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CONTENTS

SUPRASEGMENTAL TRANSCRIPTION *

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This chapter deals with problems in the transcription of duration/length, stress, and intonation whereas tones in tone languages are left out of consideration. The emphasis will be on theoretical issues and rather less space will be devoted to purely technical/notational aspects. I shall also sidestep the more philosophical issue: what it is to transcribe at all. In other words, I am assuming a consensus about both the necessity and the feasibility of transcribing suprasegmental phenomena, but I will discuss such problems as degree of abstraction, descriptive or prescriptive transcription, validity and reliability, and reader target groups.

You will note that I have chosen to understand by "suprasegmental" the rather strictly linguistic phenomena. Thus, voice quality (which may, in fact, serve distinctive, linguistic purposes, cf. Ladefoged, 1980) and the various other aspects of speech production (like variation in loudness and tempo, pauses, etc.) which are a necessary part of discourse analysis, are left out of consideration here. They are treated in separate chapters in this volume.

Even though prosodic analysis has received considerable attention in the literature over the past decade or two, relatively little has been published about suprasegmental transcription, whereas - in later years - a number of publications have dealt with the transcription of segments. To a large extent, of course, segmental and suprasegmental notation pose the same type of general problems (validity, reliability, target readers, etc.) which have accordingly been treated in the literature, and which are also the subject of Vieregge's and Tillmann's contributions to this volume. Left to me are those considerations which are specific to transcribing length, stress, and intonation.

If I have anything to say at all that will not be trivial to most readers, it is that I do not think it meaningful to transcribe a language or a dialect without knowing (speaking) it,

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at least rudimentarily, and that a useful transcription must be based on some (hypothetical) model for prosody in the language in question. (In fact, some notational systems - particularly the 'digitalized' ones - have implicit in them such a model, but the model is often not defended on independent grounds, so that the notation becomes the model becomes the notation....) Transcribing without knowing the speaker's intention may be a good exercise in ear-training but the output is rarely of any use for linguistic purposes. Thus, it is entirely possible to transcribe in such a way that the notation may be said to re-present acceptably the "noise" on one's tape, but a speaker of the language, whether phonetically trained or not, will not be able to recognize the message behind the transcription. A few examples will illustrate my point. Speakers of a language that has high rounded front vowels will be tempted to tran-scribe some of the very fronted varieties of (British and American) English /u:/ as [ɤ:] or [y-:]. This is quite adequate phonetically, but it makes no sense to the native speaker, who would probably choose to modify the [u:]>[u⁺:]. Most foreigners transcribing Danish will render Danish /ð/ as [ɫ]. Again, this can be defended phonetically, since Danish /ð/ lacks friction, i.e. it is phonetically a sonorant, and it also has a rather considerable velarization. True, there is no contact between apex and/or tongue blade and the alveolar ridge in Danish /ð/, but this is also true of many varieties of velarized [ɫ].

If the listener is not familiar with the phonetic cues to stress in the language he is transcribing, he may place his stress marks on the wrong syllables. Thus, I have seen tran-scriptions of Russian which consistently had stress marks on the syllable immediately succeeding the one which the speaker intended to be stressed. The post-tonic syllables carried the relatively highest pitch, and it is not unreasonable to associ-ate this tonal prominence with stress, unless you are aware that there are other cues to stress in Russian, namely vowel duration and vowel quality. A further difficulty in a com-pletely "naïve" transcription is the lack, or the arbitrari-ness, of word boundary assignment. A model for prosody ensures that the transcriber has at least been obliged to consider the number and type of elements which make up the prosodic system of the language, and he will also have had the opportunity to consider how these elements interact in their phonetic mani-festation. (Needless to say, some or all of these preconceived ideas may have to undergo revision, as the transcription and analysis progress.) For one thing, this will prevent an otherwise rather common confounding of stress and intonation, in languages where one of the cues to stress is pitch varia-tion. It is also evident that transcriptions of suprasegmental phenomena should rest upon a theoretical basis when they serve comparative and/or didactic purposes, i.e. when they are in-tended for other linguists or for language learners. - The importance of knowing why and for whom you transcribe, where segmental notation is concerned, is treated by Martinet (1946).

There are two more provisos in this chapter. I am assuming
that the transcriber is an experienced one and that she is
transcribing tape-recorded speech. Problems specific to field
work with informants, without recourse to taped material, as
well as problems that arise due to lack of sophistication in
the transcription, are dealt with in Rischel's contribution.

I also wish to state something which is repeated in the various
sections, but which is important enough for the exposition as
a whole to deserve to be underlined here: I believe prosodic
transcription to be a vastly more complicated task where spon-
taneous speech is concerned as compared with read, or other-
wise monitored, speech material. This is primarily because
duration and stress variation will be shaded to more and finer
degrees, to suit the pragmatic purposes of enunciation. We may
also expect that the pitch patterns characteristic of monitored
speech will be less explicit in a situational context, where
they are not alone in carrying the communicative burden.

Finally, the reader should note that I do not - in this chapter
- restrain myself to the conventions of the International
Phonetic Association, mainly because the guidelines laid down
in the IPA-conventions are not sufficient to meet the demands
of all the rather different prosodic systems one may encounter.

LENGTH

Length or duration of sounds is a relative measure. This is a
trivial observation and we never attempt to mark absolute dura-
tions. But for a given rate of delivery, a given speech tempo,
some sounds are longer than others. Several factors contribute
towards this variation.

PHONOLOGICAL DISTINCTIONS

The language may have a phonological distinction between short
and long sounds. Some languages know only of short and long
vowels. In Danish, the majority of the short/long vowel pairs
have identical quality. Thus, e.g. [viːlə]/[vilə] and [kʰuːlə]
/[kʰulə] ('to rest/wild' and 'ball/cold'). In English and Ger-
man the short vowels have a more centralized quality. Thus,
e.g. [biːd/bɪd] and [wuːd/wʊd] ('bead/bid' and 'wooed/wood');
[biːtən/bɪtən] and [ʃpuːkən/ʃpɒkən] ('to bid/to ask' and 'to
haunt (the place)/to spit'). In the latter case, you may choose
to indicate both the durational and the qualitative differences,
as I have done here. But one may also wish to introduce a cer-
tain degree of abstraction, according to the phonological ana-
lysis of the vocalic systems of, in casu, English and German.
If the length difference is considered phonologically primary,
the qualitative differences may be omitted in the transcription
(to render [biːd/bid - wuːd/wud - biːtən/bitən - ʃpuːkən/
ʃpukən]); and vice versa, if the qualitative difference is con-
sidered primary, the length mark may be omitted from the long
vowels (to render [bid/bɪd - wud/wʊd - bitən/bɪtən - ʃpukən/

ʃpɔkən]). (Note that I am not here discussing the criteria
by which you arrive at one or the other solution, whether they
be purely phonological/historical or based on auditory cues to
the identification of vowels in the language.) The choice of
transcription will also depend on the target readers. Germans
learning English may not need to be reminded of the difference
in quality accompanying the difference in length (or vice versa),
whereas it is essential to Danish learners of both English and
German to be made expressly aware of the centralization of the
short vowels. Mixed into, or cutting across, these considera-
tions of the degree of abstraction away from the physical re-
ality and of the choice of feature to be considered redundant
is the question, whether the transcription is to be purely de-
scriptive or prescriptive/normative. Into these considerations
is also mingled a decision about how broad the transcription
is to be, in terms of geographical area, i.e. whether more
than one variety of the language is to be encompassed. For
example, a transcription which is to represent both Standard
North German and South German will disregard the qualitative
difference in the long and short vowels (South German does not
have the centralization of the short vowels which is charac-
teristic of North German). On the other hand, a prescriptive/
normative transcription, such as one would write in a pro-
nouncing dictionary which indicates the pronunciation to be
recommended for foreigners, will want to point to precisely
this difference between the Standard German and other norms.

A number of languages also have long and short consonants.
In Swedish and Italian, vowel and consonant length are in
complementary distribution in stressed syllables, i.e. a long
vowel is succeeded by a short consonant, and vice versa. Thus,
Swedish [viːla/vilːa] and [feːt/fɛtː] ('to rest/villa' and
'fat (adj.)/fat (sb.)') and Italian [ɛːko/ɛkːo] and [faːto/
fatːo] ('echo/here' and 'fate/fact'). In Swedish the short
and long vowels may differ only slightly in quality (this is
true of short and long /i/) or considerably (this is true of
e.g. short and long /u/). Here again, one may choose to note
the duration of both vowels and consonants (as well as the
qualitative differences in the vowels), or one may consider
the variation in consonant duration to be a concomitant fea-
ture of vowel length and thus leave consonant duration un-
specified, or vice versa, depending on the analysis. (The
facts of Swedish and Italian phonology are more complicated
than one would be led to think from these examples, but that
is of no consequence for the present exposition.) In a lan-
guage like Finnish any combination of short and long vowels
with short and long consonant may occur. Thus [muta/mutːa/
muːta/muːtːa] ('mud/(something) else/but/without (something)
else').

Needless to say, phonological distinctions in length must be
captured by the transcription, irrespective of its purpose or
target group. In the examples above I have employed the IPA
convention for marking length, a colon after the sound in
question. This gives you the opportunity to modify the nota-
tion of "halflong" sounds, which are marked with only one dot.

Likewise, "overlong" sounds may be noted with double colons
(::). The distinction between short, long, and overlong may
be phonological. Thus, in Estonian [sada· - sa:da· - sa::da]
and [lina· - lin:a· - lin::a] ('one hundred/send°(2. ps.sg.°
imp.)/(to) become' and 'linen'/genitive of 'town'/illative of
'town'). The half-length on the word final [a·] in the first
two words in each series is determined by the structure of the
preceding syllable - it is a bound variation (Diana Krull, per-
sonal communication).

There are other ways to mark length, of course. You may double
the symbol of the long sound (e.g. Danish [viilə]). However,
insofar as each vowel symbol traditionally constitutes a syl-
lable, this is not the most fortunate of conventions, unless
one or the other of the two be marked for non-syllabicity
(e.g. [vi͜ilə] or [vi̯ilə]). I do not know of any non-arbitrary
way to decide whether the first or the second part of the long
sound is the best candidate for this semi-vowel status, since
it does not make any sense phonetically unless the vowel is
actually diphthongized. The gemination of symbols may, how-
ever, be adequate in a phonological transcription where, like-
wise, one may find long vowels denoted as a sequence of vowel
plus consonant (/w/, /j/, /h/ - see, e.g., Trager and Smith
1957).

STRESS

Another factor which influences the relative duration of sounds
is stress. Sounds - particularly vowels - are longer in stres-
sed syllables than in unstressed ones, ceteris paribus. The
lengthening of vowels in stressed syllables may be particular-
ly pronounced in languages that do not have a phonological
distinction between short and long vowels, like Spanish and
Portuguese. Thus, Portuguese ['fa:brikɐ/fɐ'bri:kɐ] ('factory/
(he) manufactures'). Insofar as these durational variations
are one of the auditory cues to the identification of stress,
we may wish to indicate them in the transcription. On the
other hand, if the transcriber and the reader, both, are famil-
iar with this effect of varying the duration of vowels accord-
ing to the degree of stress, such a notation may be considered
redundant, and the extra length be contained within the stress
mark. See further below.

SENTENCE ACCENT

In languages where sentence accent is an obligatory phenomenon,
sounds may be extra lengthened in the syllable which receives
this special prominence. That is, a stressed syllable will
have even longer sounds, ceteris paribus, when it occurs under
sentence accent. Thus, English [ðə 'blæ·k *bɜ::d / ðə 'bɜ:d
iz *blæːk] ('the black bird / the bird is black' - the star
denotes the sentence accent, see further below). However, the
extra length may also be omitted and considered part of the
realization of [*].

POSITION

Position in the utterance is another variable. A number of
languages have <u>final lengthening</u>. The sounds in the last syl-
lable(s) before a phrasal (or stronger) boundary are longer
than in other positions, ceteris paribus. This will be most
apparent in syllables which are not already lengthened for
other reasons, e.g., in unstressed syllables. Thus, English
[ðə 'jɛləŏ̃ *bɜ::d / ðə *bɜ::d ɪz 'jɛlə·ŏ̃·] ('the yellow bird /
the bird is yellow'). Again, one may wish to note this
lengthening or not, according to the purpose of the transcrip-
tion and the degree of sophistication of one's readers (that
is to say: their degree of familiarity with the language).
Thus, it is useful to mark final lengthening in the teaching
of English to Danes who lack this phenomenon in their mother
tongue.

PHONOLOGICAL SURROUNDINGS

Phonological surroundings also interfere. There are languages
where vowels are perceptibly longer before voiced consonants
than before unvoiced ones. This is true of, e.g., English and
French. Thus [biːd/bi·t] and [ɹɛ·ĭz/ɹɛĭs] ('bead/beat' and
'raise/race'); [gʁɛ·v/gʁɛf] and [ʁɔ·g/ʁɔk] ('strike (sb.)/
scion' and 'roe/rock'). However, the degree to which the
voicing of homosyllabic succeeding consonants lengthens the
preceding vowel (and possible intervening sonorant consonants)
is language specific. Thus, the lengthening is much more pro-
nounced in English than in French. It is, once more, a matter
of choice and evaluation whether these durational variations
are to be captured in the transcription. If one is comparing
English and French, e.g. for didactic purposes, it may be of
the utmost importance for both sets of learners that the tran-
scription of English clearly indicates the more considerable
lengthening before voiced consonants, compared with French.

INTRINSIC DURATION

Intrinsic duration is the term given to the phenomenon that
certain sounds are inherently longer or shorter than other
sounds, ceteris paribus. For instance vowels with high tongue
/jaw position are shorter than vowels with low tongue/jaw
position. Fricatives are longer than unaspirated or weakly
aspirated stops, ceteris paribus; apical consonants are shorter
than at other places of articulation, etc. These durational
variations go completely unnoticed by the listener. Either
because they are below the 'just noticeable difference' for
duration of speech sounds, or because of compensatory per-
ceptual mechanisms. Thus, every listener is also a speaker,
and as such she "knows" that in the production of a certain
(sequence of) sound(s) an intended sameness in duration is
blurred by constraints in the peripheral speech production
mechanism, and she therefore overhears, ignores, the (not
inconsiderable) difference in duration between, e.g., high

and low vowels. (This difference is of the order of magnitude
of 50 msec, and thus well above the difference limen for dura-
tion.)

It should be clear from the above that the choice of framework
for notation of duration is heavily influenced by one's ana-
lysis and the reader target group. Thus, a lot of the variation
in duration may be rule governed and can be taken care of in
the introductory notes to one's transcription, provided the
rules have been discovered and can be formulated clearly (which
of course presupposes an earlier stage in the analysis with a
narrow transcription which includes all the perceptible dura-
tional differentiation in the material). The extreme case of
abstraction or simplification is the purely phonological tran-
scription.

PERCEPTUAL ILLUSIONS

When we transcribe segments we are prone to perceptual illusions
as well as phonetic/phonological expectancy, cf. Oller and
Eilers (1975). It is perhaps less evident that "we hear what
we expect to hear" where duration is concerned. This would mean,
for example, that we perceived a long vowel when a short vowel
was actually pronounced, or vice versa. I know of no empirical
data to support my contention, but I think it much more likely,
given my experience with listening to e.g. Danish spoken by
foreigners or by hearing-impaired speakers, that deviations from
the expected durational norm are noticed as precisely such by
native speakers of a language. This is undoubtedly true when
phonological distinctions are thereby lost, but also such phe-
nomena as the wrong amount (whether too much or too little) of
lengthening of sounds in stressed syllables, in sentence accented
syllables, or in pre-phrasal boundary syllables are noticed by
native speakers of a language. Thus, Englishmen and Swedes
react to Danes and think their English or Swedish speech abrupt
because, inter alia, Danish does not have final lengthening as
part of the prosodic system. I wish to claim that native
speakers of a language have a high sensitivity to those dura-
tional phenomena which are part of their prosodic system. But
it is equally true that listeners in general are deaf to dura-
tional phenomena in foreign languages which do not occur in their
mother tongue. Thus, Danes have a hard time perceiving long
consonants, which do not occur in Danish, except across word
boundaries. We are likewise insensitive to final lengthening,
and durational variation due to voicing in succeeding consonants
may also be troublesome for a Dane. This only goes, of course,
for naïve listeners. One of the distinctions of a phonetically
trained, experienced transcriber is that she is much less re-
strained by the phonological system of her mother tongue and
less prone to suffer from the phonetic/phonological expectancy
syndrome.

Reliability of length notation can best be checked by the degree
of consensus reached by a group of trained transcribers. Acoustic
analysis may be of some aid, but does not solve any and every

dilemma, because it is true of duration - as of other phenomena
- that the relation between acoustics and perception is not
bi-unique. Listeners are bound by perceptual limitations and
by the indoctrination which being simultaneously speaker and
listener subjects us to. Another check on the reliability and
validity of one's transcription would be to try and synthesize
the transcribed text in a speech synthesis system where intrin-
sic durational variation is supplied "internally", i.e., by
the system itself. Gross discrepancies between the original
speech and the re-synthesized version are likely to be detected
that way. Such a check will always, however, be reserved for
a few test cases. First of all, you need access to synthesis
facilities and, secondly, it is a time consuming procedure.

STRESS

Stress is a far more controversial phenomenon than length/dura-
tion. Among other things because the articulatory, acoustic,
and perceptual cueing of stress is not one-dimensional. Length
has one correlate, namely time, but stress has several. Rela-
tive prominence of one syllable over others may be achieved by
variation in fundamental frequency[1], in duration, in sound
quality, and maybe in intensity/loudness, or by any combination
of these parameters, cf. Berinstein (1979). Not only is the
cueing complex but our perception of prominence is heavily de-
pendent on expectancy and on a semantic/syntactic analysis of
what is being said, i.e. on the understanding of the utterance.
It is also my experience that stress is one of the hardest con-
cepts to teach people. Thus, it is difficult - in e.g. a class
of first year language students - to reach a consensus among
native speakers of Danish about the number, let alone the loca-
tion, of the stressed syllables in short Danish utterances, and
the bewilderment increases when they are dealing with a foreign
language. I am speaking here only of recognition of stressed
versus unstressed syllables. The task becomes nearly hopeless
when such practically linguistically naïve listeners are re-
quested to distinguish more than two degrees of stress.

STRESS VARIATIONS

These observations will collide with the apparent confidence
with which many writers about (American) English phonology and
prosody operate with stress variations involving four (or more)
degrees of relational stress (see e.g. Bloch and Trager 1942,
Trager and Smith 1957, and Liberman and Prince 1977). The
phonetic reality of these analyses is seldom, if ever, put to
any empirical test, and the one experiment (Lieberman, 1965)
which tests the ability of a trained linguist to hear stress
gradations when he could not resort to a linguistic analysis,
goes largely unnoticed. The outcome of Lieberman's experiment
was that when utterances are stripped of their content (through
a synthesis procedure which replaces the original signal with
a series of [a]'s, retaining the amplitude and F_o contours of
the original) a trained linguist could only reliably recognize

the stressed and unstressed syllables. Reduced main stress
and secondary stresses went largely untranscribed. This is
in contradistinction to the transcription of the complete
utterances, where four stress degrees were recognized accord-
ing to the Trager and Smith (1957) tradition (main stress,
reduced main stress, secondary stress, and no stress). Lieber-
man suggests that only two degrees of stress may have acoustic
correlates independent of vowel quality. This is in accord
with my own qualms about perceiving stress gradation beyond
two degrees, in non-emotional, pragmatically neutral speech.
(I disregard the special prominence attached to the 'sentence
accent' in languages where this is a relevant parameter, see
further below.) Danish phoneticians are perfectly able to
assign four degrees of syllable weight in Danish compounds,
for instance. Thus 'landmand' ['lanman'] ('agriculturer' -
literally: 'landman') has the word stress on its first syl-
lable, whereas the second member of the compound is subjected
to a stress reduction, which is mainly signalled through the
F_0 contour. It behaves tonally like an unstressed syllable,
like in 'landlig' or 'landet' ('rural, the country'); that is
to say: F_0 rises immediately after the stressed syllable, and
the second syllable lies at the peak of a rising movement,
which then falls again if more unstressed syllables succeed.
You will note that the stød[2] of 'mand' in 'landmand' is re-
tained. In 'landmandsliv' ['lanmansli'ŭ] ('rural life'), the
second syllable is further reduced through its loss of stød,
and if we add the definite particle: 'landmandslivet' ['lan-
mansli'ŭəð], it is not without meaning to speak of four de-
grees of syllable weight, as follows: 1 3 2 4, where the dis-
tinction between the lowest degree (4) and the higher ones is
carried by the distinction non-full vowel quality versus full
vowel quality, and where the distinction between the highest
degree (1) and the lower ones is carried by the course of F_0.
The distinction between the two intermediary degrees may have
an acoustic correlate (presence versus absence of length and/or
stød), but not invariably, i.e. not if the syllable in question
has a short vowel and never takes stød. Thus, there is prob-
ably no acoustic distinction between the second syllable of
'landluft' and 'trykluftbor' ['lanlɔfd̥] and ['tʀœg̊lɔfd̥boʌ̆']
('country air' and 'pneumatic drill' - literally: 'pressure-
air drill') which can be directly referred to a difference in
stress (2nd versus 3rd degree). However, it is possible that
differences may occur which have to do with the different number
of unstressed syllables (one versus two) - i.e. differences
which are not specific to specific types of composita. Insofar
as Danish listeners would still assign different syllable
weights to the two 'luft's, my claim is that such an analysis
derives from a knowledge of the syntactic composition of the
word. - I have carefully avoided the term 'stress' here, be-
cause I expressly do not think that we are dealing with four
degrees of stress in words like 'landmandslivet' or in
'élevàtor-ôperàtor' (which would digitalize into 1 4 3 4 2 4 3
4), to quote a famous example from Bloch and Trager (1951, p.
48). The listener's experience - in neutral speech - of some
syllables as heavier than unstressed but lighter than main
stressed may be a real one, but it derives from properties in

the speech signal which are not independently controlled by
the speaker, in the same way the difference stressed/unstressed
is. The sensation of a further gradation is a by-product of
the segmental and syntactic composition of the word/phrase/
utterance. In other words, the purportedly suprasegmental
hierarchies of generative phonology (e.g. Chomsky and Halle,
1968) and metrical phonology (Liberman and Prince, 1977) are
syntactic, not prosodic, ones. Furthermore, the lack of a bi-
unique syntactic/prosodic relation makes it impossible to read
off the syntactic structure directly from the prosodic surface
manifestation (the distribution of stresses of varying degrees),
as also pointed out by Rischel (1972). Simultaneously I wish
to say, though, that I think this is something which deserves
empirical verification in a somewhat larger-scale experiment
than Lieberman's (1965) one.

You will note that I have carefully avoided to note anything
but the main stresses in the examples given above. This is in
line with the claim that lower degrees of stress are deductible
from the syntactic and segmental make-up of the word or phrase.
However, it is of course perfectly possible to mark a perceived
syllable weight between main stress and no stress, and even to
make a gradation like in [ˈlanˌmansˌˌliˈŭəð]. There are also
other means than vertical strokes to note stress. Accent marks
above the vowels are quite common, as in Bloch and Trager (1951)
'élevàtor-ôperàtor', and may be a good solution for its typo-
graphical simplicity and for the fact that one does not have to
make any decisions about syllable boundaries. On the other
hand, the same accents are used in the notation of syllable
tones or word tones, and insofar as tones and stress may exist
simultaneously in a language, as is certainly the case in
Norwegian and Swedish, a confusion between tones and stress
may arise. If the transcription indicates more than two de-
grees of stress, digitalization is possible, although I think
that it much too easily effects an impression in the reader
of absolutes and objectivity, notions which have no foundation
in physical facts.

When speech is transcribed from spontaneously spoken texts -
where the semantic and pragmatic context determines a variation
in prominence among the stressed words, i.e. among syllables
with main stress - the question of how many degrees to take
down in the notation becomes more preponderant, but I do not
know how to answer it non-arbitrarily.

Before I proceed, I want to point out that stress is apparently
not a relevant parameter - neither phonologically nor phonetic-
ally - in all the languages of the world. It is hard to assign
any independent meaning to stress in Greenlandic, for instance.
In other words, there is no systematic variation in segment
and syllable duration beyond that conditioned by syllable struc-
ture and syllable sequence. Likewise, there is no systematic
variation in F_0, except that the three final morae before a
phrase boundary are characterized by a (high-)low-high F_0 pat-
tern, which lends a certain prominence to the antepenultimate
(Mase 1973, Mase and Rischel 1971, Rischel 1974, p. 91ff,
Jacobsen 1986).

SENTENCE ACCENT

We will return now to languages that have sentence accent as an obligatory feature of their prosodic systems. The phenomenon has many names: sentence accent, sentence stress, primary accent, primary stress, nucleus, nuclear accent, focal accent, tonic, Satzakzent. There is not complete agreement across authors and languages about neither the semantic/pragmatic function, nor the phonetic manifestation of sentence accent (which is the cover term I employ here), but - roughly speaking - it is the label given to the somewhat greater prominence attached to one stressed syllable over other stressed syllables in a phrase or an utterance. The greater prominence is generally achieved by a more elaborate F_0 movement and greater duration than in the surrounding stressed syllables. If nothing else is specified by the context, this extra prominence will be located on the last lexical item in the phrase or utterance. Languages which lack sentence accent as an obligatory prosodic element, such as Standard Danish, do not have any special phonetic prominence attached to the last or any other lexical element in the phrase or utterance in non-emotional, pragmatically neutral speech.

I will not be concerned, in the following, with the function of sentence accent, whether or not it focalizes semantic material, to what extent it reflects a theme/rheme structure, or what (pragmatic and other) rules govern its occurrence for the speaker. I will limit myself to a discussion of the perception and transcription of sentence accents when and where they occur, regardless of the why's and wherefore's. - The perception of sentence accent is not as straightforward as one may be led to believe from the description of the phenomenon given in most textbooks and introductions to the phonetics of specific languages. Thus, Brown et al. (1980) describe two experiments, where trained phoneticians, linguists and professional language teachers - who were all familiar with the concept of tonic - marked tonic placement in a set of Scottish English sentences, read aloud and in spontaneous speech, respectively. The disagreement across transcribers about both number of tonics and their placement was rather remarkable, even in short utterances. Thus, in the read sentence 'There is my house' (where acoustic analysis revealed 'there' as having the highest F_0, the largest F_0 movement and the highest intensity) 12 judges marked 'there' as the only tonic, 14 marked 'house' as the only tonic, and 3 judges marked both 'there' and 'house' as tonics. The authors conclude about the read sentences, inter alia, that "In no case, even in two-word sentences, was only one tonic identified. In all cases the judges, between them, identified at least two tonics and usually three, four or five. Any item perceived as stressed seems to be at risk. Judges reported that they found the task a very difficult one - this was true even of seasoned phoneticians who have been teaching intonation for years." (p. 146). In the spontaneous speech material, the phonetic cues to tonicity (as defined by the authors: F_0 peak and range, and intensity) tend to cumulate on one item, and the judges, con-

currently, identify fewer tonics and also disagree less. In
the read material it appeared that the last lexical item con-
stitutes the default case since "it is regarded as being the
tonic by right of being the last lexical item if some other
item is not heavily marked phonetically as being in competi-
tion." (p. 146). In contradistinction, in the spontaneous
speech material, the authors conclude that where contrast
(determined by the semantic and pragmatic context) is involved,
"only phonetic cues are available to mark it. The ponetic
cues therefore cumulate on this item and the judges regularly
recognise only one tonic, the contrasted element, even in a
long structure." The first observation lends justification
to the prescription of sentence accent finally in context-
free, neutral sentences, for learners of the language. The
second observation indicates that contrast may justifiably be
considered a phenomenon different from focalization and rheme-
signalling, see further below.

