as 1954, and extending for many years beyond that time (e.g. 1972). In this volume, it is fitting to return, in a modest way, to that topic, to acknowledge the contributions that Eli has made to our understanding of stop consonant acoustics and production.

The properties of the vocal-tract walls also influence the airflow that occurs in the first few milliseconds following the release of a stop consonant. During the consonant closure, the increased intraoral pressure causes the walls of the vocal tract to expand outwards. The amount of expansion of the vocal-tract volume is in the range of 10-20 cm^3. Immediately following the consonant release, a substantial component of the airflow comes from the rapid inward movement of the vocal tract walls as they return to their normal position and the intraoral pressure begins to decrease (Stevens 1998). Thus the vocal-tract walls contribute to enhancing the amplitude of the noise burst that is generated at a stop consonant release.

5. Discussion

We have described several aspects of speech production for which the mechanical properties of the vocal-tract walls play a role in either enhancing the acoustic attributes that contribute to a phonetic distinction or helping to define an articulatory target that produces a stable and distinctive acoustic result. As is well known, there are several attributes of the human speech-production system that favor the use of this system to produce sounds with acoustic properties that are distinctive, and for which there are corresponding articulatory correlates (Stevens 1972; 1989). For example, the approximately equal lengths of the pharyngeal and oral portions of the vocal tract favor the classification of vowels in the front-back and high-low dimensions, with corresponding acoustic correlates. This vocal tract geometry also permits the formation of a class of consonants with constrictions in the oral cavity, all of which have distinctive acoustic attributes such as a lowered first-formant frequency. The different places of articulation within the oral cavity also have distinctive acoustic attributes because of the length of the oral cavity in relation to the pharynx. The remarks in the present paper suggest that the factors contributing to the formation of distinctive categories for spoken language are tied not only to the geometry of the speech production system but also to the properties of the surfaces that form the boundaries of the vocal and nasal tracts. The contribution of the vocal-tract walls in creating sounds with distinctive acoustic properties is one more piece of evidence for the unique matching that appears to exist between the human cognitive predisposition to classify sounds in terms of a small set of categories and the sound-generating properties of the complex consisting of the vocal tract, the laryngeal structures, and the respiratory system.

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