In the examples given in the section on length above, I marked
the sentence accent with a star. This is to indicate that it
may be advantageous to consider sentence accents as being dif-
ferent in kind, rather than just in degree, from stressed syl-
lables in general. I will try and justify this position in
the following, but wish to point out right away that this is
an area where a good deal of empirical research is called for,
and it may turn out that my claim is not tenable. First of
all, the perception of sentence accent need not be triggered
by any phonetic cues at all, cf. Brown et al.'s results above
and their conclusion about last lexical items. Secondly, it
is said about British English in numerous publications, e.g.
O'Connor and Arnold (1961), that no accented syllables can
follow the nucleus. Thus, in their description, a distinction
is being made between accented syllables, which are stressed
syllables that are also made prominent by tonal means (a skip
up or down or an extensive movement), and stressed syllables
which have no such tonal prominence. And their claim is that
the nucleus can be preceded by accented (tonally prominent)
syllables but accented syllables cannot succeed it. This makes
the nuclear accent distinct from other accents and stresses
which do not constrain their surroundings in this manner.
Unfortunately, I know of no empirical acoustic evidence for
these statements, and they are also somewhat at odds with the
Brown et al. (1980) conclusions. If nuclear accents were so
unambiguously signalled they ought not to be so hard to reach
a perceptual consensus about. We may be dealing here with a
rather characteristic difference between prescriptive and de-
scriptive analyses: the prescriptive analysis which serves
didactic purposes represents an idealized picture of reality,
which is often more complex than the prescription would have
you believe. - On the other hand, there are data from German,
an acoustic analysis of a material read aloud, that do bear
out my initial statement about sentence accents as a special
phenomenon. Bannert (1985) publishes F_0 tracings of German
sentences which clearly demonstrate that stressed syllables
before the Satzakzent are associated with F_0 movements, they
are accented, but stressed syllables after it run smoothly to
the end of the utterance without any F_0 deflections. The

Satzakzent itself need not have any particularly elaborate F_0 excursion. The German material was read sentences, which furthermore were presented in a context that left no choice on the part of the readers as to Satzakzent assignment, as opposed to the Brown et al. sentences which were presented to the readers without any context. This may account for the ambiguous acoustic and perceptual results from Scottish English.

To conclude about sentence accent: I believe that in non-emotional, neutral speech, controlled for semantic and pragmatic effects, sentence accents can probably be recognized by the phonetic cues supplied by the speaker, i.e. increased duration and increased F_0 excursion, and by the lack of any F_0 perturbations after it. I also believe that it is a phenomenon apart from ordinary stress, and should be noted as such, by a special symbol in the transcription. The German sentence 'Der französische König war ein launischer Geselle' (in answer to the question 'Was für ein Geselle war der französische König?') would transcribe as follows: [dɛɛ̆ fʁɑnˈtɕøːzɪʃə ˈkʰøːnɪç vɑ aɪ̆n *laɑ̃nɪʃɐ gəˈzɛlə] (the example is from Bannert 1985 and translates as follows 'The French king was a moody fellow.'). Note that such a transcription involves a good deal of abstraction. It requires an understanding and interpretation of what is being said, and relies on the presence of a context. It does not indicate the difference between stresses before and after the [*], but see further below. - I am less sure that sentence accents can be easily defined and perceived in spontaneous speech, as an 'otherness', i.e. as a different category, in relation to stressed syllables in general (cf. the Brown et al. 1980 results).

EMPHASIS FOR CONTRAST

Emphasis for contrast, or simply contrast, is another phenomenon within the realm of neutral speech, i.e. speech devoid of any particular speaker attitude or emotion, though it does demand a context, as the term implies: one of the words in an utterance is contrasted with an element which is explicitly mentioned or is implicit in the larger textual context.

From Jones (1960) we learn that "Contrast emphasis is expressed mainly by intonation. The special intonation may be accompanied by extra stress or length, but these are secondary." (§ 1047). It further appears from his text and examples that the F_0 movement associated with contrast is more extensive than that associated with sentence stress and that "the only syllable with a really strong stress is the stressed syllable of the emphatic word. Other syllables may have a medium or fairly strong stress, but they have the intonation of unstressed syllables." (§ 1050). Bannert (1985) also notes that contrast is associated with larger F_0 movements than Satzakzent. He does not say, but it appears from his figures, that there is a further difference between Satzakzent and contrast: the F_0

movements preceding the contrasted syllable are partially sup-
pressed or completely deleted, so the only clear F_0 excursion
is the one associated with the contrast. That ties up with
Jones' observation quoted above, and is similar to results I
have obtained in an analysis of emphasis for contrast in short
utterances in Danish (Thorsen, 1980): Emphasis for contrast
will make the stressed syllable of the emphasized word stand
out clearly from the surroundings, which is brought about by
an F_0 raising of and/or an elaborate F_0 rise within that syl-
lable and by a deletion of the F_0 deflections in neighbouring
stress groups, to the effect that the immediate surroundings,
except the first post-tonic syllable, fall away sharply from
the emphasized syllable. In an informal experiment with LPC-
synthesis of the sentence 'Det er sidste bus til Tiflis'
[deːe ˈsisdə ˈbus tˢe ˈtˢiflis] ('It is the last bus for Tif-
lis.') I found that it is the shrinking of the F_0 movements
associated with 'sidste' and 'Tiflis', rather than the higher
location in the frequency range associated with 'bus', that
will make 'bus' appear as the contrasted element.

The semantic distinction between sentence accent and contrast
emphasis is not always clearcut, there will be many instances
in spontaneous speech where one cannot decide whether a par-
ticular prominence is to be classified as one or the other,
because phonetic and contextual cues are open to both inter-
pretations. But when the distinction can be made, emphasis
for contrast and sentence accent should be transcribed dif-
ferently. Again, I think it is appealing to treat emphasis
for contrast as being different in kind from stress in general,
mainly due to its effect on surrounding stressed elements.
In English and German, for instance, where stressed and ac-
cented syllables are distinguished, contrast emphasis de-
accents both preceding and succeeding stressed syllables. In
Danish, it would be possible to operate with a similar distinc-
tion, namely between stressed syllables which are associated
with F_0 changes and such that are not. This would be an inno-
vation in the terminology in Danish phonetics and phonology.
It is customary to speak of main stress and secondary stress,
in which case one would say that emphasis for contrast in
Danish leads to a reduction to secondary stress of the stressed
syllables surrounding the emphasized element. In either case,
the de-accentuation or destressing of the surroundings can be
deduced from the presence of the mark for contrast, so it may
still be appropriate to transcribe the Danish example given
above as follows: [deːe ˈsisdə ⁺bus tˢe ˈtˢiflis]. It is
equally possible to note the change in the surroundings, and
for this purpose the lowered stress stroke may be used:
[deːe ˌsisdə ⁺bus tˢe ˌtˢiflis]. That would make the German
moody king with sentence accent and contrast emphasis, respect-
ively appear as follows: [dɛ̆ fʁanˈt̪søːzɪʃə ˈkʰøːnɪç va aïn
*laⱷnɪʃɐ gəˌzɛlə] and [dɛ̆ fʁanˌt̪søːzɪʃə ˌkʰøːnɪç va aïn
⁺laⱷnɪʃɐ gəˌzɛlə] which makes explicit the difference in the
effect that contrast and sentence accent have on preceding
stressed syllables.

PHRASAL UNIT ACCENTUATION

There is yet another type of stress which deserves mention
here, the so-called phrasal unit accentuation, applied under
certain syntactic conditions to a group of words which, in a
vague formulation, can be said to constitute a single semantic
concept, see further Rischel (1983). (The phenomenon has re-
ceived modest attention in the literature of other languages,
and the following examples are all from Danish. However, I
suspect that phrasal unit accentuation is not an exclusively
Danish phenomenon, though the syntactic conditions which
trigger it may be different and less extensive in, say, Swedish,
German, and English.) This type of stress does not involve any
extra phonetic prominence on the stress bearing element (in
contradistinction to sentence accent and emphasis for contrast)
but is characterized solely by a downgrading of another element.
Thus, e.g. 'læse romaner', 'købe hus' (to read novels, to buy
a house) have main stress on 'romaner' and 'hus', respectively,
and reduced stress on the verbs. The reduction is always and
at least signalled with tonal means in Danish, i.e. the reduced
stresses are not associated with any F_0 excursions (in German
and English terminology, they are de-accentuated). Stød is
normally lost, too, but the length of long vowels may be re-
tained, according to criteria that I do not think have been
established yet. In this case, I do not find it justified to
mark the stressed member of these units in any special way,
but rather to note the reduction. Whether to employ a lowered
stress stroke or to leave the reduced items without any stress
mark at all, [ˌlɛːsə ʁoˈmæːˀnʌ] or [lɛːsə ʁoˈmæːˀnʌ], depends on
the purpose and the target group of readers. Both are accept-
able phonetically, except maybe that no independent meaning
can be ascribed to the lowered stress stroke, it is redundant.
It can be defended in a transcription which involves a certain
degree of abstraction - on the grounds that it reflects the
process involved in phrasal unit accentuation.

It is apparent that transcription of stress, even in non-emo-
tional, neutral speech, almost invariably involves some degree
of abstraction, and relies rather heavily on the listener's
comprehension of what is being said and on the choice made in
the analysis of such phenomena as stress reduction in compounds,
sentence accent, emphasis for contrast, and phrasal unit accent-
uation. I have suggested the minimal solution in the tran-
scription of non-emotional, neutral speech, i.e. a restriction
to a distinction between stressed and unstressed syllables, with
a further separate notation of sentence accent, when and where
that is relevant, and of emphasis for contrast. This is due
primarily to a reservation with regard to listeners' ability
to reliably identify more stress degrees. Two degrees of
stress will probably also satisfy most descriptive and pre-
scriptive purposes. - I wish to repeat, though, that the
transcription of spontaneous, pragmatically unrestrained speech
most likely will presuppose a renewed consideration of the pos-
sibility of a further gradation among the prominent syllables.

Objective checks of the validity of one's stress notation are
not available. Partly because several parameters are involved
(F_0, duration, sound quality, and - possibly - intensity), but
primarily because the relation between any single one of these
acoustic parameters and perceived prominence is not bi-unique.
Thus, it is a fairly common mistake that intensity directly
reflects stress. It cannot, because intrinsic properties of
sounds intervene and other parameters than physiological effort
influence physical intensity. High vowels have lower intensity
than low vowels, ceteris paribus. Sounds pronounced on a high
fundamental frequency have higher intensity than on low funda-
mental frequency, ceteris paribus. Long sounds and vowels with
non-reduced vowel quality may well exist in unstressed syl-
lables. - In languages where stressed syllables are associ-
ated with a higher F_0 than their unstressed surroundings,
stress and intensity may correlate fairly well (which does not
make intensity a primary stress cue, however), but when stres-
sed syllables are associated with lower F_0, unstressed syllables
may well appear in intensity registrations with higher intensi-
ty than stressed syllables.

INTONATION

Intonation, understood narrowly here as "speech melody", is in
one sense as straightforward as length/duration: its physical
correlate is unambiguous, namely rate of vocal fold vibration,
i.e. fundamental frequency, F_0. In this section I will main-
tain a distinction between the physical parameter, F_0, and its
perceptual correlate, pitch. I will employ "tonal" indiscrim-
inately about both, when no such distinction is relevant. The
complexity in the transcription and analysis of intonation
arises from the fact that several linguistic (as well as extra-
linguistic) phenomena are signalled in this medium. In lan-
guages where pitch change is one of the cues to the perception
of stress, part of the variation in the F_0/pitch course of an
utterance is stress-determined. When sentence accent and con-
trast are signalled by tonal movements, this is equally true.
Phrase and sentence junctures may also be tonally cued. Be-
sides, there is the more strictly intonational phenomenon
which has the whole phrase or utterance as its domain (such
as the distinction between terminal and non-terminal, de-
clarative and interrogative). In brevity, the complex course
of F_0/pitch through an utterance may contain elements of sen-
tence function, sentence accent, contrast, stress and juncture
(and word or syllable tone). Furthermore, acoustic F_0 regis-
trations contain "noise" which is due to the intrinsic proper-
ties of sounds, and to variations arising at the boundary be-
tween sounds, see further Thorsen (1979). These latter dis-
turbances are not heard and identified by the listener as
prosodic variations, because - as with duration - the listener
uses her knowledge as a speaker in her interpretation and com-
pensates perceptually for such F_0 differences and variations
which are due to constraints in the speech production mecha-
nism. (However, F_0 variations caused by intrinsic properties
and by coarticulation may play a role in the identification

of the segments of speech, see further Reinholt Petersen,
forthcoming.)

NOTATIONAL CONVENTIONS

Methods to convey graphically the ups and downs of pitch
abound in the literature. A few examples will have to suffice:
Trager and Smith (1957) employ a digitalized system, where [4]
indicates the highest and [1] the lowest pitch level. Within
each level, four varieties are distinguished: [ᵥ] for the low-
est, [.] for the next higher variety, [ᴧ] for still higher,
and [-] for the highest:

> /[²ᴧ]hâw [²₵]də [²]ðèy [³]stɛ́[↓]diy[⁻]/ ('how do they study?', p. 42)

where the final 'minus' indicates a terminal fall in pitch.
Pike (1945) also transcribes in terms of four pitch levels, but
here 1 is the highest and 4 the lowest level:

> 'Two   times 'three 'plus two is 'ten.
>
> °2-4-3/ 4-   °2   °1-   -4-3/ 3- °2-4// (p. 33)

where " " denotes the beginning of a primary contour, "/" in-
dicates a tentative, and "//" a final pause.

Fries (1964) employs horizontal lines cutting through the
printed text:

> I'll go if you|want|me to go (p. 246)

Lee (1960, quoted from Hartvigson and Jürgensen 1971, p. 19)
indicates rises, falls and high and low levels as follows:

> \Now Frank, are you ↑coming on the /train or \cycling back?

Schubiger (1964) uses accent marks, placed above or below the
line:

> Unˇfortunately he 'died without having 'made a ˏwill. (p. 257)

Bolinger (1970) lets the print rise and fall on the page:

> Hand
>   pen
>   me that little
>   knife of yours. (p. 141)

Armstrong and Ward (1926) use an interlinear transcription
which has been widely employed since

> ⁻ · · ⁻   ·
> ‾‾‾‾‾‾‾‾‾‾‾ ＼ · · ·
> 'wɒt ə ju 'gɔɪŋ tə 'du: əbaɵt ɪt? (p. 6)

Musical notation can be seen in, e.g., Fónagy and Magdics (1963).

The Trager and Smith (1957) and Pike (1945) transcriptions re-
flect a phonemic analysis of intonation in terms of four dis-
tinctive pitch levels. Whether or not you agree with this ana-
lysis, you may still consider their digitalization as a nota-
tional system, but as such I think it suffers from a pretended
objectivity which is not justified by listeners' perception,
though it _may_ serve its purpose in a descriptive account of
intonation. However, once the notation is no longer intended
to depict the result of a particular phonological analysis,
one may question the number four. Why not six, or eight?
Whatever we arrive at, it is an arbitrary decision.

Lee's (1960) and Schubiger's (1964) systems may be criticized
on the grounds that they are really not very explicit, and
thus demand a good deal sophistication on the part of their
readers, but they are appealing in their simplicity, and easy
to handle typographically.

Bolinger's (1970) transcription is remarkably transparent, but
difficult to handle practically, and I much prefer the inter-
linear transcription of Armstrong and Ward (1926) which con-
tains just as explicit intonational information, with the ad-
ded advantage of distinguishing stressed and unstressed syl-
lables.

Musical notation is difficult to employ for anyone not musical-
ly trained. Furthermore, speech is not necessarily produced
in the semitone intervals of the twelve tone octave.

Whichever notational system we employ, there are a number of
factors that are left out of consideration. - Just as dura-
tion is a relative measure, so is pitch. We do not ordinarily
concern ourselves with the absolute frequency but with the
relations within a given speaker's range. And we know that
different speakers speak within different ranges, i.e. higher
or lower in the frequency scale. (Men generally have lower
pitched voices than women, and children have still higher
voices.) Different speakers may also cover differently sized
intervals. One speaker may habitually only employ a range of,
say, 10 semitones, whereas another may cover $1\frac{1}{2}$ octaves. These
differences likewise do not concern us, except as a cue to
speaker identity, sex, and age.

I have voiced a preference for the interlinear notation, where
the pitch course in the stressed syllables is depicted with
straight or curving lines, as the case may be, and unstressed
syllables are rendered as points. This warrants two comments.
First, the reduction of the course of pitch in unstressed syl-
lables to points in the frequency range is justified by the
fact that unstressed syllables will often be too short to
allow the listener to detect any pitch movement, even though
F_0 may perform steep rises and falls (detected in instrumental
acoustic analysis). There is a limit to our perception of
pitch movements, a limit that is set partly by the duration
of the movement and partly by the frequency range it spans,
cf. Rossi (1971, 1978). When movements are not perceived as

such, a level pitch is heard which corresponds to the fre-
quency value of the glide at a point in time 2/3 of the dis-
tance from the onset of the glide. Second, the notation is
discontinuous, although it may be argued that our perception
of pitch is continuous, i.e. we fill in - by interpolation -
the empty spaces left by unvoiced sounds in the speech chain.
On the other hand, it may also be argued that we anchor our
perception of intonational phenomena on certain points in the
time varying course of pitch and disregard what lies between
such fix points. I do not know that anyone has yet settled
this argument, or suggested an experiment which can resolve
the issue. In the end, we may choose a continuous or discon-
tinuous notation, regardless whether our perception of pitch
is discontinuous or not.

At the lowest level of abstraction the transcription renders,
as accurately as possible, the perceptual equivalent of F_0
curves as they are produced by acoustic analyses. This tran-
scription may be checked against a truly objective, instrument-
ally obtained one, if one remembers, firstly, that perceptual
limitations constrain the amount of detail we can perceive and,
secondly, that the rather considerable variation introduced by
intrinsic F_0 differences between sounds and by coarticulation
goes unnoticed by the listener. Thus, F_0 may easily be 25-30
Hz higher, ceteris paribus, in [i] than in [ɑ] with female
speakers, 10-15 Hz with male speakers, corresponding to rough-
ly 2 semitones (cf. Reinholt Petersen 1978, and Hombert 1978).
In other words, [i] and [ɑ] may appear on F_0 tracings consider-
ably spaced in the vertical dimension and still justifiably be
perceived as having the same pitch.

NOTATIONAL SIMPLIFICATIONS

F_0 tracings, and perceptual equivalents thereof, are generally
much too rich in information and detail to be of any use for
descriptive or comparative or didactive purposes. The informa-
tion must be simplified, an abstraction made, irrelevant infor-
mation or information which can be deduced from the remainder
be filtered out. In languages where stress is a relevant
parameter and is cued by pitch, the notation may be anchored
on the stressed syllables. Their pitch levels and movements
should be specified. It is generally also necessary to keep
track of the relation between stressed syllables through the
utterance, because the overall drift created by these pitch
relations may be (part of) the signal for sentence intonation
function. The shape and slope of this overall trend is the
only prosodic cue to sentence function in some languages (e.g.
Danish, cf. Thorsen 1978); in other languages overall trends
coexist with special final pitch movements (e.g. Swedish, cf.
Gårding 1979, and German, cf. Bannert 1985). These final move-
ments are the "terminal contours" in the analyses of Pike (1945)
and Trager and Smith (1957). How much information about the
pitch course of the unstressed syllables to include or leave
out will depend on the purpose of the transcription, the lan-
guage transcribed, and on the readers. There are languages

where the unstressed syllables, at least in non-final position,
have no independently controlled signalling function, at least
not in non-emotional, pragmatically neutral speech. This is
the case in Standard Danish, for example, where unstressed syl-
lables describe a high-falling course, relative to the pre-
ceding stressed syllable. Readers familiar with Danish need
not - for many purposes - be given this information, whereas
it may be crucial to supply it for foreign learners, especial-
ly since this does not seem to be the most wide-spread pattern
in the languages of the world. Stressed syllables commonly are
the higher pitched ones.

In this connection the Dutch approach to intonation analysis
should be mentioned. 't Hart and Cohen (1973) and 't Hart and
Collier (1975) describe a procedure where Dutch utterances are
synthesized on the basis of an original, spoken version. The
synthetic version retains the spectral (segmental) and dura-
tional aspects of the original, but the complex F_0 variations
can be replaced with stylized and simplified, straight-line
approximations to the original. The stylization is performed
while retaining a perceptual similarity between the original
spoken version and the synthesis, i.e. unto the point where
this similarity is lost. The authors - in this manner - arrive
at a description of what they consider to be the perceptually
relevant pitch movements in Dutch. The procedure has been ap-
plied to English by Willems (1982).

With this - and similar synthesis facilities available - you
can perform an abstraction of the original to various degrees:
you can stylize F_0 so as to retain a perceptual identity be-
tween the original and the copy. The outcome would correspond
to an interlinear transcription performed by a truly expert,
acute listener. That is, it will resemble the original, except
that those variations which no human listener can detect have
been "filtered" out. This "close-copy" can be useful as a
spot check on the transcriber's accuracy and reliability/
validity. You can stylize further, without losing the percep-
tual similarity, as 't Hart and co-workers have set out to do,
and thus establish classes of contours that sound similar
phonetically - without regard to their linguistic function.
You can carry the simplification one more step, presumably,
while letting go of perceptual similarity but maintaining
identical linguistic function. That is, although the two
utterances, the original and the synthetic one, no longer sound
similar, they still function adequately as, say, terminal de-
clarative utterances with X number of accented syllables.

I do not think that synthetic speech, of this or any other
kind, can ever become a primary tool in transcription. For
one thing, it cannot be made available to all and everyone
who needs to transcribe intonation. Secondly, it is time con-
suming and cannot be applied to every utterance of large corpo-
ra. But it is a sophisticated and excellent tool for the
further, phonetic and linguistic, analysis of intonational
data, and possibly in the education of transcribers.

ALIGNING PITCH AND SEGMENTS

In some cases the indication of the alignment of segments with
pitch movement is decisive. Firstly, pitch movement alone may
carry the primary cue to syllabicity. Thus, Danish 'kom' and
'komme' (imperative and infinitive, respectively, of 'come')
consist of the same sequence of segments [kʰʌm] when the final
schwa is dropped from the infinitive, which is normal in fluent
speech. However, the infinitive has a somewhat longer nasal,
and a rising pitch movement in the nasal, which distinguishes
it from the imperative, approximately thus:

[kʰ ʌ m   kʰ ʌ m·]
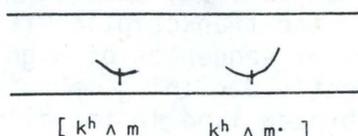
In words like 'bonde, bundne, bundene' (peasant, tied (adj.,
pl.), the bottoms) duration and pitch and timing of pitch move-
ments signal the difference, which phonologically is one of
number of segments and syllables: /bɔnə bɔnnə bɔnənə/. In
the first word the pitch begins to rise at the transition be-
tween vowel and nasal. In the second word, the pitch turning
point lies in the initial part of the long nasal. In the third
word, likewise, the pitch does not begin to rise till after the
onset of the nasal, and here the rise is completed and the
succeeding fall initiated, before the onset of the schwa, ap-
proximately thus (note that these are impressionistic tran-
scriptions, not tracings from F_0 meters):

['b̥ ɔ nə   'b̥ ɔ n: ə   'b̥ ɔ n:: ə]
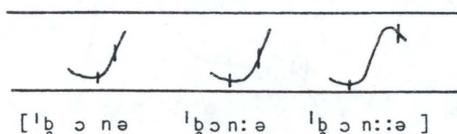
CO-OCCURRENCE OF PROSODIC SIGNALS

In numerous languages the last part of a phrase or an utterance
carries a heavy burden of prosodic information: sentence accent
may be located here and be signalled with F_0, sentence function
likewise, and junctures, as the following example, adapted from
Bruce (1977, p. 93 and 94) shows (Swedish is a word accent lan-
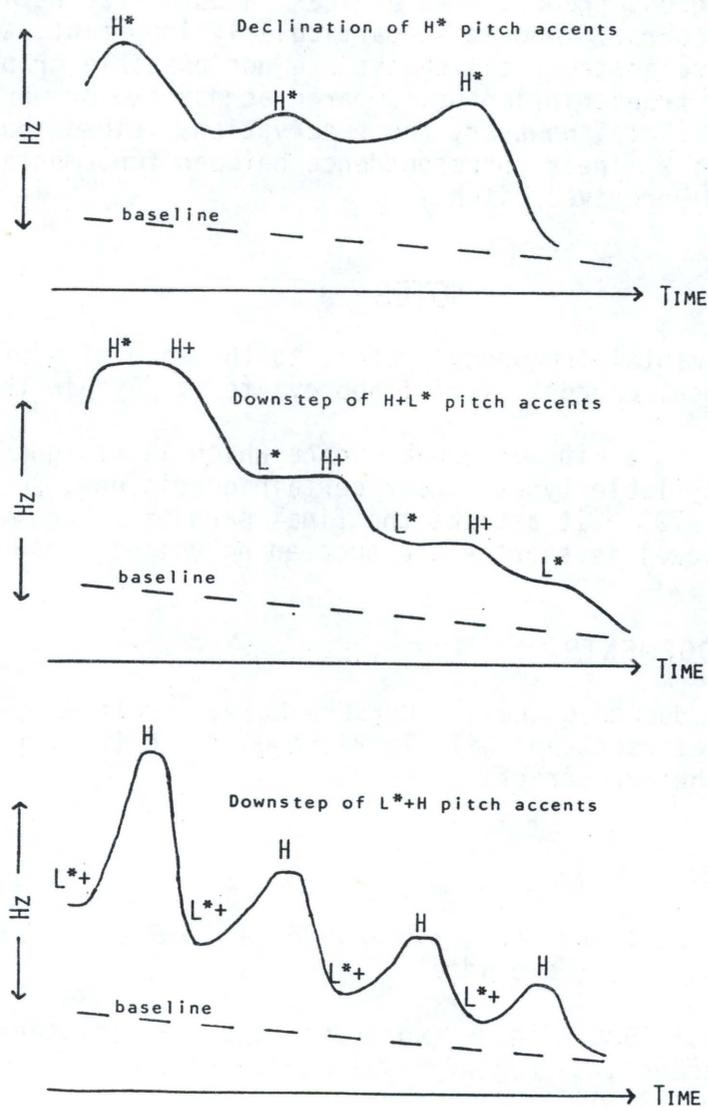guage, and I have included an example of both accents):
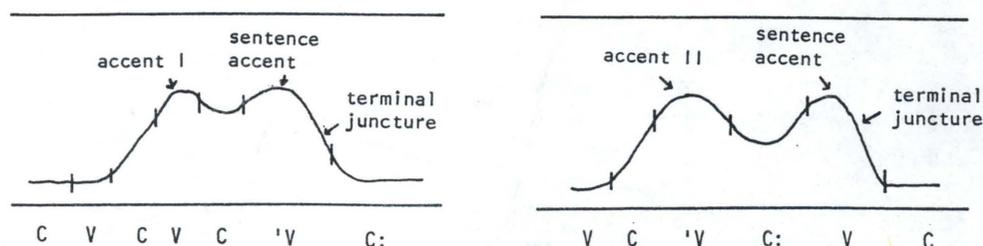
For the mere taking down of the pitch course, the separation
of these various contributions is not essential, but for the
ensuing analysis it is crucial to segregate each element and
know that there are three components here, which overlap part-
ially in time and modify each other.

A typographical notation system which satisfies this demand
has been developed by Pierrehumbert (1980) and further modi-
fied and expanded by Liberman and Pierrehumbert (1984). You
do not have to agree with their phonological analysis (as I
happen not to do, cf. Thorsen 1983 and 1985) to appreciate the
elegance and flexibility of the transcription from F_0 traces
to a transcription in terms of sequences of high and low tones.
On the background of a slightly declining, physiologically
determined, baseline (the broken line in the illustration),
parameters such as <u>prominence</u> relations between stressed syl-
lables, <u>downstep of high tones</u> in certain tonal contexts,
<u>lowering of tones</u> in final position together account for the
time varying course of F_0 through phrases and utterances. In
the examples below (from Pierrehumbert, personal communication)
you see F_0 traces of two phrases: 'Anna came with Manny' which
differ in the degree of emphasis on the two proper names:
'Manny' is focalized in the upper, 'Anna' is focalized in the
lower tracings. A star indicates that the tone is associated
with a stressed syllable, and "%" denotes a phrase boundary
tone. The weighting of prominence was not indicated in the
example.
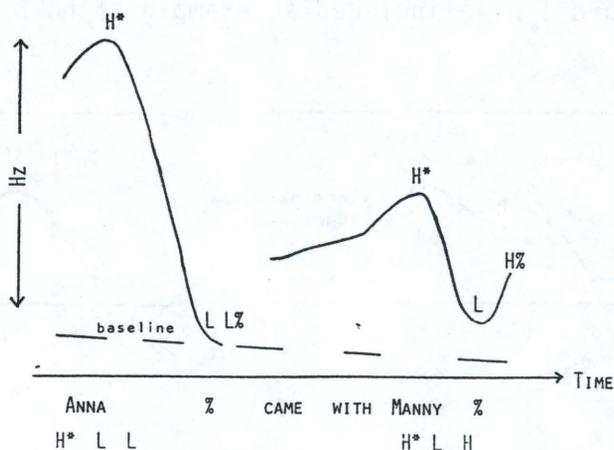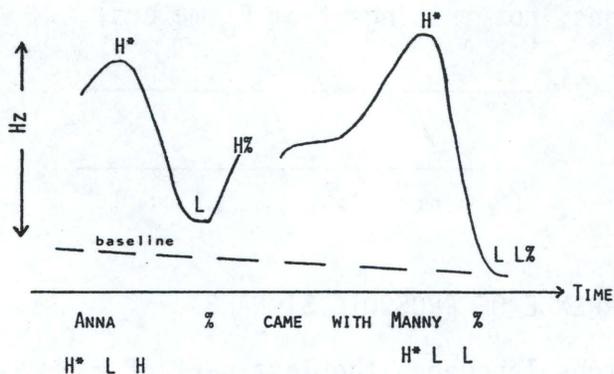
Below are three examples (also from Pierrehumbert, personal communication) of F_0 traces and their tonal transcription which show the effect of the baseline declination upon a succession of three high tones (above). The relatively lower medial H* is presumably due to a lesser prominence, which is not specified here. The downstepping of H tones is illustrated in the two lower graphs, where the H's form part of bi-tonal pitch accents, indicated with a linking "+". The rule lowers a high tone by a certain fraction of the preceding high tone in the context H+L_ and H L+_, see further Pierrehumbert, 1980, and it applies iteratively, that is, every time the condition for its application is met, also if the conditioning tone has itself been lowered.

H*

Declination of H* pitch accents

H*

H*

Hz

baseline

TIME

H* H+

Downstep of H+L* pitch accents

L* H+

L* H+

Hz

L*

baseline

TIME

H

Downstep of L*+H pitch accents

H

L*+

L*+

H

Hz

L*+

H

L*+

baseline

TIME

The downstepping is not explicitated in the notation, but can
of course be supplied, if the formulation of the rule is not
sufficient for one's purpose. The particular transcription of
the examples above is directly related to the phonological ana-
lysis. For instance, the shallow local low points in the upper
tracing is not given any tonal representation, whereas the mere
levelling out of the F_0 course in the middle tracing has war-
ranted "L*" marks. That need not concern us here. I do believe
that the system may be used as a notational tool, adapted - as
far as complexity or simplicity is concerned - to one's needs,
with more or less information specified in the notation or sup-
plied by rules, respectively. The problem with such a notation
is not inherently larger or smaller than with any other intona-
tion transcription, where reliability is concerned. Intonation
is notoriously "difficult" to transcribe, i.e. it is hard to
reach agreement even among experienced transcribers, if not
about the gross trends, then at least about finer details in
the pitch course. And it is particularly important, therefore,
that - where instrumental checks are not possible or practic-
able - the transcription be compared across two or more tran-
scribers. (Note, however, the reservations voiced above about
the lack of a linear correspondence between fundamental fre-
quency and perceived pitch.)

NOTES

1. 'fundamental frequency' refers to the rate of vibration of
    the vocal chords. I will abbreviate it "F_0" in the following.

2. 'stød' is a kind of creaky voice which is assigned to cer-
    tain syllable types, under certain conditions, see further
Basbøll (1972). It attacks the final part of a long vowel or
- if the vowel is short - the succeeding voiced consonant.

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REFERENCES

Armstrong, L.E. and Ward, I.C. 1926: *A Handbook of English
    Intonation*, (Cambridge)

Bannert, R. 1985: "Fokus, Kontrast, und Phrasenintonation im
    Deutschen", *Zeitschrift für Dialektologie und Linguistik
    52*, p. 289-305

Basbøll, H. 1972: "Some remarks concerning the stød in a
    generative grammar of Danish", *Derivational Processes,
    Proceedings of the KVAL Spring Seminar, April 9-10, 1972*

Berinstein, A.E.   1979: "Stress", *Working Papers in Phonetics,
UCLA, 47*, p. 1-59

Bloch, B. and Trager, G.L.   1942: *Outline of Linguistic Ana-
lysis*, Linguistic Society of America, Baltimore, Md.

Bolinger, D.:   "Relative height", In: *Prosodic Analysis*, (eds.:
Léon, P.R., Faure, G., and Rigault, A.), (Paris), p. 109-
125

Brown, G., Currie, K., and Kenworthy, J.L.   1980: *Questions
of Intonation* (London)

Bruce, G.   1977: "Swedish Word Accents in Sentence Perspective",
Travaux de l'Institut de Linguistique de Lund XII, (Lund)

Chomsky, N. and Halle, M.   1968: *Sound Patterns of English*
(New York)

Fónagy, I. and Magdics, K.   1963: "Emotional patterns in into-
nation and music", *Zeitschrift für Phonetik, Sprachwissen-
schaft und Kommunikationsforschung 16*, p. 293-313

Fries, C.C.:   "On the intonation of 'yes-no' questions in Eng-
lish", In: *In Honor of Daniel Jones* (eds.: Abercrombie, D.
et al.), (London), p. 242-254

Gårding, E.   1979: "Sentence intonation in Swedish", *Phonetica
36*, p. 207-215

't Hart, J. and Cohen, A.   1973: "Intonation by rule: A percep-
tual quest", *J. Phonetics 1*, p. 309-327

't Hart, J. and Collier, R.   1975: "Integrating different levels
of intonation analysis", *J. Phonetics 3*, p. 235-255

Hartvigson, H. and Jürgensen, B.   1971: *Engelsk Intonation*,
(Copenhagen)

Hombert, J.-M.   1978: "Consonant types, vowel quality, and
tone", In: *Tone - A Linguistic Survey* (ed.: Fromkin, V.),
(New York), p. 77-111

Jacobsen, B.   1986: *Rytmisering, stavelsesvægt, og begrebet
tryk i grønlandsk*, Unpublished essay for the cand.phil.
degree, 49 pp.

Jones, D.   1960: *An Outline of English Phonetics, 9th edition
(1967 reprint)*, (Cambridge)

Ladefoged, P.   1980: "Cross linguistic studies of speech pro-
duction", *Working Papers in Phonetics, UCLA, 51*, p. 94-
104

Lee, W.R.   1966: *An English Intonation Reader*, (London)

Liberman, M.Y. and Pierrehumbert, J.   1984: "Intonational in-
     variance under changes in pitch range and length", In:
     Language Sound Structure (eds.: Aronoff, M., Oehrle, R.T.)
     (Cambridge, Ms.), p. 157-233

Liberman, M.Y. and Prince, A.   1977: "On stress and linguistic
     rhythm", *Linguistic Inquiry 8*, p. 249-336

Lieberman, P.   1965: "On the acoustic basis of the perception
     of intonation by linguists", *Word 21*, p. 40-54

Martinet, A.   1946: "Savoir pourquoi et pour qui l'on tran-
     scrit", In: *Le Maître Phonétique 86*, p. 14-17 (reprinted
     in Martinet, A.: *La Linguistique Synchronique*, (Paris,
     1965, p. 162-167)

Mase, H.   1973: "A study of the role of syllable and mora for
     the tonal manifestation in Greenlandic", *Ann. Rep. Inst.
     Phon., Univ. Copenhagen 7*, p. 1-98

Mase, H. and Rischel, J.   1971: "A study of consonant quantity
     in West Greenlandic", *Ann. Rep. Inst. Phon., Univ. Copen-
     hagen 5*, p. 175-247

O'Connor, J.D. and Arnold, G.F.   1961: *Intonation of Colloquial
     English*, (London)

Oller, D.K. and Eilers, R.E.   1975: "Phonetic expectation and
     transcription validity", *Phonetica 31*, p. 288-304

Pierrehumbert, J.   1980: *The Phonology and Phonetics of English
     Intonation*, (M.I.T.), Doctoral dissertation

Pike, K.   1945: *The Intonation of American English*, University
     of Michigan Press, (Ann Arbor)

Reinholt Petersen, N.   1978: "Intrinsic fundamental frequency
     of Danish vowels", *J. Phonetics 6*, p. 177-189

Reinholt Petersen, N.   (forthcoming): "Perceptual compensation
     for segmentally conditioned fundamental frequency pertur-
     bation", to appear in *Phonetica*

Rischel, J.   1972: "Compound stress in Danish without a cycle",
     Ann. Rep. Inst. Phon., Univ. Copenhagen 6, p. 211-228

Rischel, J.   1974: *Topics in West Greenlandic Phonology*,
     (Copenhagen)

Rischel, J.   1983: "On unit accentuation in Danish - and the
     distinction between deep and surface phonology", *Folia
     Linguistica XVII*, p. 51-97

Rossi, M.   1971: "Le seuil de glissando ou seuil de perception
     des variations tonales pour les sons de la parole",
     Phonetica 23, p. 1-33

Rossi, M. 1978: "La perception des glissandos descendants
     dans les contours prosodiques", *Phonetica 35*, p. 11-40

Schubiger, M. 1964: "The interplay and co-operation of word-
     order and intonation in English", In: *In Honour of
     Daniel Jones*, (eds.: Abercrombie, D. et al.), (London),
     p. 255-265

Thorsen, N. 1978: "An acoustical investigation of Danish in-
     tonation", *J. Phonetics 6*, p. 151-175

Thorsen, N. 1979: "Interpreting raw fundamental frequency
     tracings of Danish", *Phonetica 36*, p. 57-78

Thorsen, N. 1980: "Neutral stress, emphatic stress, and sen-
     tence intonation in Advanced Standard Danish", *Ann. Rep.
     Inst. Phon., Univ. Copenhagen 14*, p. 121-205

Thorsen, N. 1983: "Standard Danish sentence intonation -
     phonetic data and their representation", *Folia Linguistica
     XVII*, p. 187-220

Thorsen, N. 1985: "Intonation and text in Standard Danish",
     J. Acoust. Soc. Am. 77, p. 1205-1216

Trager, G.L. and Smith Jr., H.L. 1957: "An Outline of English
     Structure", *Studies in Linguistics. Occasional Papers 3*,
     (Washington)

Willems, N. 1982: *English Intonation from a Dutch point of
     view*, (Dordrecht).

PERCEPTUAL COMPENSATION FOR SEGMENTALLY CONDITIONED FUNDAMENTAL FREQUENCY PERTURBATION*

Niels Reinholt Petersen

*The paper deals with the role of two types of segment-
ally conditioned fundamental frequency (Fo) perturba-
tion in speech perception, i.e. the differences in Fo
between high and low vowels and the effect of pre-
vocalic obstruent voicing on Fo. The literature re-
levant to this issue is reviewed, and the results of
a supplementary experiment on Fo as a cue to vowel
identity are reported. On this basis three major
points are made: (1) Although the pitch of vowels is
influenced psychoacoustically by their spectral shape,
this effect is too small to be of any significant im-
portance in speech perception. (2) The two types of
Fo perturbation are not treated differently in the
speech perception process, and (3) irrespective of
type, the segmentally conditioned Fo variation can
function as a cue both to segment identity and to the
identity of prosodic categories, depending on the ac-
tual demands upon the speech perception system.*

I. INTRODUCTION

It is a well-established fact that the fundamental frequency
(Fo) of speech is not only determined by higher-level linguistic
information such as sentence type, stress pattern, and tone but
also by the segments constituting the utterance. The latter,
microprosodic Fo variation can be described as having two sour-
ces, one being the inherent Fo differences between segments and
the other being coarticulatory effects of segments (consonants
in particular) on Fo in adjacent ones. Although the underlying
mechanisms are still subject to discussion, both types of micro-

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prosodic variation are generally assumed to be a result of phys-
iological and/or acoustic constraints of the speech production
apparatus and thus beyond the active control of the speaker
(see e.g. Ohala 1973, Reinholt Petersen 1978, 1983, Silverman
1984a).

The present paper will deal with the role of microprosodic phe-
nomena in the perception of speech, concentrating upon intrinsic
Fo of vowels (i.e. the tendency for high vowels to have a higher
Fo than low vowels, ceteris paribus) and the influence of ob-
struent voicing on Fo in the following vowel (Fo being lower
after voiced than after voiceless obstruents) as examples of
the two types of microprosodic Fo variation. In connection
with the discussion of phonetic explanations for the develop-
ment (or nondevelopment) of linguistic tones from segmental
effects on Fo (Hombert 1976a,b, 1978, Ohala 1978, 1982), the
question was raised whether the two types of segmentally con-
ditioned Fo perturbation are treated differently by the per-
ceptual system. Considering the tendency for the development
of tones from initial consonant voicing to be far more frequent
than the development of tones from vowel height (in fact, no
unambiguous cases appear to have been reported), it has been
assumed that consonantal influences on Fo are detected by
listeners, whereas intrinsic differences among vowels go un-
noticed, presumably due to some sort of perceptual compensatory
effect (Hombert 1976b, Silverman 1984a). Since this issue is
relevant not only to theories of tonogenesis but also, of course,
of primary interest to general phonetic theory, the following
study will attempt to give a comprehensive review of experi-
mental data available in the literature that may illuminate
the question whether intrinsic Fo differences and consonantal
influences on Fo are treated differently in terms of compensa-
tion in the process of speech perception. In addition it is
the aim to report the results of an experiment carried out on
a point which - as will appear - has been neglected in previous
research.

II. ACOUSTIC CHARACTERISTICS

Before turning to the data on the perception of microprosodic
Fo variation it may be appropriate to survey briefly the acous-
tic characteristics of the two types of segmental influence
considered here. The effect of vowel height on Fo can be ade-
quately described as a shift parallelling the underlying Fo
contour, i.e. the contour determined by higher-level linguistic
information, perhaps with a tendency for the effect to be
smaller at the beginning and end of the vowel than in the mid-
dle. In stressed vowels the magnitude of the difference be-
tween high and low vowels ranges between about 4 and 20%, with
typical values of approximately 10%; in unstressed vowels the
differences tend to be somewhat smaller.

With respect to the influence of obstruent voicing on Fo in
the following vowel there seems to be general agreement that,

at vowel onset, Fo is lower after a voiced than after a voice-
less obstruent, and that the difference - although being gradu-
ally reduced - often persists during the greater part of the
vowel. There is less consensus, however, about the direction
of the Fo contour following the onset of the vowel. Mohr
(1971), Lea (1973), and Hombert (1978) report a rising contour
after voiced and a falling contour after a voiceless obstruent,
whereas more recent research (Haggard et al. 1981, Ohde 1984,
1985, Silverman 1984b) has shown that Fo may have a falling
contour after both obstruent types, but more steeply falling
after voiceless than after voiced obstruents. Obviously, as
is the case for intrinsic Fo of vowels, the effect of obstruent
voicing on Fo comes out as a deviation from the underlying Fo
contour and can be described as a fall or rise in relation to
that contour. This point is illustrated in figure 1, which
shows Fo contours in the vowel [i] after [p] and [b] under
three different tonal conditions. The tracings are derived
from unpublished material on Dogri, an Indo-Aryan language
spoken in the Jammu and Kashmir State in India.

The magnitude of the differences reported in the literature
seems to vary a great deal, partly due to the use of different
experimental methodologies, and partly due to the fact that
speakers display a considerable amount of variation even under
identical experimental conditions, but roughly estimated the
differences in stressed vowels are typically in the neighbor-
hood of 10-15% in the early part of the vowel, being reduced
proportionally towards the end, where it is in most cases
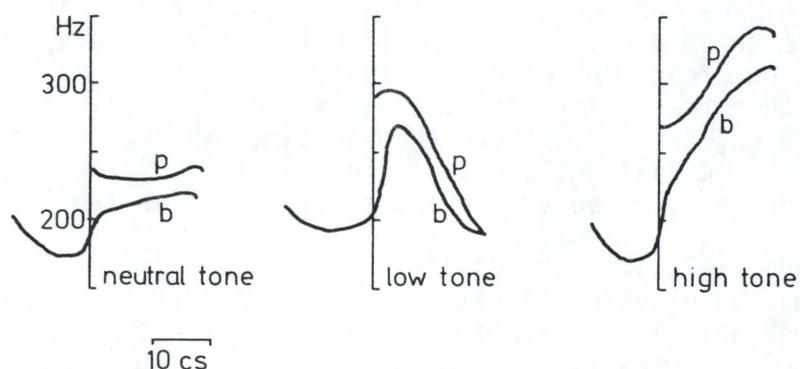eliminated.

Figure 1

Fo tracings (average of 5 Fo curves) in the vowel
[i] after [b] and [p] under three tonal conditions
in Dogri. The tracings are lined up around the on-
set of the vowel.

III. PSYCHOACOUSTIC CONSIDERATIONS

In terms of detectability there seems to be no essential differ-
ence between the two types of segmental Fo perturbation de-
scribed above. Both types exceed the difference limen of about
0.25% for Fo in monotone synthetic steady-state vowels obtained
by Flanagan and Saslow (1958) and Klatt (1973); and, what is
more important, they also exceed the considerably greater dif-
ference limen (2.1%) obtained by Klatt in vowels with linearly
changing Fo.

There is, however, evidence from a number of studies that the
intrinsic Fo differences among vowels may be, to some extent,
reduced in the auditory process as a result of an interaction
between vowel quality and pitch. This was first reported by
Hombert (1976b), who found that in pairs of high and low vowels
the low vowel was judged to be higher in pitch than the high
vowel when the two vowels had the same Fo. From this follows
that, in order for the two vowels in a pair to be judged equal
in pitch, the low vowel must be lower than the high vowel in
Fo. Hombert does not state how much lower, but since listeners
gave 90% or more correct 'different' judgements when the two
vowels in a pair differed by 5 Hz in Fo, he estimates the Fo
distance at equal pitch not to exceed 5 Hz. A more exact maxi-
mum estimate can, in fact, be arrived at from the distribution
of responses between equal Fo and a 5-Hz Fo difference, and
under the assumption of normal ogive psychometric functions.
On this basis the maximum Fo difference at equal pitch is es-
timated to 1.26 Hz in i-a pairs and 1.32 Hz in u-a pairs. More
recently the effect of vowel quality on pitch has been investi-
gated by Chuang and Wang (1978), Stoll (1984) and Di Cristo
(1985). The two former studies find, in agreement with Hombert
(1976b), that at equal pitch low vowels have to be lower in Fo
than high vowels. Di Cristo (1985) found no clear effect; the
reported biases vary greatly among subtests, not only in magni-
tude but also in direction. Directional variation among sub-
tests was not found in the other studies. It should be added,
perhaps, that the difference limens given by Di Cristo are re-
markably high, 4-6%, i.e. more than 10 times the values found
by Flanagan and Saslow (1958) and Klatt (1973). The results
of the studies referred to above are summarized in table I.

The observed relation between pitch and vowel height is indeed
what should be expected if pitch bias were a result of some
sort of perceptual compensation for intrinsic Fo differences
among vowels. However, Chuang and Wang (1978) and Stoll (1984)
present evidence indicating that the pitch biases observed for
vowels can be accounted for by pitch perception processes com-
mon to the general class of complex tone signals, of which
speech vowels are, of course, a subset. The results of Stoll
(1984) are particularly interesting in this respect. In this
study, which examined not only high and low vowels but the
entire set of German tense vowels plus schwa, Stoll found a
very close correlation between experimentally obtained pitch
biases and biases predicted by a pitch extraction algorithm
devised by Terhardt and co-workers, which, on the basis of

Table I

Pitch biases in percent of the reference

	i-a	u-a	y-a
Hombert (1976b)	1.26	1.32	
Chuang and Wang (1978)	1.53	2.80	
Stoll (1984)	0.96	0.78	1.42
	0.71	0.89	
Di Cristo (1985)	1.30		
	-0.80		
	0.00		
	-0.65		
	2.41		

Note that in the case of Hombert (1976b) the values listed are estimated maximum values. Positive values indicate $Fo_{high} > Fo_{low}$, negative values $Fo_{high} < Fo_{low}$ at equal pitch.

our present knowledge of pitch perception, describes the relation between spectral properties and pitch of complex tones (see Terhardt 1979, Terhardt et al. 1982a,b).

Thus, the intrinsic Fo differences among vowels and the Fo differences due to consonant voicing can be said to be treated differently by the auditory system. The former type of Fo perturbation is reduced as a result of the interaction between spectral shape and pitch, while the latter is, of course, left unaffected. But it should be pointed out that the pitch bias effect observed in the above studies is quite small, little more than 1% on the average and not exceeding 3%, even if the experimental conditions - direct comparison of monotone stimuli - may be assumed to enhance such an effect as compared to more speech-like conditions. Since the Fo differences between high and low vowels are typically about 10%, the pitch bias effect, however interesting it is from a psychoacoustic point of view, can hardly be assumed to play anything but a marginal role in the perception of speech.

IV. Fo PERTURBATION AND LINGUISTIC CATEGORIES

The fact that the pitch bias effect cannot be assumed to compensate for Fo differences among vowels does not preclude, of course, that perceptual compensation can take place at a higher

(i.e. linguistic) level where it is conditioned not by the
spectral properties as such but by the·phonetic characteristics
of the vowels. However, if such a higher-level compensatory
effect may be assumed to exist, there is no obvious reason why
it should be restricted to operate on Fo differences among
vowels, and not on the perturbations caused by the voicing state
of the preceding obstruent. It is true, as argued by Hombert
et al. (1976), that the effect of vowel height may be more
closely associated with the conditioning factor in perception
because it occurs simultaneously with it, compared with the
effects of obstruent voicing, where the perturbation and the
factor causing it are located in different segments. On the
other hand, the effect of obstruent voicing on Fo in the fol-
lowing vowel is analogous to the influence of consonant place
of articulation on the formant frequencies of adjacent vowels.
This effect has been shown to be adjusted for perceptually in
that the perceptual boundaries between vowel phonemes are
shifted systematically as a function of the place of articula-
tion of the neighboring consonants (Lindblom and Studdert--
Kennedy 1967). Thus, it can reasonably be argued that percep-
tual compensation for perturbatory effects within one segment
can operate whether the conditioning factor occurs in that seg-
ment or in neighboring segments. Consequently, there seems to
be no firm basis, theoretically, for assuming that the two
types of segmental Fo perturbation dealt with here are treated
differently in the speech perception process; both types may
or may not be compensated for.

The question whether or not segmentally conditioned Fo pertur-
bations are actually compensated for can be addressed in terms
of the manner in which they interfere with the perception of
the identity of the segments themselves on one side, and with
the perception of prosodic categories on the other. If a seg-
mental effect on Fo is not compensated for, i.e. it is heard by
the listeners, Fo could, at the segmental level, be able to
function as a perceptual cue to the phonetic feature which is
responsible for that effect and, at the prosodic level, the Fo
perturbations could be expected to distort the prosodic struc-
ture of an utterance as a function of the segmental composition
of the utterance. Conversely, if a segmental effect on Fo is
perceptually compensated for, it will not interfere with the
prosodic information of the utterance, nor can it be expected
to act as a cue to segment identity.

With respect to the influence of Fo on the perception of seg-
ments, there is evidence from a number of studies using syn-
thetic speech that Fo in a vowel can be a cue to the voicing
category of the preceding obstruent (Haggard et al. 1970,
Fujimura 1971, Abramson 1975, Massaro and Cohen 1976, 1977,
Abramson and Erickson 1978, Haggard et al. 1981, Bernstein
1983, Abramson and Lisker 1985). In cases where the voice on-
set time, which is the primary cue to the voicing distinction,
is ambiguous, a low Fo in the following vowel will favor
'voiced' responses, whereas a higher Fo will favor 'voiceless'
responses. According to Massaro and Cohen (1976, 1978), and
Haggard et al. (1981), the most salient Fo characteristic in

the vowel for the perception of voicing seems to be the Fo
level at vowel onset, rather than the general level in the
vowel or the direction (rising versus falling) of the Fo con-
tour following vowel onset. The results of Abramson (1975),
Abramson and Erickson (1978), and Abramson and Lisker (1985)
suggest, however, that the general Fo level may also be of
some importance. In their studies, rising versus falling Fo
in the vowel was found to affect the categorization of voicing,
and more effectively so when the duration of the Fo movement was
100 and 150 ms instead of 50 ms, i.e. when the 'Fo perturba-
tion' lasted longer. Now, since in natural speech onset Fo,
general Fo level, and in some cases also the direction of the
initial slope are covarying as a function of consonant voicing,
it seems beyond reasonable doubt that the Fo perturbation en-
countered in natural speech can be used by the perceptual sys-
tem determining the voicing state of the preceding obstruent.

The question whether intrinsic Fo can contribute to the per-
ception of vowel height has, to my knowledge, not been investi-
gated experimentally. It could be argued that the cases in
which Fo can be a significant cue to the identification of
vowels are those in which two vowels are close together in
vowel height and, consequently, in intrinsic Fo. However, in
the Danish material reported by Reinholt Petersen (1978), the
Fo differences between adjacent vowels on the vowel height
scale were found to be about 5% on the average (ranging from
0 to 11%); and the differences between /i:/ and /e:/ and be-
tween /u:/ and /o:/, which are very close in vowel height,
averaged 5.5%. Differences of this magnitude may very well
be hypothesized to play a role in the perceptual categorization
of vowels, particularly if the vowels are closely spaced as is
the case in the Danish examples referred to above.

At the prosodic level of speech the results of a study on Danish
(Rosenvold 1981) suggest that intrinsic Fo differences between
high and low vowels are compensated for in the perception of
stress. In Danish, a stressed syllable is characterized by a
relatively low Fo, followed by a high Fo in the first post-
tonic syllable (see, e.g. Thorsen 1984). In an identification
experiment, Rosenvold demonstrated that raising the Fo of the
second syllable in an isolated two-syllable word from a level
equal to that of the first syllable, would shift the perceived
stress position from the second to the first syllable, and -
what is important here - Fo had to be raised to a higher level
for the shift to occur when the vowel in the second syllable
was high than when it was low. Not only the direction of the
change of boundary but also - and particularly - its magnitude,
which was approximately 10%, give strong support to the view
that the speech perception system can compensate for intrinsic
Fo differences between high and low vowels. And at the same
time, the magnitude of the effect rules out the possibility of
a psychophysical pitch bias effect to be involved to any sig-
nificant degree.

Whether similar boundary shifts may occur as a result of per-
ceptual compensation for Fo perturbation due to consonant voic-
ing has been investigated by Abramson and Erickson (1978) in a
study on the identification of tonal categories in Thai. Their
stimuli were CV syllables synthesized with voice onset times
appropriate for [ba], [pa], and [pʰa], and combined with the
members of a fan-shaped Fo continuum, in which all Fo variants
started from a common origin at 120 Hz and moved towards end
points ranging from 92 to 152 Hz. For the sake of clarity the
Fo continuum has been redrawn in figure 2. A number of Thai
subjects were to identify the stimuli as having low, mid, or
high tone. As it turned out, the boundaries between the tonal
categories (indicated by arrows in fig. 2) were influenced by
the preceding stop consonant, but in a somewhat ambiguous man-
ner.
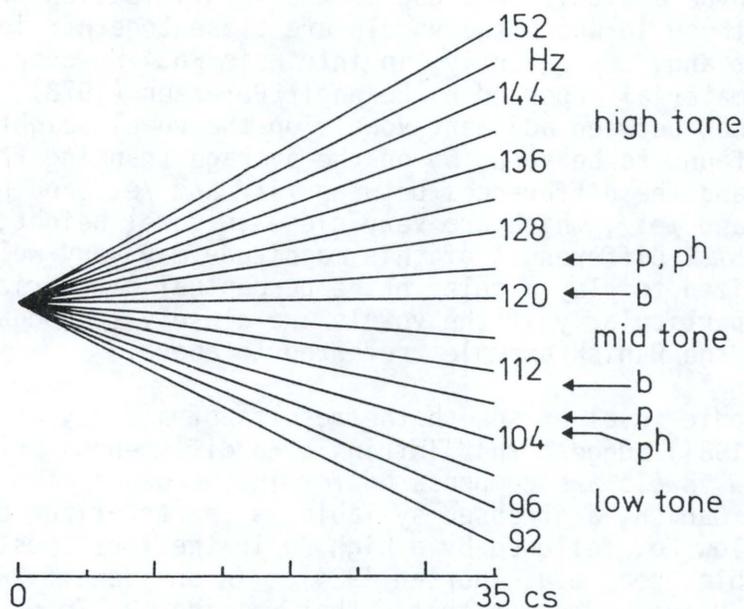
Figure 2

*Schematic representation of the Fo variation in the
stimuli used by Abramson and Erickson (1978). The
boundaries between tonal categories are indicated by
arrows (redrawn on the basis of figures in Abramson
and Erickson, 1978).*

Before dealing further with the results it may be worthwhile to
discuss how the tonal boundaries could be expected to vary in
the continuum used by Abramson and Erickson, if Fo perturbation
due to consonant voicing is perceptually compensated for. This

depends, of course, on which aspect of the Fo variation the listeners focus upon in their identification of the tonal categories. In the study at hand the listeners had two (covarying) cues on which to base their judgments, the slope of the Fo contour and the end point (fig. 2).

If the absolute frequency of the end point, irrespective of slope (or, perhaps, the general Fo level, which directly depends on the end point) were the cue to tone identification, then - assuming compensation for the effect of consonant voicing - the boundary between two adjacent tonal categories should be expected at lower end points after voiced than after voiceless stops.

Conversely, if the Fo slope alone were the cue, the boundary between the low and mid tones and between the mid and high tones should be expected at less steeply negative and more steeply positive slopes, respectively, after voiced than after voiceless stops. In other words, the slope representing the boundary between two adjacent tonal categories should be positive after voiced and negative after voiceless stops in relation to a 'neutral' (i.e. unperturbed) boundary slope. And, if this interpretation is expressed in terms of end point values, the boundaries should be expected at higher end points on the stimulus axis after voiced than after voiceless consonants, since a slope with a higher end point is more steeply rising - or less steeply falling - than a slope with a lower end point.

Thus, it is seen that the assumption of perceptual compensation for the effect of consonant voicing will predict opposite directions of boundary shifts depending on whether Fo level or Fo slope is the more important cue to the perception of tonal categories.

The ambiguity of Abramson and Erickson's results rests on the fact that their listeners put the high-mid boundary at lower end points after voiced than after voiceless stops, whereas they had the reverse order of boundaries for the mid-low distinction (fig. 2). Taking the considerations above into account, the results can be interpreted to reflect the operation of a compensatory effect for consonant voicing, if it may be assumed that the listeners used different aspects of the Fo variation as cues to their identification of tones, namely the end point value, or general Fo level, for the high-mid tone distinction and the Fo slope for the mid-low tone distinction. The explanation ventured here is, of course, highly speculative, and calls for further substantiation, but one point speaks in favor of perceptual compensation - or, rather, against non-compensation -, namely the fact that the tonal boundaries were affected by consonant voicing at all. If no compensation had taken place, the boundaries should have been expected to remain constant irrespective of the voicing state of the preceding stop consonant.

In the preceding paragraphs experimental data have been re-
viewed relating to the questions whether or not segmentally
determined Fo perturbations are perceptually compensated for,
and whether the two types of perturbation under consideration
here receive the same or different treatments in the speech
perception process. If the explanation of the results of
Abramson and Erickson (1978) attempted above is tenable, two
points stand out being of major interest in relation to these
questions. One is that in the perception of prosodic catego-
ries (stress position and tone), the Fo perturbation due to
vowel height and the perturbation due to obstruent voicing
both seem to be compensated for. This is in agreement with
the view expressed above that the two types of perturbation
should not necessarily be expected to be treated differently
in speech perception. The other point is that the consonantal
Fo perturbation is evidently used by the listeners as a cue to
consonant identity, i.e. it is 'heard' by the listeners, where-
as, when the identification of tonal categories is concerned,
it appears to be compensated for perceptually.

Before any conclusions are drawn as to the implications of the
data reviewed above it is necessary to consider one issue which
- as mentioned earlier - has not been investigated experiment-
ally, namely the interaction between intrinsic Fo differences
among vowels and the perception of vowel height. The experi-
ment to be reported in the following was intended to examine
this issue, that is, more specifically, to give an answer to
the question: can Fo act as a cue to the perception of vowel
height in the same sense as it does to the perception of con-
sonant voicing?

V. Fo AS A CUE TO VOWEL HEIGHT,
A PILOT EXPERIMENT

In order to investigate this question a series of words of the
type ['bV:ðə] was synthesized on an OVE III speech synthesizer.
The strèssed vowel was varied in seven equal logarithmic steps
from /u:/ to /o:/. The formant frequencies at the extremes of
the vowel quality continuum were: F_1=225 Hz, F_2=825 Hz, F_3=
2100 Hz for /u:/, and F_1=325 Hz, F_2=650 Hz, F_3= 2400 Hz for /o:/.
Each vowel quality was combined with three essentially parallel
Fo contours at different levels as shown in figure 3. The dif-
ferences between adjacent Fo levels were 6 Hz, which approxim-
ately corresponds in magnitude to the differences in intrinsic
Fo between /u:/ and /o:/ reported for Danish by Reinholt Peter-
sen (1978) (see above). The 21 stimuli were arranged in 10
different random orders in an identification test in which the
listeners were to decide whether they heard an /u:/- or an
/o:/-word. The test was taken by a group of 7 Danish listeners,
all staff members or students at the Institute of Phonetics.
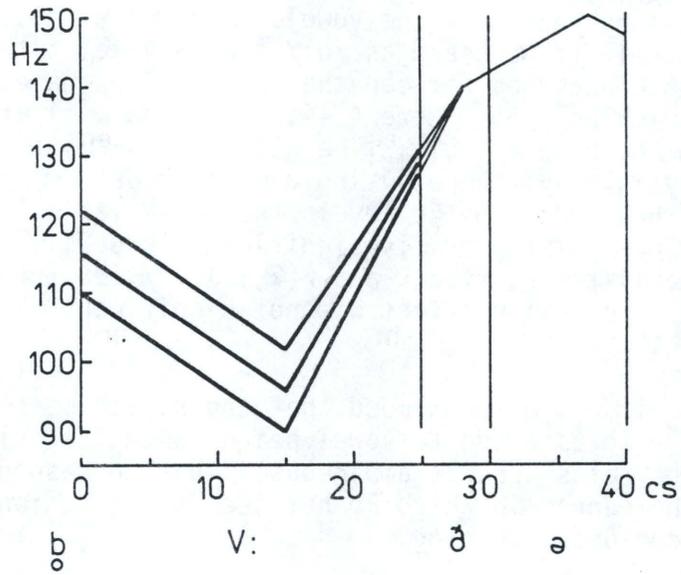
Figure 3

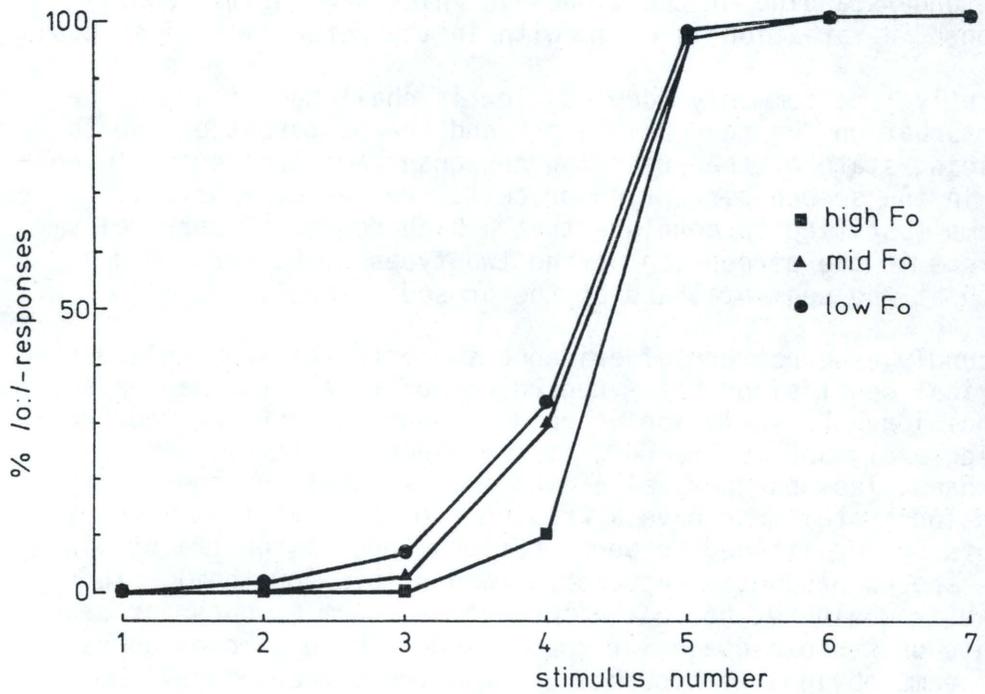*Fo contours of the synthetic* [ˈb̥V:ðə] *stimuli used for the identification test.*

Figure 4
Identification functions (percentage of /o:/-responses) for all subjects pooled under high, mid, and low Fo conditions.

The identification functions for all subjects pooled are displayed in figure 4. It is seen that the response distributions are influenced by the Fo of the vowel. A vowel with a lower Fo is more likely to be heard as /o:/ than a vowel with higher Fo. The mean boundaries between the two vowel phonemes, expressed in stimulus steps, were 4.44, 4.21, and 4.11 at high, mid, and low Fo, respectively. The data were submitted to a two-way analysis of variance, using a mixed model, where listeners were the random and Fo levels the fixed variable. Both main effects were statistically significant ($p<0.01$), $F(6,189)$ = 4.5 for the listener effect, and $F(2,12) = 7.536$ for the Fo effect. The interaction effect was not significant $F(12,189)$ = 0.867, $p>0.10$.

On this basis it can be concluded that the speech perception system can use Fo as a cue to vowel height when the primary cue, i.e. spectral shape, is ambiguous. This corresponds closely to the manner in which Fo has been shown to function as a cue to consonant voicing.

VI. CONCLUSIONS

The results of the experiment reported above on Fo as a cue to vowel height give additional support to the interpretations outlined previously on the basis of the research surveyed in the present paper. Thus, a pattern of evidence seems to emerge of which two points are of particular significance to the understanding of the manner in which segmentally conditioned Fo variation is dealt with in the perception of speech.

Firstly, the commonly adopted view is challenged that the Fo perturbation due to vowel height and the perturbation due to voicing state of the preceding consonant are treated differently in the speech perception process. On the contrary, it seems justified to conclude that a high degree of parallelism exists in the perception of the two types of Fo variation, both at the segmental and at the prosodic level.

Secondly, the pattern of evidence suggests the seemingly paradoxical conclusion that - regardless of type - the segmentally conditioned Fo variation is both compensated for, at the prosodic level, and is 'heard', at the segmental level. This is, perhaps, less paradoxical if we consider that the speech perception system must have a knowledge of the existence of segmentally conditioned Fo perturbations (or the constraints in the speech production apparatus responsible for them), otherwise it would not be able either to use them as cues for segments or to compensate for them. Under these circumstances it seems obvious to hypothesize that the perceptual system may be sufficiently flexible to apply this knowledge at either level, the segmental or the prosodic, depending on the actual demands on the system. That is, it focuses selectively upon the level where the acoustic input is ambiguous in relation to the identity of the linguistic categories and/or where the greater importance is attached to the correct categorization.

Such a task-dependent behavior of the perceptual system can be considered likely to come out most clearly under the experimental conditions used in the studies considered, which are typically designed to examine one level at a time. In natural speech, cases may well be imagined where the acoustic cues to category membership are ambiguous at the segmental and at the prosodic level at the same time, resulting in misperceptions at one of the levels, or both. However, the probability of occurrence of such cases will, perhaps, be rather small, and in natural speech - as opposed to experimental conditions - the speech perception process will have recourse to the linguistic context in a wide sense.

Finally, it should be emphasized that the conclusions arrived at here clearly call for further experimental substantiation. Indeed, except for the research into the function of Fo as a cue to obstruent voicing, remarkably little experimental work has been done relating to the role of segmentally conditioned Fo variation in the perception of speech. The present paper may, hopefully, provide a framework for such future experimentation.

REFERENCES

Abramson, A.S. 1975: "Pitch in the perception of voicing states in Thai: Diachronic implications", *Status Rep. Speech Res., Haskins Labs. 41*, p. 165-174

Abramson, A.S. and Erickson, D.M. 1978: "Diachronic tone splits and voicing shifts in Thai: Some perceptual data", *Status Rep. Speech Res., Haskins Labs. 53*, p. 85-96

Abramson, A.S. and Lisker, L. 1985: "Relative power of cues: Fo shift versus voice timing", In: *Linguistic Phonetics* (ed.: Fromkin, V.), p. 25-33

Bernstein, L.E. 1983: "Perceptual development for labeling words varying in voice onset time and fundamental frequency", *J. Phonetics 11*, p. 383-393

Chuang, C.-K. and Wang, W.S.-Y. 1978: "Psychophysical pitch biases related to vowel quality, intensity difference, and sequential order", *J. Acoust. Soc. Am. 64*, p. 1004-1014

Di Cristo, A. 1985: *De la microprosodie à l'intonosyntaxe*, (Aix-en-Provence)

Flanagan, J.L. and Saslow, M.G. 1958: "Pitch discrimination of synthetic vowels", *J. Acoust. Soc. Am. 30*, p. 435-442

Fujimura, O. 1971: "Remarks on stop consonants - synthesis experiments and acoustic cues", In: *Form and Substance* (eds.: Hammerich, L.L., Jakobson, R., Zwirner, E.), p. 221-232

Haggard, M., Ambler, S., and Callow, M.   1970: "Pitch as a voicing cue", *J. Acoust. Soc. Am. 47*, p. 613-617

Haggard, M., Summerfield, Q., and Roberts, M.   1981: "Psycho-acoustical and cultural determinants of phoneme bound-aries: Evidence from trading Fo cues in the voiced-voice-less distinction", *J. Phonetics 9*, p. 49-62

Hombert, J.-M.   1976a: "Phonetic explanations of the develop-ment of tones from prevocalic consonants", *Working Papers in Phonetics, UCLA 33*, p. 23-39

Hombert, J.-M.   1976b: "Development of tones from vowel height", *Working Papers in Phonetics, UCLA 33*, p. 55-66

Hombert, J.-M.   1978: "Consonant types, vowel quality, and tone", In: *Tone: A Linguistic Survey* (ed.: Fromkin, V.), p. 77-111

Hombert, J.-M., Ohala, J.J., and Ewan, W.G.   1976: "Tonogenesis: Theories and queries", *Report of the Phonology Laboratory, Berkeley 1*, p. 47-77

Klatt, D.H.   1973: "Discrimination of fundamental frequency con-tours in synthetic speech: Implications for models of pitch perception", *J. Acoust. Soc. Am. 53*, p. 8-16

Lea, W.A.   1973: "Segmental and suprasegmental influences on fundamental frequency contours", *Consonant Types and Tone, Southern California Occasional Papers in Linguistics 1* (ed.: Hyman, L.M.), p. 17-69

Lindblom, B. and Studdert-Kennedy, M.   1967: "On the role of formant transitions in vowel recognition", *J. Acoust. Soc. Am. 42*, p. 830-843

Massaro, D.M. and Cohen, M.M.   1976: "The contribution of funda-mental frequency and voice onset time to the /zi/-/si/ distinction", *J. Acoust. Soc. Am. 60*, p. 704-717

Massaro, D.M. and Cohen, M.M.   1977: "Voice onset time and fundamental frequency as cues to the /zi/-/si/ distinc-tion", *Perc. Psychophys. 22*, p. 373-382

Mohr, B.   1971: "Intrinsic variations in the speech signal", *Phonetica 23*, p. 65-93

Ohala, J.J.   1973: "Explanations for the intrinsic pitch of vowels", *Monthly Internal Memorandum, Phonology Labora-tory, University of California, Berkeley*, p. 9-26

Ohala, J.J.   1978: "The production of tone", In: *Tone: A Lin-guistic Survey* (ed.: Fromkin, V.), p. 5-39

Ohala, J.J.   1982: "Physiological mechanisms underlying tone and intonation", *The XIII International Congress of Lin-*

guists, Working Group on Intonation, preprints, p. 1-12

Ohde, R.N. 1984: "Fundamental frequency as an acoustic corre-
    late of stop consonant voicing", *J. Acoust. Soc. Am. 75*,
    p. 224-230

Ohde, R.N. 1985: "Fundamental frequency correlates of stop·
    consonant voicing and vowel quality in the speech of pre-
    adolescent children", *J. Acoust. Soc. Am. 78*, p. 1554-1561

Reinholt Petersen, N. 1978: "Intrinsic fundamental frequency
    of Danish vowels", *J. Phonetics 6*, p. 177-189

Reinholt Petersen, N. 1983: "The effect of consonant type on
    fundamental frequency and larynx height in Danish",
    Ann. Rep. Inst. Phon., Univ. Cph. 17, p. 55-86

Rosenvold, E. 1981: "The role of intrinsic Fo and duration in
    the perception of stress", *Ann. Rep. Inst. Phon., Univ.
    Cph. 15*, p. 147-166

Silverman, K. 1984a: "What causes vowels to have intrinsic
    fundamental frequency?", *Cambridge Papers in Phonetics and
    Experimental Linguistics 3*, p. 1-15

Silverman, K. 1984b: "Fo perturbations as a function of voicing
    of prevocalic and postvocalic stops and fricatives, and of
    syllable stress", *Proceedings of the Institute of Acoustics,
    (Autumn conference, Windermere) 6*, p. 445-452

Stoll, G. 1984: "Pitch of vowels: experimental and theoretical
    investigation of its dependence on vowel quality", *Speech
    Communication 3*, p. 137-150

Terhardt, E. 1979: "Calculating virtual pitch", *Hearing Re-
    search 1*, p. 155-182

Terhardt, E., Stoll, G., and Seewann, M. 1982a: "Algorithm for
    extraction of pitch and pitch salience from complex tonal
    signals", *J. Acoust. Soc. Am. 71*, p. 679-688

Terhardt, E., Stoll, G., and Seewann, M. 1982b: "Pitch of com-
    plex signals according to virtual pitch theory: tests,
    examples, and predictions", *J. Acoust. Soc. Am. 71*,
    p. 671-678

Thorsen, N. 1984: "Variability and invariance in Danish stress
    group patterns", *Phonetica 41*, p. 88-102.

TEXT AND INTONATION -
A CASE STUDY*

Nina Grønnum Thorsen

This is a report about a study of intonation in a text which
was not designed for intonation analysis, and which exists in
one edition only. The text is the tape-recorded instruction to
a language laboratory exercise which, incidentally, rehearses
tag-questions in British English. It is a sample of self-suf-
ficient, self-explanatory, non-fictive prose, unique in its kind
in terms of human communication, though very familiar. It was
recorded once, by the author of the programme, MG.

This study represents my first, cautious step away from the
laboratory on the way to spontaneous speech. The need for in-
vestigations of intonation in spontaneous speech is obvious.
There are basic research problems involved, and the results may
be applied in teaching, as well as in synthesis and automatic
recognition of speech.

Appendix I is a copy of the first page (of a total of five) of
my transcript of the recorded text. I have added stress-marks
to the orthographic representation and indicated the duration
of pauses as well. Occasional glottal attacks are also marked.

The list of questions which you may reasonably expect the ana-
lysis of this and similar texts to answer is fairly long. For
reasons of time and space I shall limit myself here to answer
two of them, which both test the validity of aspects of an in-
tonation model for isolated, read sentences (see Thorsen 1978,
1979, 1980a, 1980b, 1982a, 1982b, 1983a, 1983b, 1984, 1985,
forthcoming):

1) Will the tonal pattern associated with the prosodic stress
    group occur as regularly and in the same shape? I.e. will

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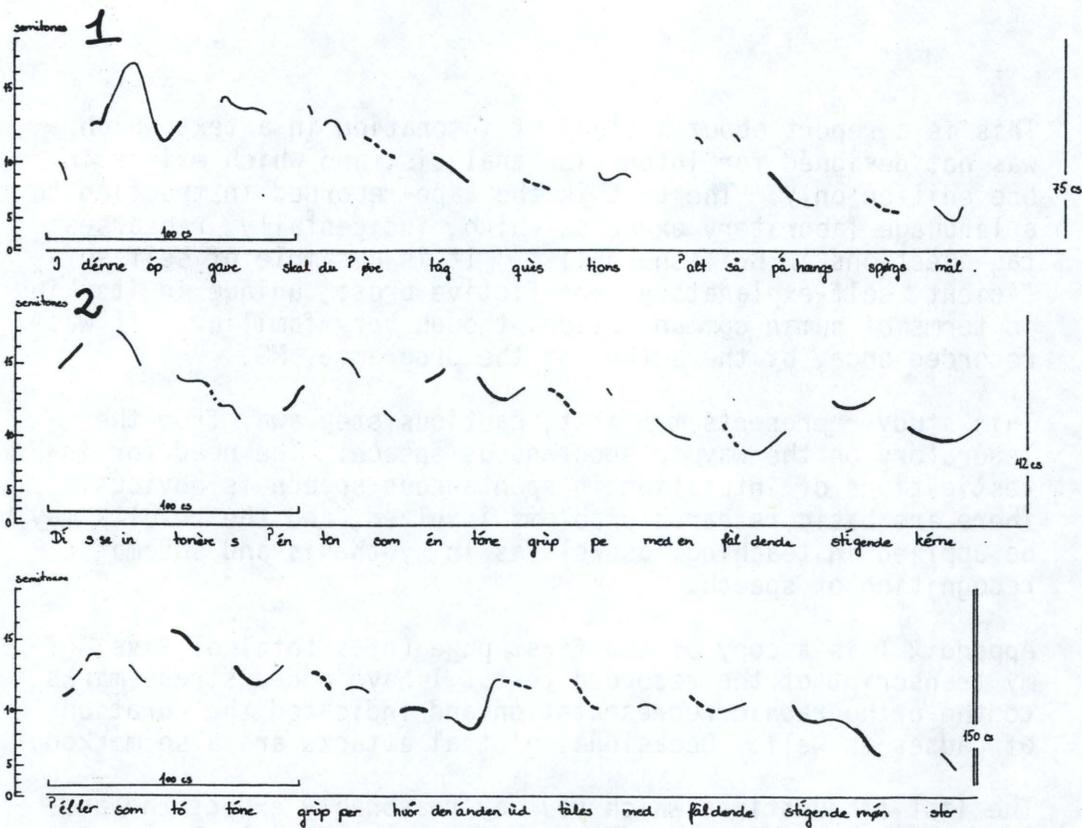
Figure 1

Fo tracings of the first two sentences in the text. The stres-
sed vowels have been touched up with thicker lines. Syllables
with secondary stress are indicated with broken lines. Vertical
bars indicate pauses, with pause duration in centiseconds added.
Zero on the logarithmic frequency scale corresponds to 100 Hz.

any succession of a stressed plus all following unstressed syllables describe a low plus high-falling fundamental frequency (F_0) pattern?

2) Does the magnitude of the rise from low stressed to high post-tonic decrease gradually through the sentence or phrase, as it does in pragmatically neutral, read speech?

Before I proceed to answer these two questions I wish to say that I have found this a rather difficult project, because it is hard to separate chance variability from systematic variation, and it is difficult to know when there are no more interesting observations to be wrung from the data.

The tape was processed with hard-ware intensity and F_0 meters (F-J Electronics) and registered on an Elema 800 mingograph, at a paper speed of 100 mm/sec, to yield the standard oscillogram, intensity and pitch curves. The F_0 tracings were transferred to tracing paper without any further processing. Figure 1 is an example - of the first two sentences in the text.

First a little statistical information to characterize the text. There are 60 sentences in the material. I have defined a sentence here operationally, as any passage which appeared between periods in MG's own text from which she read aloud and recorded the tape. These 60 sentences consist of 111 clauses. On the basis of visual inspection of the curves AND the auditory impression I have counted 92 intonational phrases. An intonational phrase does not necessarily coincide with a sentence or a clause, as can be seen from these figures.

Sentence boundaries are always accompanied by pauses whose duration average 104 centiseconds (with a very large standard deviation of 34.3 cs). There are 49 sentence internal clause boundaries, 26 of which are accompanied by a pause, with a mean duration of 46 cs (SD = 19.7 cs). Despite the large standard deviations, the difference in sentence and clause boundary induced pauses is statistically significant beyond the 0.0005 level. There are 14 pauses which are not associated with any major syntactic boundary. Their average duration is 21 cs (SD = 2.3 cs). The difference between these pauses and clause boundary pauses is statistically significant at the 0.025 level. - There is thus a clear tendency that heavier boundaries are associated with longer pauses.

There are 421 stressed syllables in the text, which I have determined by listening. That makes 7 stressed syllables per sentence, on the average (with a minimum of 2 and a maximum of 26). There are 111 clauses, i.e. 3.8 stressed syllables per clause (with a minimum of 1 and a maximum of 10). There are 92 intonational phrases, i.e. 4.6 stressed syllables per phrase (minimum: 1, maximum: 11). All this is probably characteristic of the text as a sample of speech read from a manuscript. Spontaneous speech will hardly turn up with as many complete sentences, nor with so many long clauses, sentences, and intonational phrases.

Now to the question of stress group patterns. This question
derives from my previous analyses of Danish, based on fairly
short sentences, read out of context - typical laboratory ma-
terial and speech. A prosodic stress group is associated with
a pitch pattern which in Standard Danish can be characterized
as low plus high-falling. The stressed syllable is succeeded
by a rise in F_0 which normally reaches its peak during the
first post-tonic syllable, see the full lines in figure 2.

There are 421 prosodic stress groups in the text. 80 of those
are monosyllabic, i.e. they consist only of a stressed syllable
with no post-tonics. Those are not expected to have any rising-
falling F_0 pattern (cf. Thorsen 1984). The remaining 341 stress
groups are polysyllabic. Only 32 of those, or 9%, do NOT have
a rise in F_0 after the stressed syllable. It appears justified
to conclude that a sequence of stressed plus unstressed syl-
lables is normally - in this type of text - accompanied by a
rise in F_0.

The magnitude of the F_0 rise from stressed to post-tonic syl-
lable varies a good deal, and I cannot assert that it decreases
in a monotonous and simple fashion through the phrase or utter-
ance, as it does in short, context-free sentences (cf. figure
2). Nor can I find any other systematic trend in the varia-
tion of the low-to-high interval. I venture to guess that
varying the magnitude of the pitch rise from the stressed syl-
lable - as this speaker does - serves pragmatic purposes, in
that it lends slightly varying degrees of prominence to the
stressed syllables, without their falling out of the range of
what may be termed neutral, non-emphatic, main stress. Thus,
greater prominence would be associated with a higher rise after
the stressed syllable.

It is important to note that rise in pitch from a stressed syl-
lable to the post-tonic is not the only cue to its stressed-
ness. (This is evident in the case of monosyllabic stress
groups, where there are no post-tonics to carry such a rise.)
Instead, I propose, the relation to surrounding stressed syl-
lables may determine a syllable as stressed. That is, if a
syllable falls into place in a rhythmic pattern and an intona-
tional contour, established by preceding and/or succeeding
stressed syllables, and if its duration, its vowel quality,
and its lack of stød do not contradict it, such a syllable will
be perceived as stressed. It may further warrant a characteri-
zation as ACCENTED if it is succeeded by one or more post-tonics
and has an associated pitch rise; if there is no such pitch
rise to post-tonics the stressed syllable is NON-ACCENTED.
The distinction between accented and non-accented stressed syl-
lables does not apply to monosyllabic stress groups.

The distinction between stress and accent, as outlined above,
would bring Standard Danish on a par with German, as described
by Bannert (1985), with British English, as described e.g. by
O'Connor and Arnold (1961), and with Dutch, as described by
't Hart and Collier (1979), where a similar distinction can be
made between stressed syllables which are tonally prominent
(accented) and stressed syllables which are not (non-accented).
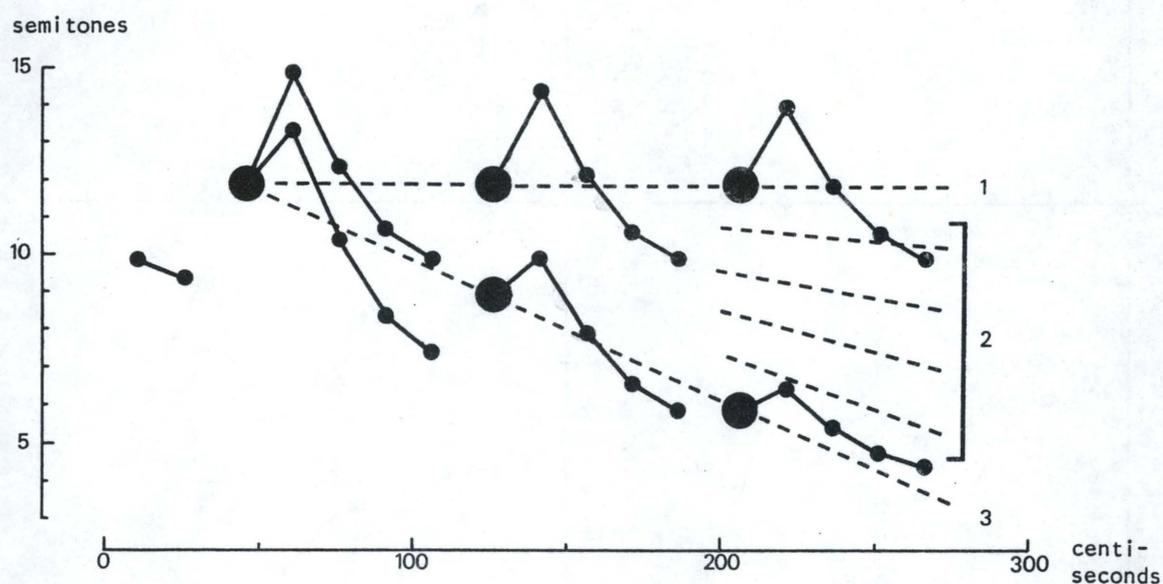
Figure 2

A model for the course of fundamental frequency in
short sentences in Standard Danish. (1) Syntactically
unmarked questions. (2) Questions with word order in-
version and/or interrogative particle; non-final de-
clarative and interrogative clauses. (3) Terminal de-
clarative statements. Large points denote stressed
syllables, small points depict unstressed syllables.
Full lines represent the Fo pattern of prosodic stress
groups; broken lines indicate the sentence intonation
contour.
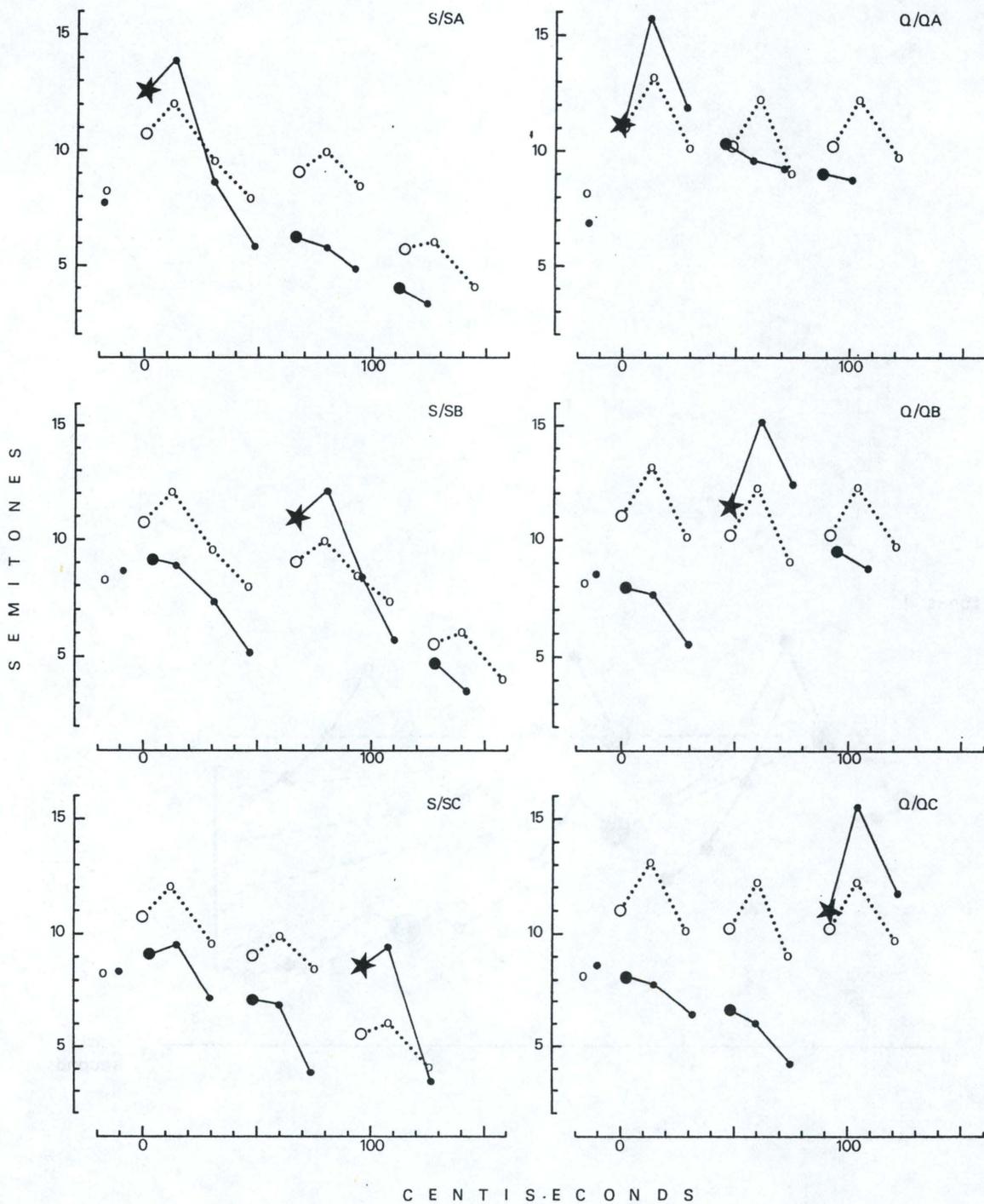
Figure 3

Stylized tracings of the course of fundamental fre-
quency in statements (S - left) and questions (Q -
right), which are prosodically neutral (open circles
and dotted lines) or have emphasis for contrast
(stars, points and full lines) in initial position
(top), medial position (mid), and final position
(bottom). Stars denote the emphatically stressed
syllables, large points denote other stressed syl-
lables, and small points depict unstressed syllables.

It appears, then, that in read speech in Danish, at least the speech I have analysed so far, stressed syllables are normally also accented. In the materials I have looked at before the present one, this has been true without exception, which is why I have not thought to introduce a distinction between stress and accent before. In retrospect, the behaviour of stressed syllables surrounding an emphasis for contrast could have provoked a discussion of accented versus non-accented: Stressed syllables which are neighbours to an emphasis for contrast suffer a reduction or deletion of their F_0 pattern, cf. figure 3. However, I am not sure whether this reduction is not also a de-stressing (that is how it has been treated previously). This is clearly a point where empirical research is called for, both in terms of acoustic and perceptual studies. - It is not my intention, and I am not able here, to do more than suggest the utility of a distinction between stressed syllables which are associated with a tonal change, and those which are not. I also want to suggest that stress is binary: either a syllable is stressed or it is not (whatever the criteria may be that determine this), but accentuation is a continuous function. Syllables are more or less accented in proportion to the amount of pitch change they are associated with, everything else being equal.

There is one snag about the dichotomy accented/non-accented, if it is to apply to stressed syllables only. There are 104 syllables with secondary stress in the text. (The decision about syllables carrying secondary stress has been reached on purely formal grounds: secondary stress occurs when a main stress gets reduced in composite words, and in phrasal units (cf. Rischel 1980). This is an emergency procedure, since I do not know how to localize, consistently, secondary stresses in running speech by prosodic criteria. Even so, a certain arbitrariness invariably persists in the assignment of secondary stress.) 95 of the 104 secondary stresses are succeeded by unstressed syllables. 21 of those 95, i.e. 22%, are associated with a rise in F_0. Does this mean that secondary stresses may also be accented? Or does it mean that the stress reduction is only partial? Previously, secondary stresses have been characterized prosodically as lacking the pitch rise typical of main stress, but retaining all other stress cues (duration, quality, stød). - If accented/non-accented is a relevant distinction in stressed syllables, then lack of pitch rise is not a feature confined to secondary stresses. Conversely, if there are secondary stresses with associated pitch rises, then accentuation is not confined to stressed syllables.

There is a vast amount of research to be done on stress in Danish, not least perceptual experiments - and it will also be evident from the discussion in the afternoon that stress and accent are among the most elusive phenomena in speech production and perception.

REFERENCES

Bannert, R. 1985: "Fokus, Kontrast, und Phrasenintonation im
    Deutschen", *Zeitschrift für Dialektologie und Linguistik*
    52, p. 289-305

't Hart, J. and Collier, R. 1979: "On the interaction of accen-
    tuation and intonation in Dutch", *Proceedings of the Ninth*
    International Congress of Phonetic Sciences, vol. II,
    p. 395-402

O'Connor, J.D. and Arnold, G.F. 1961: *Intonation of Colloquial*
    English, (London)

Rischel, J. 1980: "Phrasenakzent als Signal des Objekts ohne
    'determiner' im Dänischen", *Kopenhagener Beiträge zur ger-*
    manistischen Linguistik, Sonderbd. 1, p. 262-279

Thorsen, N. 1978: "An acoustical analysis of Danish intona-
    tion", *J. Phonetics 6*, p. 151-175

Thorsen, N. 1979: "Interpreting raw fundamental frequency
    tracings of Danish", *Phonetica 36*, p. 57-78

Thorsen, N. 1980a: "A study of the perception of sentence in-
    tonation - Evidence from Danish", *J. Acoust. Soc. Am. 67*,
    p. 1014-1030

Thorsen, N. 1980b: "Neutral stress, emphatic stress, and sen-
    tence intonation in Advanced Standard Copenhagen Danish",
    Ann. Rep. Inst. Phon. Univ. Copenhagen 14, p. 121-205

Thorsen, N. 1982a: "On the variability in F_0 patterning and
    the function of F_0 timing in languages where pitch cues
    stress", *Phonetica 39*, p. 302-316

Thorsen, N. 1982b: "Sentence intonation in Danish", *Preprints*
    for the Working Group on Intonation at the XIIIth Inter-
    national Congress of Linguists, Tokyo, August 29 - Sep-
    tember 4, 1982, p. 47-56

Thorsen, N. 1983a: "Standard Danish sentence intonation -
    Phonetic data and their representation", *Folia Linguistica*
    17, p. 187-220

Thorsen, N. 1983b: "Two issues in the prosody of Standard
    Danish", In: *Prosody - Models and Measurements* (eds.:
    Cutler, A. and Ladd, D.R.), (Heidelberg), p. 27-38

Thorsen, N. 1984: "Variability and invariance in Danish stress
    group patterns", *Phonetica 41*, p. 88-102

Thorsen, N. 1985: "Intonation and text in Standard Danish",
    J. Acoust. Soc. Am. 77, p. 1205-1216

Thorsen, N. (forthcoming): "Intonation and text in Standard
    Danish - with special reference to the abstract represen-
    tation of intonation", In: *Phonologica 1984*.

APPENDIX I

Transcript (the first of five pages) of the analysed text.
Stress marks have been added, to designate emphasis ($^-$), normal
main stress ($^'$) and secondary stress ($^`$). Glottal attacks (?)
are also marked. Pause durations are likewise given in paren-
theses (in centiseconds).

I dénne ópgave skal du øve tág-quèstions, altså påhǽngsspørgsmål.(75)

Dísse intonères ?énten som én tónegrùppe med en fàldende stígende

kérne,(42) ?éller som tó tónegrùpper, hvór den ánden ùdtàles med

fàldende stígende mønster.(150) Det første dú skal fóretàge dig i

dénne ópgave er at lỳtte på påhǽngsspørgsmål ?ùdtàlt som en énkelt

tónegrùppe.(100) Betíngelserne for at fá en ?énkelt tónegrùppeùd-

tàle ?ér,(60) ?énten at påhǽnget følger efter en impérativ,(68)

?éller at både påhǽnget ?og den fóranstìllede deklárative konstruk-

tión ?er négative eller pós(i)tive,(55) ?éller at táleren stìller

den tíltàlte persón frít (23) med hénsyn til at svàre já eller

néj (16) på det gívne spørgsmål.

Øvelse ét.(120)

I dénne øvelse skal du øve impérativer med et ?éfterfølgende påhǽng.(140)

Du hører først spéakerens ?índtàling af påhǽngsspørgsmålet,(60) og

?ùmiddelbart hérèfter kòmmer sætningen ?i en filtréret fórm,(52) sálédes

at du hører intonatiónen men?íkke segménterne.(150) Du skal forsøge

at sỳnge méd på den filtrérede sætning(44) - du kan for eksémpel sýnge

på?'m'(51) -?éller du kan vǽlge bàre at lỳtte til intonatiònen i den

filtrérede sætning.(135) I den éfterfølgende páuse (16) er det dín túr til

at índtàle påhǽngsspørgsmålet med den rígtige intonatión.(182) Éfter

dít forsøg hører du spéakerens versíon (28)?éndnu en gáng,(40) ?og

kan hérèfter gøre ?éndnu et forsøg.(60) (Jǽvnfør modéllen.)(125)

Húsk (at) sàt(te) tǽlleren på núl ?índen du stárter.

(((exercise)))

A PHONETIC STUDY OF THE
STØD IN STANDARD DANISH

ELI FISCHER-JØRGENSEN

Abstract

Chapter I gives a brief survey of phonological interpretations of the Danish stød, the dialectal and historical background, and previous phonetic investigations.

Chapter II gives an account of the material, subjects and procedures used in the present investigation.

Chapter III contains the results. In accordance with Svend Smith a distinction is made between the first and the second phase of the stød.

The first phase is characterized acoustically by a higher pitch level and often a higher intensity level than syllables without stød, and by a relatively high subglottal pressure and airflow, thus generally by a relatively high expenditure of energy. In the second phase, the stød phase proper, there is a strong decrease in intensity, particularly in the lower part of the spectrum and, for the majority of the speakers, a noticeable decrease in fundamental frequency and/or aperiodicity. Moreover the airflow is low, and inverse filtering shows a decreasing amplitude of glottal flow peaks. There is also a slight decrease in subglottal pressure, and all speakers have a constriction of the vocal folds and often of the ventricular folds as well, but with large interindividual variation as to the degree of constriction. On the boundary between the first and the second phase most speakers have a strong contraction of the vocalis and lateralis muscles, obviously preparing for the glottis constriction of the second phase.

Chapter IV discusses the stød in relation to phonation types and concludes that the stød is closely related to creaky voice though without sharing all of its characteristic features.

Moreover the causal relations among the various properties of the Danish stød are discussed. The author cannot follow Svend Smith in assuming that a sudden contraction and relaxation of the respiratory muscles resulting in a quick rise and fall in subglottal pressure, constitute the primary factor. There is rather an independent contraction of a number of muscles, and neither the high pitch in the start nor the fall in pitch and intensity in the second phase can be explained by the subglottal pressure contour. The high pitch level in the start may be explained by activity in the cricothyroid, and the decrease in pitch and the low intensity in the second phase is probably

*due to the glottis constriction, although the fact that the
decrease in intensity starts rather early, raises some problems.*

*Finally the question of the origin of the stød is taken up
again. It is suggested that the stød in Danish perhaps origi-
nated from a reinforcement of the first syllable due to reduc-
tion and loss of a following syllable in common Scandinavian.
The reinforcement may have been accompanied by a rise in pitch
so that developments in different directions (involving stød
or tonal accents) were possible.*

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I. INTRODUCTION

A. PHONOLOGICAL ASPECTS OF THE STØD

1. STØD AS A PROSODY

The Danish stød is a prosodic phenomenon connected with certain
syllables. It generally shows up as a decrease in intensity
and (often) pitch, in distinct speech ending in irregular vi-
brations (creaky voice), in very emphatic speech probably some-
times in a complete glottal closure. A distinction is often
made between "stød in the vowel" and "stød in the consonant".
But the stød is not, primarily, connected with specific seg-
ments. The irregularities (or dip of the Fo- or intensity
curves) are generally found about 10-15 cs after the start of
the vowel; therefore, if the vowel is long they will coincide
with the end of the vowel, and if the vowel is short with the
beginning of a following sonorant consonant. The stød requires
for its manifestation a certain stretch of voicing. Therefore,
syllables ending in a short vowel or in a short vowel plus
voiceless consonant(s) cannot have stød in Standard Danish.
They are said to lack "stød-basis". As Danish syllables do
not have voiced obstruents after short vowels (phonetically
Danish [ð] is a sonorant, not an obstruent), only syllables
with short vowel plus sonorant consonant can have stød. More-
over, the stød requires a certain degree of stress (primary or
secondary stress) and disappears if the syllable loses its
stress in the sentence. It also disappears in song (at least
in traditional higher style singing). These facts show that
it is not a segment but a prosody. In phonetic transcription
it is traditionally indicated by a raised comma (') or some-
times by the symbol for a glottal stop (ʔ) placed after a long
vowel or after a sonorant consonant following a short vowel
(see Note 1 on phonetic transcription).

2. STØD IN DIFFERENT WORD TYPES

The presence or absence of stød can often be predicted. This
is, however, not always the case; and there is quite a number
of minimal pairs (see below).

As far as native monomorphemic words are concerned, the pres-
ence of stød is characteristic of monosyllables (provided that
they have stød-basis) in contradistinction to disyllables.
(1) Almost all monosyllables with long vowel have stød, e.g.
pil [pʰiːʼl] 'arrow', *hus* [huːʼs] 'house', *bæst* [bɛːʼsd] 'beast'.
The only exceptions are the contracted forms *far, mor, bror*
[faː, mo(ː)ɐ̯, bʁo(ː)ɐ̯] 'father, mother, brother', and, in the
younger Copenhagen standard ("Advanced Standard Copenhagen")
words with assimilation of /r/ to a preceding [a] or [ɒ],
e.g. *mark* [maːɡ] 'field'. (2) Almost all monosyllables with
short vowel plus sonorant consonant plus consonant have stød,
e.g. *kant* [kʰanʼd] 'border', *helt* [hɛlʼd] 'hero', *sans*
[sanʼs] 'sense'. Only words with /r/ plus voiceless consonant

are excepted, e.g. *vers* [vɛɐ̯s] 'verse', *birk* [biɐ̯g] 'birch'.
(In this position /r/ was voiceless earlier and still is in a
very conservative norm.) (3) Of monosyllables with short vowel
plus sonorant consonant some have stød and others not, and this
gives rise to various minimal pairs, e.g. *ven* [vɛn] 'friend'
vs. *vend* [vɛn'] 'turn!' (imperative), *man* [man] (indefinite
pronoun) vs. *mand* [man'] 'man', *spil* [sbel] 'play' (noun) vs.
spil [sbel'] 'play!' (imperative) (final sonorants are very
short in Danish, and may have been too short to get stød, ex-
cept when they were geminated or in clusters; later shortenings
or assimilations of long consonants and clusters gave rise to
a number of minimal pairs with short vowel plus sonorant con-
sonant). The recent shortening of vowels before [ð] has in-
creased the number of minimal pairs, e.g. *fed* [feð] 'clove' vs.
fed [feð'] 'fat' (adjective), in the more conservative norm
[fe:'ð].

Disyllables in *-e* [ə] never have stød. But disyllables in *-er*,
-en, *-el* [ɒ (ɔ), n̩, l̩] vary (some were old monosyllables, some
polysyllables, and some are loanwords), and there is quite a
number of minimal pairs in *-er*, thus *kælder* [kʰɛlɒ] 'cellar'
vs. *Keller* [kʰɛl'ɒ] (a name), or *læser* [lɛ:sɒ] 'reader' vs.
læser [lɛ:'sɒ] 'reads'.

As for polymorphemic words, the most general rule is that flex-
ives and derivatives do not cause any stød change. The presence
or absence of stød in inflected forms may therefore indicate
whether the stem is mono- or polysyllabic, e.g. *tanken* [tʰaŋgn̩]
definite form of *tanke* 'thought' vs. *tanken* [tʰaŋ'gn̩] definite
form of *tank* 'tank'. However, in many cases the stød of mono-
syllabic stems is lost, e.g. before endings in *-e* [ə], for
instance the plural *-e* in nouns and adjectives (*hus* [hu:'s]
'house', plur. *huse* [hu:sə]), and generally before *-ede* [əðə]
(preterite of weak verbs), whereas in other cases there is ad-
dition of stød, e.g. in the definite form of stødless nouns in
short vowel plus sonorant consonant, e.g. *ven - vennen* [vɛn]
[vɛn'n̩]. The ending *-er* [ɒ] behaves inconsistently, which may
give rise to minimal pairs like *piber* [pʰi:bɒ] plur. of *pibe*
[pʰi:bə] 'pipe' or nomen agentis of the verb *pibe* [pʰi:bə]
'peep' vs. *piber* [pʰi:'bɒ] pres. of the verb *pibe*. There is
inconsistency even with the same grammatical ending, e.g. *ven*
[vɛn] 'friend', plur. *venner* [vɛnɒ] and *han* [han] 'male', plur.
hanner [han'ɒ].

Monosyllabic first parts of compounds often lose their stød,
e.g. *sol* [so:'l] 'sun', but *solskin* ['so:l̩ˌsgen'] 'sunshine'.
On the other hand, disyllabic verbs or verbal derivatives (as
well as complex adjectives) with prefixes or as second part of
compounds often have stød addition. Whereas e.g. *tale* [tʰæ:lə]
'to speak, speech' and the nominal compound *udtale* ['uðˌtʰæ:lə]
'pronunciation' do not have stød, there is stød addition in the
verbs *betale* [beˈtʰæ:'lə] 'pay' and *udtale* ['uðˌtʰæ:'lə] 'pro-
nounce' and in the noun *udtalelse* ['uðˌtʰæ:'ləlsə] 'utterance'
derived from the verb *udtale*. (Further examples illustrating
the rules are found in the word lists, Appendix I.)

Integrated foreign words follow the stød rules for native words.
Polysyllables with stress on the last syllable are treated as
monosyllables, e.g. *supplikánt* with stød on *-kánt* like the mono-
syllable *kant* (except some French words with final vowel). Di-
syllables and words with penultimate stress generally do not
have stød (like native disyllables in *-e*, e.g. *kane*), e.g.
káno, panoráma. Words with stress on the antepenultimate have
stød on this syllable, e.g. *fólio* (the native pattern <u>may</u> in
this case be the type *løbene* ['lø:'bənə] definite plur. of the
monosyllabic noun *løb* [lø:'b] (but native trisyllabic words
may also lack stød, e.g. *løbende* [lø:bənə] pres. participle
of the disyllabic verb *løbe* [lø:bə]). Sometimes foreign words
are treated like compounds, e.g. lat. *scribunt* with stød on
-bunt. (Latin words traditionally get stød, but otherwise stød
is very rarely transferred when Danes speak foreign languages.)

Thus the rules are complicated and not always exceptionless,
and the conditions may be both phonological and morphological;
although it is connected with the syllable,the stød may charac-
terize morphological types.

3. LINGUISTIC DESCRIPTION OF THE STØD

The first description of the Danish stød is given by Jens
Pedersen Høysgaard (1743, 1747, 1769). He sets up a system
of four so-called "åndelav" (i.e. 'breath types' or 'phonation
types') based on a cross-classification of stød and vowel length
(with a terminology which varies somewhat in the three differ-
ent books). Høysgaard does not give examples of four very
similar words like *kæle, kæler, kælder, Keller* [kʰɛ:lə,
kʰɛ:'lɒ, kʰɛlɒ, kʰɛl'ɒ], but many pairs; his examples are per-
fectly clear, and he is well aware of the fact that his four
"åndelav" are based on a cross-classification of stød and vowel
length. He also distinguishes clearly between "åndelav",
stress, metrical ictus, and the role of pitch and duration in
stress. Moreover, he gives the main rules for the occurrence
of stød with many examples and a number of minimal pairs, and
he proposes that the different "åndelav" should be indicated
in orthography by means of accents. As a first description of
the stød, this is an admirable achievement. It influenced the
description of Danish prosody deeply for the next hundred
years, and it is still considered useful by many dialectol-
ogists. The only deviation from later descriptions of the
stød is that Høysgaard considers words with stød on a syllable
final vowel (e.g. [sø:'] as belonging to the type [hal'] (i.e.
stød in syllables with short vowel plus sonorant consonant),
and not to the type [hæ:'l] (i.e. stød in words with long
vowel). The reason may be that he heard the type [hal'] as
"stopping of the breath", and the type [hæ:'l] as first stop-
ping of the breath and then "giving it speed again", i.e.
rather [hæ'æl] with a rebound of the vowel, as it is still
often pronounced (and obligatorily so in the Zealandish stød
in long vowels). And he may not have had this rebound finally.
Moreover, in the distribution of the stød he is influenced by
his Jutlandish origin. In his main work on prosody (1747)

he mentions that strictly speaking one might set up a fifth "åndelav", viz. for words with apocope and lengthening of the final consonant, as in *skinne* 'shine', e.g. in Jutlandish.

Some of Høysgaard's followers made a few revisions, e.g. considering the type [sø:'] as having stød in the vowel, or adding a 6th type (thus Rask considered the contracted type *far* [fɑ:] to be a special type with overlong vowel, cp. Bjerrum 1959). Levin (1844) distinguished the stød-opposition from the length-opposition, but in a not too clear way, which was not accepted. Later Jessen (1861, cit. Bjerrum 1959) proposed this distinction again, and since then it has been customary to distinguish the two oppositions completely. At the same time the grammarians started describing the type [hæ:'l] as having "stød in the vowel" and [hal'] as having stød in the consonant, e.g. Lyngby in the fifties (cp. Bjerrum 1959, p. 226), Bruun (1883), and Jespersen (1897-99). This was, in a way, a step backwards from a functional point of view.

Uldall (1933) places the stød among the consonants in his sound chart, but later (1936) he describes it as a prosody. However, at this stage of Hjelmslev's and Uldall's linguistic theory a marginal unit which can occur only initially or finally in a syllable, but cannot occur in both positions, is a prosody, and thus /h-/ is also a prosody.

Martinet (1934 and 1936) emphasizes that the stød is a prosody in the more traditional sense of the word, arguing that it disappears in unstressed syllables and in song, and that its place in the syllable is automatically regulated and without phonological value. Martinet also states that although a long vowel with stød may be somewhat shortened, it does not represent a neutralization of long and short vowels, realized as short (as proposed by Uldall 1935), since it keeps the quality of a long vowel; this is particularly clear in the cases of /ɔ/ and /a/, where the difference in quality between short and long vowels is obvious (e.g. [æ: - a]). Martinet also mentions the only exception, viz. the so-called enclitic stød in a case like *lad os* ['la'ɔs] with [a], where the enclitic word begins with a vowel, but he considers this case as dialectal. - In any case, this type of enclitic stød is no longer common in Standard Danish (cf. Brink and Lund 1975, p. 511f), and the case is a very special one, cp. that in e.g. *lad mig* ['lam'ai] the enclitic stød occurs in the following consonant.

Aage Hansen (1943), who has given the most detailed description and discussion of the functional aspect of the stød, also describes it as a prosody. He considers it as connected with the syllable, but characterizing certain word types, in the first place monosyllables; but also, in prefix words and compounds, the last part of a complex unit.

In glossematic and generative descriptions it has been attempted to get rid of the exceptions, and thus of the stød, in the ideal (glossematic) or underlying (generative) representation.

Hjelmslev (1951) interprets the words containing short vowel
plus sonorant with stød as containing a cluster consisting of
sonorant plus /d/ in "ideal notation", whereas words without
stød are assumed to end in a single consonant. As for disyl-
lables in -er, -en, -el, the words without stød are interpreted
as ending in /ɛ/ plus sonorant consonant, whereas the words
with stød are interpreted as monosyllables ending in /r, n, l/
e.g. [lɛ:sɒ] /lɛ:sɛr/ vs. [lɛ:'sɒ] /lɛ:sr/. He gives various
other (rather arbitrary) rules. Rischel (1970) prefers gemina-
ted consonants to d-clusters. Basbøll (1971-73) improves
Hjelmslev's rules on various points. In his paper 1972 he
simplifies the description by permitting morphological con-
ditions in accordance with generative phonology (this was not
permitted in the glossematic expression system). Heger (1980)
gives rules for monomorphemic native and foreign words. A de-
tailed and very instructive description of stød-occurrence in
native Danish words, including stød-addition and stød-loss in
inflected words, derivatives and compounds, is given in Bas-
bøll's latest paper (1985). In this paper (which has influenced
the description given in the start of this section) he does not
set up underlying forms with consonant clusters, etc., arguing
that since these are in most cases purely ad hoc, i.e. without
any other justification than the occurrence of the stød, very
little is gained by this analysis, so that it is just as simple
to indicate stød occurrence in the lexicon.

B. STØD IN DANISH DIALECTS

1. OCCURRENCE OF STØD AND TONAL ACCENTS

The map (figure 1) shows that although most Danish dialects
have stød, the stød is lacking in the southern part of Denmark,
on the island Bornholm south of Sweden (as also in the old
Danish dialects in present-day southern Sweden), on the island
Amager close to Copenhagen, and in a very small area in the
northernmost part of Zealand. (The dialects are, however, now
to a large extent being supplanted by Standard Danish or re-
gional standards). Some of the dialects without stød have a
tonal difference instead, not only the dialects in Sweden but
also dialects in southern Funen and South East Jutland and
some of the smaller islands in this district. Finally, there
are areas in Funen, southern Jutland and some islands in Katte-
gat (e.g. Anholt) which have stød but also show tonal opposi-
tions or traces of tonal oppositions. The tonal system of the
dialect in Felsted in South East Jutland has been described
in detail by Marie Bjerrum (1947). In this dialect old mono-
syllabic words have a rather low rising-falling tone movement,
whereas old polysyllables have a two-peaked movement, the
second peak being normally lower than the first. The tonal
difference is accompanied by a dynamic difference and a certain
lengthening of accent 2 words with apocope. Since Jutlandish
dialects have apocope of final -e in former disyllables, the
number of minimal pairs is much higher than in Standard Danish,
e.g. corresponding to Standard Danish hus - plur. huse [hu:'s
-hu:sə] Jutlandish dialects with stød have [hu:'s - hu:s],

North of —: stød
South of —: no stød

≡ contrastive
  tonal accents

/// contr. ton.
    acc. in some
    word types

||| rising tone in
    some monosyll.
    types
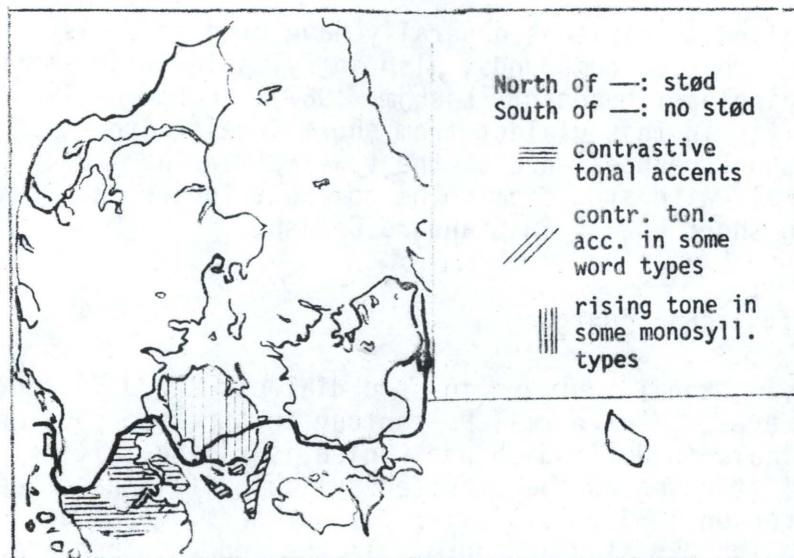
Figure 1

*Stød and tonal accents in Danish dialects (after
Køster et al. 1982)*

and in Felsted the difference is ['hu:s] with the one-peaked
tonal accent 1 vs. ['hu:s] with the two-peaked accent 2. The
dialects of eastern Funen have been described by P. Andersen
(1958). Here the manifestation of accent 1 and 2 is rather
complicated. In some areas the stød is accompanied by a rising
tone, in others rising tone and stød may occur in different
words, but monosyllables with short vowel plus voiceless con-
sonant may have falling tone, and the corresponding disyllable
rising tone. The dialect on the island Ærø (Kroman 1947) has
a tonal difference, but with a different distribution depending
partly on vowel length.

2. DISTRIBUTIONAL RULES FOR THE STØD

The distributional rules may also differ somewhat within the
stød-areas. In contradistinction to Standard Danish the Jut-
landish dialects generally lack stød in words containing a short
vowel plus sonorant consonant plus consonant, e.g. *kant* 'border'.
Jutlandish also lacks stød in verbs with unstressed prefixes,
e.g. *betale* 'pay' (but it often has stød in derivations of such
verbs, e.g. *betaling* 'payment' (see, e.g., Ringgaard 1971 and
K. Kristensen 1979). On the other hand, Zealandish dialects
have stød in positions where the standard language does not have
stød, e.g. after short vowels before voiceless consonants, con-
sistently so in the definite form of monosyllabic nouns like
kæppen (Zealandish [kʰæ'bin], definite form of the word *kæp*
'stick', but also in some other words in -*er*, -*en*, -*el*, and in
verbs with prefix, e.g. *benytte* [be'ny'də] 'utilize'.

Moreover, Zealandish dialects generally have stød in a disyl-
labic second member of compounds, also in syllables with short
vowel plus voiceless consonant (Ejskjær 1967). Long vowels
with stød differ in this dialect from short vowels with stød
by having a short reappearance of the vowel after the stød.
The short vowels with stød seem to be somewhat longer than the
corresponding short vowels in Standard Danish.

3. ACCOMPANYING TONAL CONTOURS

The accompanying tonal contours in stød dialects are different
in different areas. The normal Fo-contour in stressed plus un-
stressed syllable in Jutlandish and Funish is rising-falling,
with the fall starting in the stressed syllable if it has stød
(Fischer-Jørgensen 1983). A similar contour seems to have
characterized the old standard norm. In the modern Copenhagen
standard, described by Thorsen (e.g. 1983 with further refer-
ences) the stressed syllable (only syllables without stød are
described) is low rising and the following unstressed syllable
high, with following unstressed syllables gradually falling.
North Zealandish dialects have, according to Kroman (1947), a
rising-falling contour in disyllabic words with stød, and a
falling-rising contour in disyllabic words without stød.
Andersen (1949) is sceptical, and assumes a falling-rising
contour in North Zealandish in both cases. I have, however,
found a rising-falling contour for several North Zealandish
speakers in words without stød (Fischer-Jørgensen 1983), in
contradistinction to both Kroman and Andersen.

4. WEST JUTLANDISH STØD

A large area in the western part of Jutland, which has normal
Danish stød, also has a second type, the so-called West Jut-
landish stød (see the map figure 2). It has been described in
detail by Ringgaard (1960). Its distribution differs complete-
ly from that of the common Danish stød. It is found in poly-
syllabic words and in old apocopated disyllabic words before
the stops /ptk/ following a voiced sound. Corresponding to
Standard Danish *hat* 'hat' - plur. *hatte*, West Jutlandish has
[hat - haʔt]. This stød is also found in compounds. Accord-
ing to Ringgaard there is a complete closure continuing into
the following stop, which is unaspirated. It is not really a
stød, i.e. a prosodic phenomenon, but part of a preglottalized
stop consonant. It is obviously similar to the glottal stop
found in many East English dialects, and also in Flamish dia-
lects, e.g. English [bɛʔtə] or [bɛʔə] for *better*. The glottal
closure may also simply replace the stop in West Jutlandish,
like in English, but less often. This phenomenon is also found
in North West Funish and sporadically in Jutlandish dialects
with tonal differences (Ella Jensen 1961). The West Jutlandish
"stød" will not be treated in the following.

V-stød overalt foran *p, t, k.*

V-stød på vokal foran *p, t, k, rk, rp, gt, rt, lt < ° kt.*

V-stød på kons. foran *p, t, k.*

V-stød på vokal foran *p, t, k.*

Figure 2

West Jutlandish stød in Danish dialects (after Ringgaard 1960)

before -p, -t, -k after all sounds

before -p, -t, -k under special conditions
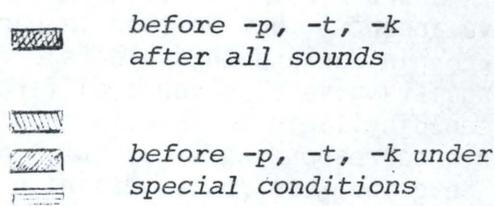
C. THE HISTORICAL BACKGROUND

1. CORRESPONDENCES BETWEEN DANISH STØD AND SCANDINAVIAN WORD TONES

There is a close correspondence between the distribution of Danish stød vs. no stød and the Swedish and Norwegian accents 1 and 2 (as well as the South East Jutlandish accents), the stød corresponding to accent 1 and no stød to accent 2.

From a phonological point of view the systems are different. In the first place Swedish and Norwegian compounds have only one accent, spread over the whole word, whereas in Danish each part of a compound or derivative may have stød or no stød (In Felsted most compounds have only one accent, but they may have two). The Danish stød is connected with a syllable, not a whole word (though it may characterize certain word types). Secondly, whereas the Danish stød must be considered the marked term of the opposition (in the Praguian sense), it is accent 2 which is the marked term in the languages with tonal accents. This statement can be supported by various facts. In the tonal languages there is no phonological opposition in monosyllables (they do not have the Danish exceptions, e.g. [vɛn] vs. [vɛn']), and as monosyllables have accent 1, this must be the unmarked term. Further, in unstressed position, where there is no opposition in any of the languages, the tone in Swedish and Nor-

wegian is close to accent 1, whereas Danish has no stød, and
in unassimilated foreign words Swedish and Norwegian generally
use accent 1, whereas Danish has no stød (see Basbøll 1972).
Moreover, Elert (1970) argues that whereas accent 2 has a posi-
tive (connective) function, indicating that the following un-
stressed syllable belongs to the same word, e.g. *vàka*, accent
1 is neutral in this respect, e.g. *váken, vák en..* .

In the large majority of words the distributional correspond-
ence is, however, clear: accent 1 = stød, accent 2 = no stød.
The influence of various morphological endings is also mostly
parallel in the involved languages. One more specific differ-
ence is that accent 1 does not, like the stød in Standard
Danish, require a long stretch of voiced sounds. Thus words
with short vowel plus voiceless consonant of the type *hat, hatten*
have accent 1, but no stød in Danish (except for the type
hatten in Zealandish dialects). However, various older Danish
linguists have observed a difference in prosodic contour be-
tween disyllabic words with short vowel plus voiceless conso-
nants corresponding to accent 1 and accent 2 words, respective-
ly, e.g. between *fedtet* definite form of the noun *fedt* 'fat'
and *fedtet* as participle of the verb *fedte* 'fatten' either a
difference in pitch (Verner 1878, Jespersen (reluctantly) 1913,
Møller 1922), or a difference of force and length (Aage Hansen
1943), particularly for Jutlandish speakers. More recently
Basbøll (1972) has noticed a difference for Funish speakers.
I made a difference myself when I was younger, the accent 1-
word having a shorter vowel, a more abrupt stress, and perhaps
a higher pitch than the accent 2-word, but the difference is
not consistent in my present speech, and it is hardly found in
the modern Copenhagen standard speech. Anyhow, it seems prob-
able that Danish used to share with the other Nordic languages
an accentual distinction between two word types even in cases
where there is no stød-basis, whereas Danish differs categoric-
ally from the other languages in this respect if we look only
at Modern Standard Copenhagen.

Seen in a historical perspective Danish stød and accent 1, are
(roughly speaking) found in wordforms which were monosyllabic
in old Scandinavian after the syncope (i.e. after around 900),
whereas no stød and accent 2 are found in wordforms which were
disyllabic at that time. In old Danish the definite article
was a separate word, and its presence did not affect the ac-
centuation of the noun form, but it came to be used enclitical-
ly, and around 1200 it seems that the stem and the definite
article fused into one word. However, this did not affect the
accentuation of old monosyllables, which kept their accent
(accent 1) also when inflected with the definite article.
Later (around 1200-1500) monosyllables with final /r, l, n/
after consonant developed a svarabhakti-vowel and became di-
syllabic, but kept their accent 1. The difference between the
accents was thus phonemicised (see, e.g., Oftedal 1952 and
Gårding 1977).

2. THEORIES CONCERNING THE
   HISTORICAL DEVELOPMENT

According to what was said above a common dependence on word types differing in syllable number seems clear. But what is still - and will probably remain - very uncertain is when and how the development of the accents and stød took place, whether the stød developed out of a tonal accent or vice versa, or whether perhaps both developed out of a common, perhaps more dynamic difference. These problems have been the subject of intensive debate among Scandinavian linguists. Only some of the main arguments will be mentioned in the following.

a. Time of origin   The fact that accents and stød are not in-
                    dicated in the orthography makes it very difficult to say when they have emerged. Some short characterizations of the Danish language by foreigners from the 16th and 17th century may be interpreted as pointing to the existence of the stød. The Swede Hemming Gad has often been quoted. In 1510 he wrote that *"the Danes press the words out as if they would cough, and seem to take pains to twist the words in their throat before they come out"* (e.g. quoted by Jespersen 1913). This may be the first description of the stød. But the first explicit description is not found until Høysgaard (1743), and the Swedish accents have not been mentioned until 1737 (very briefly by A. Nicander, see e.g. Elert 1970, p. 41-42).

Most scholars have placed the origin of the stød somewhere between 1100 and 1500. But most of the arguments are rather dubious. It has often been maintained that the stød must be younger than some definite sound changes (e.g., the weakening of final stops or the lengthening of final /m/), because the stød could not be applied to the words before the sound change in question had operated (Verner 1878, Jespersen 1897, Kristensen 1898, Skautrup 1944). But this type of argument does not hold, because the stød rules may have been productive for hundreds of years (they still are) and can have applied when new sound changes made it possible (cf. also the criticism by A. Pedersen 1912). Several scholars have also argued that the stød must have originated later than the introduction of a large number of loanwords from Middle Low German (around 1350-1500), which now have stød, since if the stød had already existed at that time, the speakers would have used forms without stød which were more like the Low German prosodic form (Storm 1875, Verner 1878). But it is very improbable that Danish speakers should have tried to imitate the foreign prosodic contour. It is much more probable that they have treated the loanwords according to Danish stød rules, as we still do (the argument could also be used to prove that we did not yet have stød in the 19th century since there are loanwords from this century and even from the 20th century which have stød).

The most problematic category of words are the verbs with unstressed prefix and stød. This word type was rare in Old Scandinavian, but was introduced in great numbers from Middle

Low German. However, as Aage Hansen argues (1943), assuming
that the stød originated later or simultaneously with these
words does not explain why they got stød. We must assume that
the type existed beforehand, and Old Scandinavian actually had
a certain number of prefixed verbs (Kock 1901) which must have
had unstressed prefixes. But the rule for stød application in
these cases is not part of the monosyllable rule, but must be
due to a special rule.

It is much safer to argue that the stød must be older than sound
changes which have changed words (which actually have stød) in
a way that made the stød rules inapplicable to them, e.g. the
addition of the definite article and the introduction of svara-
bhakti vowels. However, what can be concluded from such cases
is only that there must have been two distinct prosodic con-
tours before these changes, i.e. before approximately 1200, and
that the one characterizing monosyllables was maintained in these
words in spite of the new changes which made them disyllabic,
but we cannot know whether these contours were tonal or stød-
like at that time. Oftedal (1952) assumes that they might have
been stress differences accompanied by tone differences, cf.
that accent 2 in Swedish and in some Norwegian dialects has a
secondary stress on the second syllable. Before the changes
mentioned the two accents were only junctural (indicating the
number of syllables of the word); after the changes they were
phonemicized, and e.g. Old Norwegian *veg-inn* (the way) and
veginn (participle of 'to weigh') must have had their different
accents already when the definite article coalesced with the
stem. Gårding (1977) adds that the speakers may have found it
important to keep the definite form of monosyllables apart from
that of disyllables. Smith (1938) suggests that a concentra-
tion of energy due to the apocope, supported by the need to
keep old monosyllables and disyllables apart and thus avoid a
number of mergers, caused the emergence of the stød. Skautrup
(1944) adopts this theory, and thus dates the stød to 1100-1200,
when the weakening of the unstressed syllables is assumed to
have taken place. It is, however, problematic how imminent
the danger of mergers was. Jutlandish, where the weakening
developed into a complete apocope, at least around 1300, had
lengthening of a sonorous consonant in apocopated disyllables,
e.g. in words like *skinne* [sgen:] and perhaps also a specific
prosodic contour, the so-called circumflex, as a remnant of
the disyllabicity, so that monosyllables and old disyllables
were kept apart. This is still the case in West Jutlandish,
and in East Jutlandish the difference did not disappear until
the last century, cp. that Høysgaard mentions this lengthening,
and it is also documented in other dialects, and in a few
places the older generation still has lengthening; as for the
words with long vowel before voiceless consonant (e.g. *hus*),
Ringgaard still perceives a circumflex in West Jutlandish
(1959). And in Funish and Zealandish the apocope is much
later and still facultative in many dialects, and nevertheless
there are more cases of stød in Zealandish than in Jutlandish.

b. Did the stød develop from a   As for the relative age of
   tonal accent or vice versa?   tonal accents and stød most
                                        scholars assume that there
was first a common Scandinavian tonal difference and that the
stød originated later. There are some good arguments for this
view, viz. that the tonal accents in Danish are found in pe-
ripheral and isolated areas and are disappearing, and in some
dialects in Funen stød and tone may be variants (Andersen 1965).
Kroman (1947) advanced the theory that the tonal accents in
South East Jutland and in the southern islands should be due to
a Swedish invasion in the Viking time. But this theory has not
been accepted by other Danish scholars, and it does not explain
the traces of tones in the small islands in Kattegat. It is
thus possible that a larger part or the whole of the Danish dia-
lect area has had tonal accents, but it is only a hypothesis.

We do not know either whether the southern Danish islands which
have neither stød nor tonal accents have had one of these dif-
ferences earlier or whether they never had any difference of
this kind. The fact that all Scandinavian dialect areas with-
out any distinctions are peripheral makes them look like typical
relic areas. Haugen (1970) suggests influence from neighbour-
ing foreign languages, but it seems improbable that German
should have had more influence in Lolland than in southern Jut-
land.

Even if it should be true that the stød has replaced an earlier
tonal difference, it does not necessarily follow that it has
developed out of a definite, e.g. rising, tone. But this has
been assumed by various scholars (e.g. by Verner (2/11 1874
(1903) and 1878). Verner suggested that a quickly rising tone
involving a tension of the vocal chords, might lead to an
"überschnappen" ('snapping') and a short closure of the vocal
chords. He finds this assumption supported by his own pronunci-
ation of words with stød and by reference to the occurrence of
glottal closure in Lithuanian and Latvian in connection with a
rising-falling tonal contour (for a detailed discussion of
Verner's theory, see Smith 1944). This theory was accepted by
Jespersen (1897 and 1913), by Ekblom (1938) and by several
others. But Verner's description of his own tone contour is
rather different from what has been found for other speakers
(see later in this paper), and nobody can know how a hypothet-
ical Danish accent 1 has been. In Felsted it is rather low,
in Funish it may be rising but also falling, in Skåne it is
mainly falling, and on the whole the phonetic manifestation of
the Scandinavian word tones is extremely varied, the only
general feature being that if one of the accents is two-peaked
it is always accent 2, and if both have one peak, the peak is
later in accent 2 than in accent 1 (Gårding 1977). It is also
a general experience from tone languages that the phonetic mani-
festation is not very stable. - J. Forchhammer (1942) has an
interesting argument against Verner's theory, viz. that a rising
tone is generally obtained by stretching the vocal chords,and
that cannot produce the compression which he considers to be
the characteristic feature of the stød. On the contrary, a
falling tone with thickening of the vocal chords might rather
lead to a compression.

Others think that the stød has originated from a strong con-
centration of stress on one syllable. Storm (1875) suggests
this possibility besides assuming an earlier rising tone.
Kristensen (1899) also thinks that the stød is due to a dynamic
development and, as mentioned above, Smith is of the same opin-
ion. This explanation has the advantage that a concentration
of energy could also be assumed for words with prefix, so that
a common explanation might be obtained.

Only few scholars have assumed the stød to be very old, e.g.
A. Pedersen (1912), who dates it back to the common Scandinavi-
an syncope.

Recently Anatoly Liberman (1976 and 1982) has advanced the
hypothesis that the stød was common to Old Scandinavian (or
even Common Germanic), and that the tonal accents 1 and 2 de-
veloped much later in connection with free apocope.

According to Liberman the main function of stød is to divide
the syllable nucleus into two parts or morae, and stød is the
marked part of the opposition, compared to no-stød. Accents,
on the other hand, have a syllable-counting function; in
Swedish and Norwegian accent 2 can unite the constituent parts
of a word or a syntagm, and is marked compared to accent 1.

Old Scandinavian (like Old Germanic) was a mora-counting lan-
guage, and the tool of mora-counting was stød. It had its
main domain in words with long vowel or short vowel plus sono-
rant consonant, irrespective of the number of syllables. This
was just the type of words which were first submitted to apo-
cope (12th - 16th centuries). Apocopated disyllables became
monosyllabic and indistinguishable from old monosyllables.
Thus the stød became a signal of monosyllabicity. Accordingly
words that remained polysyllabic lost their stød. Since the
apocope was free in the beginning (later it could become
obligatory or be given up again) and partly determined by
rhythmical conditions, the same word could become monosyllabic,
e.g. medially in the phrase, but keep its weak syllable finally,
and these full forms also lost their stød and thus became iso-
lated. In order to maintain the phonetic identity of the words
which had been split up, the stød of the apocopated forms was
transformed into a circumflex, which restored the disyllabicity,
and in Swedish and Norwegian the full forms developed a second
peak, an accent 2 which became the marked member of the opposi-
tion. The stød in old monosyllables was then weakened into an
accent 1. In Danish no marked accent 2 developed and the old
monosyllables retained their stød which, besides its mora-
counting function, adopted a subsidiary function of indicating
monosyllabicity.

Words in -er, -en, -el developed in a specific way. They have
accent 1 in Swedish and Norwegian and stød in Danish. Liber-
man admits that they may have been monosyllabic at the time of
the apocope, but he prefers the hypothesis that words ending
in a closed syllable have always had stød. - He also assumes

that words with voiceless geminates had stød, and that this
stød developed into the so-called West Jutlandish stød, which
is a juncture phenomenon.

Liberman's hypothesis is based on a very thorough knowledge of
all accessible facts about Scandinavian dialects, and he finds
various dialects representing what he assumes to be transi-
tional phases of the development: the common Danish stød, the
co-existence of stød and tonal accents in Funish and (according
to Kroman) North Zealandish, the partly mora-counting function
of accents on Ærø, some traces of redundant stød in Sörmland,
and two small dialect areas in Sweden (Hedemora) and Norway
(Flekkefjord), which have (or have had) accent 1 in words be-
fore certain geminates irrespective of syllable number, inter-
preted as a relic of the mora function.

Nevertheless, I do not find his arguments convincing. In the
first place I agree with Ringgaard (1983) that the theory is
contrary to the results of areal linguistics. Ringgaard states
that apocope in Sweden and Norway is late (16th century) and
rare, restricted to some northern dialects far from cultural
centers, and he finds it improbable that a phenomenon developed
in reaction to apocope in some remote Scandinavian dialects
should have spread over the whole peninsula. Liberman might
object that he does not talk of obligatory but of free apocope,
and according to Hesselman (1948-1953, p.33ff) free apocope is
found or has probably been found in many dialectal areas in
Central Sweden. Even so, it is, however, improbable that the
innovation should spread to large areas in southern Sweden and
Norway which did not have apocope, whereas it does not arise
in Danish dialects (except for a smaller area in southern Den-
mark) which all have full or free apocope. Moreover, whereas
the very specific facts found in two small dialects before
geminates (which are the corner stones of the theory) seem
very dubious as relics of stød, it seems much more probable
that the peripheral and isolated areas in Jutland with traces
of accents are relic areas where the tones are disappearing.

The systems in the various dialects which are seen as transi-
tional phases do not really correspond to steps in the assumed
development, which therefore remains hypothetical and must be
judged according to probability. And I find the suggested de-
velopment phonologically and psychologically improbable. How
can apocopated forms become indistinguishable from old mono-
syllables and then be turned back into disyllables by means of
circumflex and accent 2? Would it not be much more probable
that they have retained some tonal or dynamic features of the
disyllables from the start? Liberman admits that the speakers
must have felt them as variants of the full forms. How can
the stød then have become a signal of monosyllables?

Finally, it is not always clear when the terms "stød" and
"accent" are used for purely functional entities (Liberman
defines them in purely functional terms) and when they are
identified phonetically. Liberman is rather uninterested in
manifestation, and he does not even use the phonetic argument

he might have taken from Asiatic languages which - according
to strong comparative and historical evidence - in some cases
developed tone from syllable-final glottal closures (or other
so-called phonation types).

However, one does not have to assume that accents and stød
are successive phenomena in the individual languages. They
may both have developed in different dialects out of an earlier
distinction which had both dynamic and tonal features. This
may even be the most probable hypothesis. This seems to be as-
sumed by Oftedal (1952) and Gårding (1977). Öhman (1967) also
assumes a common origin but according to a specific model,
which will be mentioned in the following section.

In conclusion it must be stated that we do not have any re-
liable knowledge about the origin of the stød. The problem
will be taken up again briefly in the final section of this
paper in the hope that some more arguments may be found
through a phonetic analysis of the stød in present-day Danish.

D. PREVIOUS PHONETIC DESCRIPTIONS
OF THE DANISH STØD

1. OLDER DESCRIPTIONS

As mentioned in section A the stød was first described by Høys-
gaard (1743, 1747, 1769). Phonetically he describes his four
"åndelav" (1747) as *"some peculiar thrusts and puffs of breath
in the pronunciation of syllables or their vowels and other
sounds ... different ways of exhaling the vowels"*. As for the
stød (a term proposed by Høysgaard and meaning "thrust") he
says that it sounds like *"a very little hiccup"*. After a short
vowel (e.g. *sang* [saŋ']) *"it is as if it stops the breath"*
("stødende åndelav"), after a long vowel *"it stops the breath
and then immediately gives it speed again"* (dobbelt ('double')
åndelav). In 1769 he changes the term "stødende" to "stand-
sende" ('stopping') and explains that he first called it
"stødende" because *"it bumps in the pharynx"* ("det tørner i
svælget"), but it is not really a thrust or push. It is rather
characterized by a stop of breath produced by closing up the
pharynx, which blocks the breath stream ("svælget lukker sig
for ånden"). At the same time he warns against the very strong
Zealandish stød. It should be milder.

This description ("svælget lukker sig for lyden") was taken
over by his followers (Levin 1844, Hommel 1968). It is, of
course, not very probable that there is a closure in the
pharynx ("svælget"), but Høysgaard and his followers in the
middle of the eighteenth century hardly made any distinction
between pharynx and larynx; and later the stød is described
expressly as a glottal closure, e.g. by Sweet (1877), Verner
(1878) and Jespersen (1897-99, p. 297). Verner (3/7 1872
(1901)) also reported that he felt that words with stød re-
quired more energy in the throat, and he could feel a sudden
contraction of his throat muscles.

2. THE FIRST INSTRUMENTAL
   INVESTIGATIONS

In the years 1895 and 1896 Rousselot undertook the first in-
strumental (kymographic) investigation of the stød with one
informant. In 1899 he made another, more restricted recording
with Jespersen as informant. He found (see 1897-1901, p. 873-
879) that there was hardly ever a real pause (one case out of
50) but always an evident diminution of the vibrations. There
also seemed to be a vertical and horizontal movement of the
larynx. Nevertheless, Jespersen still describes the stød as
a glottal stop in 1912 and in the 1932-edition of "Lehrbuch
der Phonetik". In the second edition of his Danish phonetics
(Modersmålets fonetik 1922) he gives the same description in
the text, but in a footnote he modifies this description by
saying that a complete closure is only found in a strong form
of the stød, e.g. finally. In the interior of a sentence and
particularly before voiced sounds there is only a narrowing
of the glottis, involving a tension of the vocal chords, which
stiffen in their movement. The narrowing occurs in the last
part of a long vowel. If it occurs on a sonorant after a short
vowel, only the beginning of the sonorant consonant is heard.

The very rare occurrence of a complete closure in the standard
language (except for emphatic speech) was confirmed by a few
later kymographic recordings: Selmer (1925), Heger (1931),
Ekblom (1933) and Abrahams (1943) (six speakers in all), but
there was in all cases a decrease of the vibrations. In con-
tradistinction to Jespersen Abrahams found that in syllables
with short vowel the minimum generally occurred at the limit
between vowel and consonant, rarely after the beginning of
the consonant. Abrahams also measured duration and found that
long vowels with stød were slightly shorter than long vowels
without stød.

Selmer, Heger and Ekblom also investigated the Fo-contour in
words with stød. Through auditive observation of his own
speech Verner (1878) had found a contour which supported his
theory of the origin of the stød from a rising tone. Whereas
he had falling Fo in disyllables without stød, he found that
words with stød start on a low tone rising quickly about a
quint at the end of the stressed vowel until the closure, the
following unstressed syllable being low: Accent 1 words with-
out stød (e.g. *drikker* 'drinks') have a low start like the
words with stød, but the rise is cut off by the voiceless con-
sonant. Thomsen (in his obituary on Verner 1896-97) suggests
that this may be a special Århus-pronunciation. But it does
not look like present Århus speech (see later), and as Verner's
father was German and his mother from Zealand, it may have
been a rather personal contour. His stød-rules are obviously
influenced from Zealandish dialect, but his Fo contour is
not Zealandish either.

Selmer, whose informant (professor Brøndum-Nielsen) was from
Jutland, but speaking a somewhat artificial standard Danish,
found a moderate rise-fall in disyllabic isolated words without

stød and a pronounced rise-fall in the first syllable of words
with stød (before a possible break). - The contour is thus the
same, only more pronounced in words with stød. Selmer does not
find this difference important. Heger thinks that the strong
rise in the stød words investigated by Selmer might be due to
emphasis. His own informant (who had spent most of his life
in Copenhagen) had a conspicuous very deep fall in Fo in the
second part of the vowel with stød. - Ekblom, whose informant
was from Copenhagen, found - like Selmer - a moderate rise-
fall in words without stød and a stronger rise-fall in words
with stød, but in the cases of a break (which might be due to
the difficulty of measuring reduced or irregular vibrations
on kymograms) this was at the top of the curve, before the
fall, not after the fall as for Selmer's informant. Ekblom
also found a somewhat more abrupt rise in two disyllabic ac-
cent 1-words with short vowel plus voiceless consonant (and
thus without stød) than in the corresponding accent 2-words.
Like Verner he finds a similarity between the Fo contour of
words with stød in Danish and that of words with stød in
Latvian and Lithuanian. Whereas Heger recorded small sen-
tences containing words with stød, Selmer and Ekblom recorded
isolated words. This makes the judgement of the Fo contour
somewhat dubious, because it must be a combination of word
(or stress) contour and sentence intonation.

3. SVEND SMITH'S ANALYSIS OF THE STØD

As for the production of the stød there has never, during the
whole period, been any doubt that it is produced by a constric-
tion or closure in the larynx, and it has been implicitly as-
sumed that the larynx was the primary source, i.e. that the
stød was due to an innervation of the vocal chords.

However, this was called in question by Svend Smith, whose
thesis (1944) constitutes the first detailed and thorough in-
strumental investigation of the phonetic aspects of the stød.
It is a pioneering work, which brings a large number of new
facts and a new theory built on these facts. The most important
new contribution made by Smith is an electromyographic investi-
gation of the expiratory muscles. He used surface electrodes
because a preliminary experiment with needle electrodes gave
too many artefacts due to movements of the muscles. The elec-
trodes were placed on the abdomen between the navel and the
trigonum scarpae (which is close to the groin), i.e. rather
low down, in order to avoid interference from the heartbeat.
Smith considers the activity recorded at this place as repre-
sentative of the activity of the total complex of expiratory
muscles. There were five subjects, all speaking Standard
Danish. They pronounced a number of word pairs (one to three
times each), read as an enumeration of individual words with
non-final intonation, but shifting between words with and with-
out stød. There were 11 different word pairs in all, but not
all were read by all subjects, and some could not be used be-
cause of various disturbances. 83 pairs belonging to different
types (mono- and disyllables, words with long and with short
vowel) were analysed. In one word pair of a special type, viz.

ending in a vowel ([tʰæ:'/tʰa]) (which was, exceptionally,
read 17 times) no clear difference was found. But 53 of the
remaining 66 pairs showed more activity in the word with stød
than in the corresponding word without stød. The activity in
the words with stød is also more abrupt with a quick rise and
fall, whereas the activity in the words without stød is more
evenly distributed over the whole word. Smith concluded that
in words with stød there is a strong ballistic movement of the
expiratory muscles, whereas in words without stød it is a con-
trolled movement. A few whispered pairs showed the same dif-
ference. In the published curves (10 pairs) the difference is
very clear. Since it is found in 53 out of 66 pairs, it is
obviously significant, but at the same time it does not seem
to be a necessary condition for the production of the stød,
since it was absent in 13 pairs. It is, of course, possible
that some subjects may have used muscles whose activity did
not show up at the abdomen (e.g. internal intercostals). It
is said that there is large inter-individual variation par-
ticularly in the amplitude of the curves, but it is not stated
whether this variation implies a more or less clear difference
between pairs with and without stød and how the exceptions are
distributed on the individual speakers. - Unfortunately, it
was not technically possible to synchronise the electromyo-
graphic recording with an acoustic recording, so that one can-
not know exactly when the activity takes place.

Smith also analysed the stød from an acoustic point of view
by means of a direct oscillographic recording. There were
six speakers who, apart from the author, seem to have been
different from those who took part in the electromyographic
recordings. Smith managed to get hold of both Heger's and
Ekblom's informants, and they read the same material as in
the old recordings. Smith himself read a list of 46 word
pairs (each pronounced once, as an enumeration of words with
non-final intonation). The other speakers read only part of
the list; and only one read more than ten pairs. This time
the individual speakers are treated separately. Smith finds
a weak tendency to a stronger rise in amplitude and frequency
in the beginning of words with stød, but only in about 1/4
of the material, and rising frequency is mostly found in words
starting with a sonorant consonant. Only one speaker (OF,
Ekblom's subject) has a frequency rise in most of the words. -
What is much more general is a fall in amplitude in the second
part of the syllable in words with stød. Strangely enough
individual results are not given on this essential point.
In the conclusion p. 105 it is said that there is "often" a
decrease in amplitude, but no exceptions are mentioned in the
more detailed discussion. The decrease is treated as some-
thing given, and it is also in accordance with earlier kymo-
graphic recordings. All illustrations show this decrease.
It may end in irregular vibrations but never in a complete
pause. There are obvious individual variations in the oc-
currence of irregularities. Three of the subjects have irre-
gular vibrations in all examples, one in almost all, one only
in one example out of ten, but he is from Funen where the stød
is normally weaker. Smith himself has irregularities in

less than one third of the examples, which may perhaps be ex-
plained by the fact that as a speech therapist he considers a
stød with irregular vibrations to be "non-normative". For most
of the speakers (except Smith) the irregular vibrations are in
the majority of cases preceded by a fall in Fo, more or less
coinciding with the decrease in amplitude. The amplitude may
increase again after the minimum, particularly in long vowels.
In the case of Heger's informant Smith did not find the very
deep and abrupt fall in Fo indicated in Heger's measurements.
Smith assumes that this deep fall was probably due to the dif-
ficulty of measuring weak and irregular vibrations on kymo-
grams. For Ekblom's informant Smith found a less steep rise
and the irregular vibrations coming after the fall, not on the
top of the curve.

Comparing the electromyographic and the acoustic recordings
Smith sets up the following hypothesis concerning the produc-
tion of the stød. There is a first phase, characterized by a
strong, ballistic contraction of the expiratory muscles, which
results in a heightened subglottal pressure. This higher pres-
sure may cause a proprioceptive reflex innervation of the vocal
chords. In the second phase the activity of the expiratory
muscles falls abruptly, which causes a fall in amplitude and
sometimes in frequency. A stød thus has two phases, and may
have three, if there is a new increase of amplitude. Since it
may be difficult to adjust the tension of the vocal chords to
the quickly falling pressure (the tension may be kept too long)
there may be a lack of balance resulting in irregular vibra-
tions. There is according to this theory no primary compres-
sion of the vocal chords as assumed explicitly by Jørgen Forch-
hammer (1942) and by Viggo Forchhammer (1954) and implicitly
by most phoneticians, and the fall in frequency is not a
primary phenomenon either, but caused by the falling subglottal
pressure.

Smith also finds indications of a more energetic articulation
in the start of words with stød based on kymograms taken with
a large and very lax membrane mounted on a Marey-capsule.
There often seems to be a quicker rise of the airflow in the
beginning of words with stød. The interpretation of these
curves is, however, rather dubious because of the very great
inertia of the membrane, which makes all delimitations very
uncertain, and it is not quite obvious why a possible quicker
rise of the airflow should be due to energetic articulation
and not to the heightened subglottal air pressure.

In conclusion the stød is characterized as a "stress accent,
a special marking movement made by a thrust-like emphasizing
of sounds."

Smith's theory is very interesting, but he has only proven
part of it, namely the contraction of the abdominal muscles.
He has not investigated the laryngeal muscles, and one there-
fore cannot know whether there is also a contraction of these
muscles (which is felt subjectively by many speakers), and how
the temporal and causal relations between these two contrac-
tions may be.

4. LATER ACOUSTIC INVESTIGATIONS

During the following 30 years very little was published concerning the phonetic aspects of the stød, and most of the papers dealt with its acoustic properties.

In a paper on vowel length in Danish (1955) the present author published some measurements of vowels with stød. The measurements were mainly based on recordings of isolated words, viz. the two triads [pʰiːbɒ, pʰiːˈbɒ, pʰibɒ] and [lɛːsɒ, lɛːˈsɒ, lɛsɒ] read once by 10 informants, and two other triads read by one informant. In a few cases the words were placed in small sentences, viz. the first two triads plus [hyːlə, hyːˈlɒ, hylə] read three times by three informants, and the first triad read eight times by one informant. The result was that the duration of vowels with stød was in between short and long vowels without stød but closer to the long vowels. In the series of isolated words all speakers except one had a difference between long vowels with and without stød, and in the series of sentences all four speakers had an average difference but with overlapping. When all speakers (in the two groups taken separately) were combined, the vowels with stød showed great overlapping with long vowels but hardly any overlapping with short vowels. The percentual duration of vowels with stød compared to long vowels without stød was 82 and 89 for isolated words and sentences, respectively, whereas for short vowels it was 50 and 60%. Thus Uldall's description of vowels with stød as phonetically short must be refuted. Martinet's observation that the quality of vowels with stød is the same as that of long vowels was mentioned above. To this may be added that the influence from surrounding consonants is also the same as for long vowels (I therefore also transcribe them with two length points, not with one as is sometimes done).

The first spectrograms of words with stød, in some cases supplemented with amplitude display, were published by M. Lauritzen (1968) in a short paper based on one informant who read 10 word pairs and some triads once. The 33 published spectrograms of words with and without stød do not show any consistent differences in formant structure, nor any indication of a difference in voice quality in the first part of the vowels with stød but, as stated by the author, a very clear drop in intensity during the stød phase (Smith's second phase) and sometimes noisiness and irregularity, and moreover a drop in Fo. - The author also mentions that the start of the vowel shows higher intensity in words with stød (and the same can be seen for Fo). - She states that the drop in intensity and Fo and the irregularities are not restricted to one segment. "Stød in the vowel" also affects the transition into the consonant, and "stød in the consonant" often affects the end of the preceding vowel.

Lauritzen also draws attention to the fact that the stød is
preserved in whisper. She published spectrograms of one whis-
pered pair which shows a clear drop in intensity.

A much more comprehensive study of the acoustic properties of
the stød was published in 1973 by Pia Riber Petersen. Her ma-
terial consists of four triads of the type [lɛ:sɒ, lɛ:'sɒ,
lɛsɒ] and four quadruplets of the type [hy:lə, hy:'lɒ, hylə,
hyl'n̥] placed in the middle of small sentences with 3-4 main
stresses and read six times each by six informants. The de-
scription is made on the basis of mingograms with Fo- and in-
tensity curves. As for the duration she did not find any con-
sistent difference between long vowels with and without stød.

Riber Petersen also measured the consonants and found a sig-
nificant difference of duration between consonants with and
without stød, the former being longer (Lauritzen found the
same difference, but on the whole her indications of duration
are dubious because she does not distinguish between words
with different number of syllables).

As for Fo, maxima and minima of the vowel contour were measured
and schematized average curves based on these measurements are
given for half of the material, viz. for the words with sono-
rant after the vowel (the quadruplets). Neither the post-
vocalic consonants nor the following weak syllables were meas-
ured. It would have been more informative if complete curves
of the words had been given as illustrations. There are no
constant differences between words with and without stød, but
there are some clear tendencies. Subject 22 differs from the
other subjects in having rising Fo in both types with a some-
what higher level in the words with stød. - For the five
other subjects the predominating contour of the stressed vowel
in words with stød is falling (more rarely falling-rising),
and the predominating contour for words without stød is falling-
rising for four of the subjects and rising for one of them
(rising-falling contours are very rare). Generally the contour
starts at a higher level and reaches a lower maximum in words
with stød than in words without stød. In V:'C-words the fall
is on the average 26.2 Hz greater than in V:C-words, and this
difference is significant; the minimum is generally closer to
the end of the vowel in words with stød.

The intensity contour is described very briefly. Like the Fo
contour it has generally a higher maximum and a deeper fall in
words with stød. For V:'C-words the fall is 6 dB greater than
for V:C-words, and the difference is significant. Subject 22
has the same difference for long vowels, but he does not have
any difference in words with short vowel.

Riber Petersen emphasizes the large variation in the acoustic
manifestation of the stød. Some subjects have normally irreg-
ular vibrations (starting, on the average, 11.8 cs after the
onset of a long vowel and 11.2 cs after the onset of a short
vowel), and there are a few cases with complete closure; some

have no irregularity, but fall in intensity and Fo, and for
subject 22 there are cases without any visible difference,
although the words sound allright. A few spectrograms seemed
to indicate some weakening of the higher formants in the words
with stød.

The author made a listening test with six examples of the word
pair [lɛ:sɒ - lɛ:'sɒ] read by speakers 22 and 26 and cut out
of the surroundings. The test was played twice to seven lis-
teners, who had to identify the words. In a surprisingly high
number of cases the stød was not perceived; but, strange as it
may seem, this occurred more often for speaker 26 (37% of the
cases), whose curves showed a clear stød, than for speaker 22
(22%).

In order to throw some more light on this question, Nina Thor-
sen (1974) conducted a small listening test with the words
[blɛ:sɒ, blɛ:'sɒ, vi:sɒ, vi:'sɒ] read by herself, and the words
[lɛ:sɒ, lɛ:'sɒ] read by Pia Riber Petersen's informant No. 22.
Nina Thorsen's stød showed up in the curves as a phase with low
amplitude and obvious irregularities, whereas in the curves of
subject 22 the vowel showed rising pitch and intensity and no
irregularities in the stød-word and a fall in intensity in the
word without stød. The words were cut in steps from the end,
the first cut keeping the beginning of the s, the last cut
leaving the first part of the vowel. Five phoneticians listened
to the words read by Nina Thorsen, two to the words read by
No. 22. The result was that when the irregular phase was cut
off from Thorsen's stød-words no stød was heard, whereas in
No. 22's words the stød was identified for all cuts! - Nina
Thorsen concluded that there must be different types of stød.
She hears a certain strained voice quality in No. 22's stød-
words, but it does not show up in spectrograms. But she adds
that since the listeners had heard the word pair before the
test they may have identified the stød-word by the higher pitch
level (or perhaps rather by the whole pitch contour of the word).

On the whole, Smith's acoustic description has been confirmed
by Riber Petersen's more comprehensive and precise analysis.
But the acoustic analysis can neither prove nor disprove the
central point in Smith's theory, viz. the physiological mech-
anism producing the stød. (Riber Petersen finds that the com-
bination of rising pitch and falling intensity often found in
No. 22's stød speaks against a relaxation of the vocal folds
due to a decrease in subglottal pressure, but this informant
is not typical.)

5. PHYSIOLOGICAL INVESTIGATIONS

A physiological investigation was made by Faaborg-Andersen as
part of his thesis (1957). He made EMG-recordings of the vo-
calis muscle and the cricothyroid muscle in "a series of sub-
jects" reading the two word pairs [mo:ɒ / mo:'ɒ] and [mølɒ /
møl'ɒ] and found higher activity in the vocalis muscle in words
with stød, but no difference in the cricothyroid.

A preliminary electromyographic investigation by the present
author and H. Hirose (1974) had the purpose to find out whether

there was a positive innervation of the laryngeal muscles in
the stød. For one informant, who read a longer list of words
with and without stød, recordings were made of the interary-
tenoid muscle (INT) and the posterior cricoarytenoid muscle
(PCA), i.e. the closing and opening muscles of the larynx.
They did not show any difference of activity in words with and
without stød, except that there was a peak in PCA after the
monosyllable [man'], probably due to a more vigorous opening
of the glottis at the end of the word. For three other sub-
jects reading the pairs [lɛ:sɒ, lɛ:'sɒ], [pʰi:bɒ, pʰi:'bɒ]
and [man, man'] sixteen times each in the frame: *"han sa: ..."*
recordings were made of the vocalis muscle, for one also of
the lateral cricoarytenoid (LCA), i.e. the internal tensing
muscles. One speaker did not show any difference, but he was
nervous and the recording was bad. The two other speakers had
a rather abrupt activity in the vocalis muscle in the words
with stød. One of them also had a clearly audible rise in
pitch, and the vocalis activity may have something to do with
this rise, but this was not the case for the other, who had a
sharp rise in vocalis activity starting at the beginning of
the vowel and having its peak at the point of the normal start
of the stød phase. There was also a slightly higher activity
in LCA. Thus this investigation (like that of Faaborg-Andersen)
pointed to an activity in the vocalis muscle in words with stød.

S. Öhman (1967) sets up a specific model for the description
of the production of the Scandinavian accents including the
stød. He considers them to be produced by a negative pulse
superimposed on the basic phrase contour and the (positive)
phonatory stress pulse which starts at the beginning of the
stressed syllable. The timing of this negative pulse in re-
lation to the stress pulse produces the different word tones.
If the negative pulse comes at the start of the word, the tone
will be rising; if it comes in the vowel, it will be falling-
rising, etc. There is always a difference between accent 1
and accent 2 in this respect, but the places may vary in dif-
ferent dialects. The stød (which is described as a glottal
stop) is produced by a very strong negative pulse at the end
of the vowel, and the Scandinavian tonal accents are con-
sidered to be a kind of soft glottal stops.

This model is also applied to a theory of the origin of the
word accents. Öhman assumes that they are developed in sen-
tence final position in Common Scandinavian. By the common
Scandinavian syncope the new monosyllables come close to the
final fall in the basic phrase contour (which is assumed to
start immediately after the end of the last stressed word).
The tonal rise of the stressed syllable is therefore truncated
and dominated by a fall. This fall comes to be considered
characteristic of monosyllables, and when later a number of
monosyllables become disyllabic by addition of the definite
article and by insertion of svarabhakti-vowels, so that the
distance to the final contour is increased again, the specific
pitch contour of the monosyllables is maintained by the in-
sertion of a negative pulse in the beginning of the second
syllable of the former monosyllables, or, if the high pitch of

the second syllable of the disyllables was considered the characteristic feature, a negative pulse could be inserted at the start of the stressed syllable of these words.

This is, of course, highly speculative. The author tries to support the idea of the negative pulses by interpreting them as an inhibition of the activity of the cricothyroid muscle (CT) which is generally held to be the main muscle responsible for pitch movements. In a pilot experiment (Öhman et al. 1967) EMG recordings were made of this muscle and the vocalis muscle for one informant. In these recordings he finds an inhibition of the CT at the points where he had placed the negative pulses and in many cases a brief increase of activity in the vocalis muscle 20 ms before the CT inhibition. In a glottal stop (an example of hard attack) he finds increase of vocalis activity.

However, a decrease in CT activity correlated with the negative pulses is not surprising, since the pulses were placed at the points of low pitch, and the increase of vocalis activity is not seen in the published curves.

Gårding (1970) made recordings of CT and vocalis for two Swedish informants speaking different dialects. She has also recorded a glottal stop in an emphatic "yes" and "no" in one of the dialects [jaʔa - nɛʔɛ]. In the glottal stops she finds a (small) peak in the vocalis muscle, but in the word tones vocalis and CT go together having higher activity for rising pitch. If the Scandinavian tonal accents were a sort of glottal stops or stød, one should expect activity in the vocalis muscle but not in the CT (see also later in this paper). Thus, Öhman's theory is not supported.

Gårding prefers to simulate word tones by positive pulses manifested in activity of the CT and vocalis muscles, which also seems more natural.

II. MATERIAL, SUBJECTS AND PROCEDURES

A. INTRODUCTORY REMARKS

The present investigation started as a teamwork at the Institute of Phonetics in Copenhagen in 1974. Its main purpose was an electromyographic analysis of the activity of the larynx muscles in the production of obstruents, stød, and (to a certain extent) stress, in continuation of preliminary investigations by H. Hirose and me conducted at the Haskins Laboratories (see Fischer-Jørgensen and Hirose 1974a and b). The main participants in the teamwork were Jørgen Rischel, Birgit Hutters, Peter Holtse, H. Hirose, and the present author. Almost all recordings took place in 1974 with some supplementary recordings in 1977, when Hirose visited Copenhagen again, and in 1979, with the help of S. Niimi. The work was delayed partly because of computer problems, partly because the members of the team were busy with other tasks, particularly the international phonetic congress in 1979. In the beginning of 1982 it was agreed that the further

processing of the obstruent recordings should be made by Birgit
Hutters in connection with her fiberoptic studies (see her re-
port in ARIPUC 18, 1984), and that I should take care of the
material on the stød. This work was further delayed by illness
but has now been finished. An analysis of the simultaneous
acoustic recordings and of quite a number of supplementary re-
cordings undertaken 1985-86 was included.

B. THE MATERIAL

The main corpus consisted of a list, used in 1974 for the re-
cording of the vocalis and the cricothyroid muscles, containing
eight word pairs, viz. [pʰiːbɒ/pʰiːˈbɒ, huːən/huːˈən, lɛːsɒ/
lɛːˈsɒ, kʰɛːlə/kʰɛːˈlɒ, kʰɛlɒ/kʰɛlˈɒ, vɛnɒ/vɛnˈn̩, vɛn/venˈ],
and [ɗu/ɗuːˈ] plus the words [vɛːˈn, vɛːˈnɒn, lɛsɒ, pʰibɒ] (see
Appendix I, list 1; for the phonetic transcription, see Note 1).
Thus care was taken to include both monosyllables and disyl-
lables, stød in long vowels and in the consonant after a short
vowel, and both high and low vowels as well as different post-
vocalic consonants. The word pairs are not all perfect minimal
pairs: in [ɗu/ɗuːˈ] a short vowel is compared to a long vowel
with stød, and the vowel in [huːən] may be pronounced relative-
ly short (there is no opposition of length before [ə]), but it
is generally pronounced long with assimilation of [ə]. The
words [lɛsɒ] and [pʰibɒ] were included for the purpose of a
comparison between the duration of long vowel, long vowel with
stød and short vowel. These examples (and those of the follow-
ing lists) may also illustrate the different types of commutable
word pairs with and without stød.

The words were read by seven subjects in the frame *det er ...
de siger* [deː ... di siⁿ] 'it is ... they say'. This is a com-
monly used frame, and it was essential to choose a short frame
in order not to prolong the electromyographic session unneces-
sarily. But since the test word was the only stressed word in
the sentence its Fo movement might be influenced by the sen-
tence intonation, which was sometimes final and sometimes non-
final. This complicated the comparison between the Fo contours
of words with and without stød, which turned out to be more
interesting than first assumed.

In BF's reading of this list 1977 and 1979 the words [vɛn] and
[vɛnˈ] were replaced by [sɛn] and [sɛnˈ], and the extra unpaired
words were left out. In 1977 the words were also read in the
frame *de siger alle* ... 'they all say ...', and in 1979 *de siger
også* ... 'they also say ...' with emphasis on *alle* and *også*,
the purpose being to have the test words read on a low tone.
These recordings also contained examples of hard attack for the
purpose of a comparison with the stød, and scattered examples
of hard attack were also found in other recordings.

In 1977 and 1979 BF also read two pairs with and without stød
in a syllable with secondary stress (see Appendix I, list 2).

In the 1974 session a further list intended for the analysis of stress and stød was recorded. It consisted of a number of nonsense words of the type *bibibibi* differing in respect of vowel length, stød and stress. Only JR read the full list of 24 different words. For the present purpose only five pairs were averaged (see list 3, Appendix I). They differ in stød vs. non-stød on the stressed syllable (as first, second and third syllable), and two of the pairs also differ in stød vs. non-stød on a syllable with secondary stress. Three of the pairs were also read by other informants, but as they had difficulty in pronouncing them correctly, each word was preceded by a normal Danish word with the same rhythm and stød-occurrence, but this only worked for one informant, and the real words were so different in their phonetic set-up that a comparison was problematic.

A very small list (list 4, Appendix I) consisting of the words [vɛn, vɛn', vɛ:'n] was read by three subjects during a recording of the interarytenoid (INT) and the posterior cricothyroid (PCA) muscles.

Part of the results from the Haskins-investigation 1972 (see Fischer-Jørgensen and Hirose 1974b) were also included. The words, which were said in the frame *de sagde* ... [di sæ: ...] 'they said ...', are listed in Appendix I, lists 5a and 5b.

In 1977 a restricted EMG-investigation with one subject (FJ) and recording of the lateral cricoarytenoid (LCA) and the middle constrictor was made at the Haskins Laboratories in co-operation with S. Niimi (see Appendix I, list 6).

In 1981 a recording of pharyngeal and esophageal pressure with one subject (also FJ) was undertaken in Oxford, using the frame *de vil sige* ... *igen* [di ve si: ... i'gɛn] 'they will say ... again' (see Appendix I, list 7).

In 1985 a relatively long list of word pairs with and without stød was read by four subjects with the special purpose of an analysis of the airflow. This list contained the same words as the main list plus a number of other word pairs (see Appendix I, list 8). It was first read by FJ with inclusion of a number of words from Smith's investigation (list 8a), but as these words were difficult to delimit, they were replaced by other word pairs for the three other speakers (list 8b). This is the main list for measurements of duration because the airflow curve made the delimitations particularly precise. It is also important for Fo measurements, partly because the words were said in a longer frame (*Jeg kan godt sige* ... *til Palle* [ja ka 'gɔd si: ... tʰe 'pʰalə] 'I am willing to say ... to Palle', partly because tracing of Fo averages by hand is in some ways better than computer averaging (see below).

In 1986 a list of four word pairs was read by four subjects and used for an analysis of larynx position and for acoustic analysis (see Appendix I, list 9). They were placed in the frame *jeg kan let sige* ... *fem gange* [ja ka 'lɛd si:... 'fɛm' 'gaŋə] 'I can easily say ... five times'.

Moreover, in 1986 three word pairs placed in natural sentences were read by three speakers (see Appendix I, lists 10,11 and 12).

A fiberoptic investigation of the vocal cords made in coopera- tion with Birgit Hutters (1986,seven subjects) was based on a list of isolated words with the vowels [i:] and [i:'], see Ap- pendix I, list 13).

Finally, a restricted number of words, read by two speakers, were subjected to inverse filtering, viz. two examples of the words [væ:lən, væ:'lən] read in isolation by FJ, and four word pairs read in sentences by BRP (see Appendix I, list 14).

In Appendix I the words are listed systematically in pairs. In the actual lists used for the recordings they were randomized in different ways.

C. THE SUBJECTS

There were 15 subjects in all. Seven main subjects took part in the original EMG-investigation 1974, viz.: BF, BH, BM, HU, JJ, JR, and NR. Some EMG recordings and other recordings were also made of the subject FJ. Further subjects are: BRP, LG, MF, ND, OB, PD, and PM. Moreover, TB and PMi from the Haskins in- vestigation 1974 are sometimes included. LG and MF only read a list of three words. BH, FJ, HU and MF are female, the others male.

BF, OB and PM speak Standard Danish on a Jutlandish background, FJ and JR speak a slightly conservative Standard Danish, the others speak "Advanced Standard Copenhagen" (ASC). (For further information on the subjects, see Appendix I.)

D. RECORDINGS, PROCESSING AND MEASUREMENTS

1. ELECTROMYOGRAPHIC RECORDINGS

The main EMG-recording was undertaken at the Institute of Pho- netics in Copenhagen in 1974. The insertion of the electrodes was performed by H. Hirose. A supplementary recording of sub- ject BF was made in 1977. A third recording of BF (plus a re- cording of a restricted number of words read by FJ) was made in 1979. In the latter case the electrodes were inserted by S. Niimi. Bipolar hooked wire electrodes were used in all cases. For the recording of the vocalis muscle (VOC) and the crico- thyroid muscle (CT) the insertion was made percutaneously through the skin of the neck, whereas for the interarytenoid (INT) and the posterior cricothyroid (PCA) the insertion was made trans- orally (see Hirose and Gay 1972 and Hirose et al. 1971). The correct placement was controlled by a series of tests, for VOC and CT by swallowing, high and low tones, gliding tones, glottal closure (ʔa ʔa ʔa) and strain. For PCA and INT by breathing, swallowing, ʔʔʔ, and voiceless aspirated consonants ([ipʰi]) (see Hirose 1971, cf. also Hirano and Ohala 1967). The tests were recorded, so that they could be inspected afterwards. It was not always possible to get at the right muscle. For NR

and for BF 1979 the lateral cricothyroid (LCA) was hit instead
of CT. It also happened that the electrode moved away after
the start of the recording. This was the case for CT in BH's
recording. Probably the sternohyoid was recorded instead. (It
might have been practical to include tests for identifying not
only the muscles aimed at but also those which might be hit by
mistake.) It turned out that it may be advisable to avoid
swallowing (if possible) until the end of the recording, be-
cause swallowing may involve a movement of the electrodes. -
The identification tests were repeated at the end of the session,
but in two cases (BF 1974 and JR) this was not possible because
the FM-recorder broke down.

The EMG-signals together with the audio-signal, picked up by
a microphone close to the mouth, were transferred to an 8-
channel FM tape-recorder. The recording was controlled con-
tinuously on an oscilloscope screen and at intervals by means
of mingographic recording.

After the session an octal code was recorded on one of the
channels of the tape. The code, together with raw and inte-
grated EMG-signals, a duplex oscillogram, an Fo-curve, and an
intensity curve based on the audio-signal were recorded on an
8-channel mingograph at the speed of 100mm/sec. The mingo-
graphic curves were used to prepare the computer treatment of
the signals. The simultaneous recording of raw and integrated
EMG-signals made it relatively easy to identify artefacts as
spikes with low frequency components at unexpected places, and
the recording of duplex oscillogram, Fo and intensity permitted
a rather precise segmentation. Up to 7 segmentation lines could
be transferred to the computer and any of them used as line-up
point. The sampling window was also marked on the mingograms
(see Figure 3). The mingographic recording and the segmenta-
tion and marking of artefacts was undertaken by A. Löfqvist
and the present writer. The information was later transferred
to code sheets and used for sampling instructions.

A good number of the recordings contained artefacts (it had not
been possible to glue the two wires together), and some showed
microphony. A number of trials showed that both microphony and
most of the artefacts could be removed by highpass filtering
without damaging the signal. Therefore a number of filtering
experiments were carried out by Jørgen Rischel and Birgit Hut-
ters (see Rischel and Hutters 1980) with samples from both EMG
channels for all subjects, in order to find out which cut-off
frequency would be adequate. This turned out to be different
for different subjects and muscles. Rischel and Hutters found
that the EMG-signal from larynx muscles mostly covers a fre-
quency range from 100 Hz upwards, the spectral energy being
most prominent below 1000 Hz, and particularly from 200-600 Hz.
There may, however, often be energy even at 2000 Hz, and in
some cases it was possible to choose a cut-off frequency be-
tween 1000 and 2000 Hz without changing the signal except for
minor details. The artefacts generally had their main energy
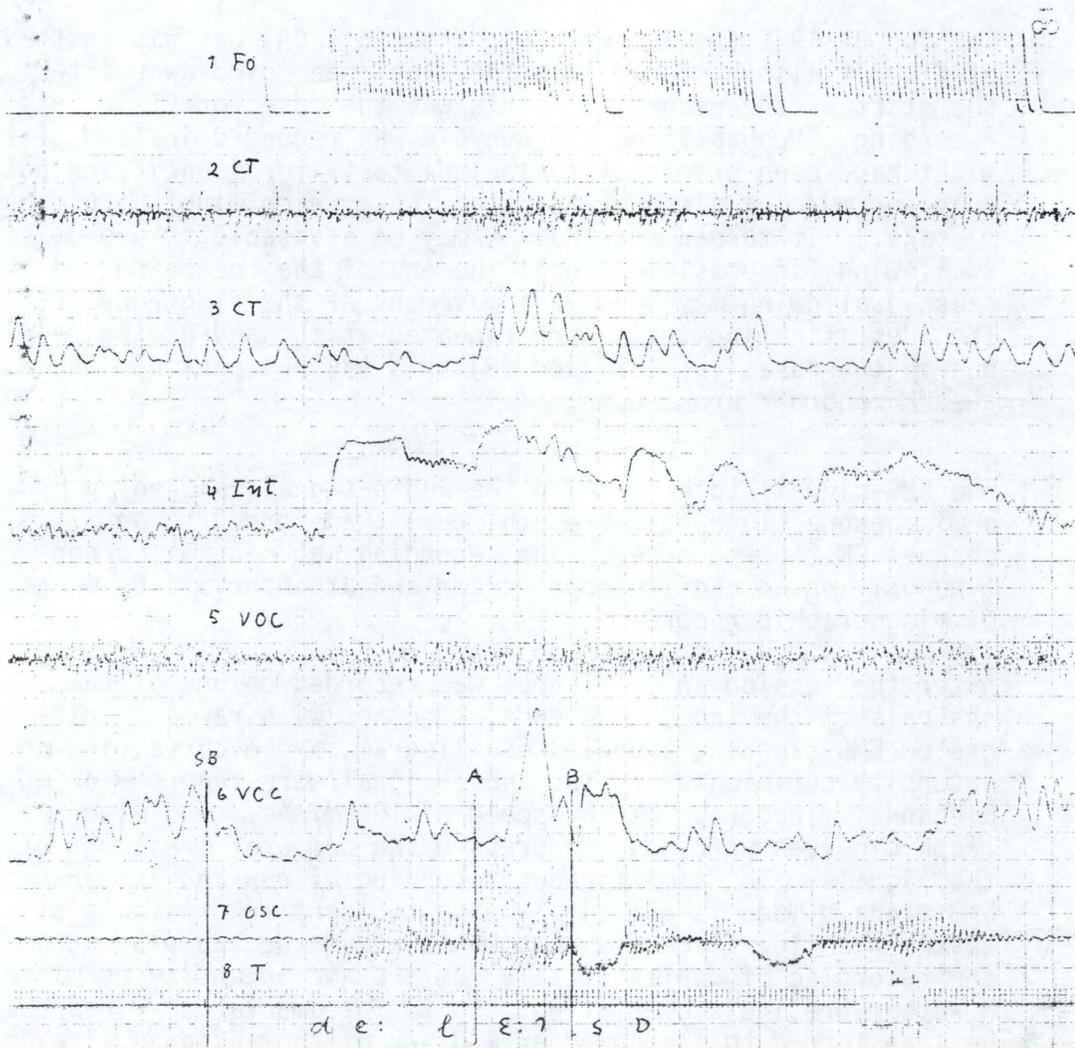
Figure 3

Example of mingographic recording as preparation for computer treatment: 1 Fo, 2-3 CT, raw and integrated, 4 intensity, 5-6 VOC raw and integrated, 7 duplex-oscillogram, 8 time signal.

at low frequencies up to 100 or 150 Hz, and in these cases they could easily be removed by filtering, but there were also artefacts which contained higher frequency components, in some cases above 1000 Hz, and in these cases it depended on the frequency components of the EMG signal whether they could be removed or not. Therefore, specific cut-off frequencies were chosen for each subject and muscle.

In the final sampling (1984-85) the following cut-off frequencies (in Hz) were used:

		VOC	CT	LCA
BF	1974	470	220	
BF	1977	390	390	
BF	1979	220		230

	VOC	CT	LCA
BM	330	51	
HU	1800	51	
JJ	420	280	
JR	230	340	
NR	165		51

The slope of the filters was 18 dB per octave except for BF
1977, BF 1979 (VOC), and HU 1974, where it was 36 dB/oct.

2. SUBGLOTTAL PRESSURE

In the 1974 investigation subglottal pressure was recorded for
one subject, BF, together with the EMG-curves by means of a
catheter inserted between the thyroid and the cricoid carti-
lages and connected to a pressure transducer (Simonsen & Weel,
Model HB 66). After one reading of the list the catheter
dropped out and was replaced by a new one, and the recording
started over again. In the middle of the 6th repetition the
catheter dropped out again and was not replaced, so that there
are only 6-7 examples of each word. The first recording was
weaker and has not been included in the averages. At the samp-
ling the curve was LP-filtered at 68 Hz.

A calibration curve in cm H_2O was recorded together with the
signals, but the computer-produced average curve can only be
measured in mm. A scale has, however, been constructed by
averaging the mingographic curves of a number of words by hand
and comparing their difference with the computer-produced
average curves.

Esophageal pressure was recorded for one subject (FJ) in the
phonetic laboratory in Oxford in 1981 for a number of words
with and without stød (see Appendix I, list 7) in co-operation
with Ameen Al-Bamerni. The recording was performed by means
of a multiple-transducer catheter with a diameter of 2.5 mm
containing two small pressure transducers (Gaeltic 3 CT) in-
tended to record pharyngeal and esophageal pressure at the
same time. However, the distance was intended for men with a
long throat, and when the transducer for esophageal pressure
was supposed to be in the right place in my case, the trans-
ducer for pharyngeal pressure was in the nose. This placement
was used for an obstruent series and gave very regular and
reliable esophageal pressures. However, for the stød series
the catheter was pushed further down so that the transducer
for pharyngeal pressure was in place, with the consequence that
the curve for esophageal pressure showed more, and more vari-
able, amplitude in the gross movements and less amplitude in
the ripple representing vocal vibrations, and the zero line
dropped out.

There was, however, a clear difference in esophageal pressure
between words with different stress placement, which were re-
corded in the same session, and there were rather consistent

differences between words with and without stød, so that it
was possible to start from the syllable *si:* of the frame as
arbitrary zero point and compare the contours, measured in mm.

3. PHARYNGEAL PRESSURE

Pharyngeal pressure in words with and without stød was recorded
for BF in the 1974 session by means of a tube inserted through
the nose (pressure transducer Simonsen & Weel, Model HB 66).
It was calibrated in cm H_2O. A scale for the computer-produced
average curves was obtained in the same way as for subglottal
pressure.

Pharyngeal pressure was also recorded for FJ in Oxford 1981
(see above). The recording was good, but there was no calibra-
tion. The same was the case for a recording of list 1 read
twice by JR in Copenhagen in 1974.

4. AIRFLOW

Oral airflow was recorded for BF together with the other curves
in 1974 by means of a Frøkjær-Jensen aerometer. It was cali-
brated in 1/min., and a scale for the computer-produced aver-
ages was constructed as for subglottal and pharyngeal pressure.

In 1985 airflow was recorded by means of a flowmeter (pneumo-
tachograph, built in the Phonetics Institute in Copenhagen)
for four subjects reading list 8. It was calibrated in 1/min.

5. LARYNX POSITION

The position of the larynx was studied for four subjects read-
ing list 9 according to the method used by Reinholt Petersen
(see Petersen 1985, p. 100). I quote from his description:
*"The recording equipment consisted of a television camera
(Sony AVC 3250 CES) and a video-recorder (Sony U-Matic type
2630). The frame frequency of the equipment was the normal
50 frames per second. The speech signal was recorded on the
sound track of the video-tape via a Sennheiser MD 21 micro-
phone placed about 15 cm from the subject's mouth. In order
to synchronize speech and video-signals a timer signal was re-
corded on the video-tape using a timing device (FOR-ACO, type
VTG 33). On playing back the tape, the timer signal was dis-
played on the monitor screen in minutes, seconds and centi-
seconds and it could, moreover, be registered together with
the speech signal on an ink writer as pulses for seconds and
centiseconds. In this manner it was possible to relate each
TV-frame to the speech signal.*

*During the recording the subject was seated in a dentist's
chair with a fixed head-rest. The camera was placed at the
level of the subject's thyroid prominence and at right angles
to his mid-sagittal plane at a distance which allowed the area*

between the subject's chin and sternum to be covered by the
field vision. The subject was wearing a light but firmly fit-
ting headgear to which a measurement scale was attached in such
a manner that it formed the background of the front of the neck
and the laryngeal prominence on the TV picture. The scale was
divided into units which corresponded to millimeter units at
the subject's mid-sagittal plane."

The contour of the larynx was drawn on transparent paper placed
on the video-screen for eight word pairs read by each of the
four subjects.

6. FIBEROPTIC INVESTIGATION OF THE VOCAL FOLDS

For seven subjects reading list 13 the movements of the vocal
folds were recorded by means of a video camera, using the same
instrumentation and set-up as described above for the recording
of larynx position, but with the optic of the TV-camera replaced
by a fiberscope (Olympos VF, type 4a), the light guide of the
fiberscope being inserted through the subject's nose and placed
in his pharynx. The video-recorder was equipped with a step-
function, so that it was possible to step forward frame by
frame. Selected frames were photographed from the screen by
means of a polaroid camera. Since the distance between frames
was 2 cs, they could be identified with points on the mingo-
graphic recording (comprising duplex oscillogram, Fo and in-
tensity curves with a temporal inaccuracy of ± 1 cs).

7. ACOUSTIC ANALYSIS

a. Duration   A number of the recordings made for other pur-
              poses (EMG, airflow, etc.) were also used for
measurements of duration. The words without stød did not give
many problems, except for a small uncertainty concerning the
boundary between initial [v] and [h] and the following vowel.
But the words with stød give problems because the stød often
shows up as weak and irregular vibrations, and these are not
always restricted to one segment. In the 1974 recording the
boundary between [ɛ] and [l] in [kʰɛ:'lɒ] is sometimes placed
rather arbitrarily where the stød phase ends, and in [kʰɛl'ɒ]
where it begins. In the 1985 recording the airflow curve was
of great help, showing a clear small dip at the start of the
[l] in all cases. And these curves showed that the irregulari-
ties in [kʰɛ:'lɒ] may continue into the [l] and cover the
boundary between [ɛ:'] and [l] in the duplex oscillogram.
Likewise they may continue into the following weak syllable in
[kʰɛl'ɒ]. The boundary between [i:'] and [b] in [pʰi:'bɒ]
may also be problematic because the [i:] with stød is very
weak at the end. But here again, the airflow shows a clear
boundary. It cannot, however, always solve the problem of
finding the boundary between vowel and [n], e.g. in [be:'nəð]
or in [vɛn'] and [vɛn'n̩].

However, in spite of these uncertainties there is a very good
agreement between the measurements of the same words and sub-
jects in list 1 and the more precisely measured list 8. The
postvocalic consonants have only been measured in list 8 ([1]
also in list 1). The delimitation of vowel before [s] does not
give any problems when the start of the s-noise is chosen as
boundary, i.e. the small pause which is often found before [s]
is included in the vowel duration.

b. Intensity   The 1974 recording (lists 1 and 3) was also
                 utilized for intensity measurements. The direc-
tion of the difference is clear, but it is not possible to make
any quantitative measurements because, by mistake, the intensi-
meter (which is part of the "Transpitchmeter") was set on
"linear display", and this scale is not linear in dB. However,
intensity curves of lists 9-12 could be measured in dB.

c. Fundamental frequency   Both the audiosignal from the 1974
                           recording and from the 1985 and 1986
recordings (lists 8-12) were used for fundamental frequency ana-
lysis by means of the "transpitchmeter". There is no problem
in looking at individual Fo-curves or in measuring a fall in
Hz. The problem arises when one wishes to produce average Fo-
curves. This problem will be treated in section 8.

d. Spectrography   A number of wide- and narrow-band spectro-
                   grams and sections of words with and without
stød were produced by means of the Kay Elemetric Sonagraph 7800
(printer 7900).

e. Inverse filtering   Both recording and analysis were carried
                       out at the Department of Speech Communi-
cation and Music Acoustics at the Royal Institute of Technology,
Stockholm. The recordings were made in an unechoic chamber
using a condensor microphone, and the speech samples were stored
on a digital tape recorder. The recorded signal contained fre-
quencies down to 20 Hz. The inverse filter analysis was done
by Inger Karlsson using an interactive digital filter programme.
A normal oscillogram, an inverse filtered oscillogram, and the
integral of the inverse filtered curve were produced for each
word.

8. STATISTICAL TREATMENT

a. The production of average curves   Both the physiological and
                                      the acoustic signals from
the 1974-79 recordings were further processed by computer and
transformed into average curves.

Sampling and averaging were performed using a PDP-8 computer.
The programme was partly based on the Haskins procedure, but in
an enlarged and modified version. It was first worked out by
P. Holtse in co-operation with J. Stellinger (see Holtse and
Stellinger 1976). Later it was modified and simplified

by P. Dømler and P. Holtse. Data are sampled through an eight-
channel multiplexed analog-to-digital converter controlled by
a real time clock. Data and results are manipulated and dis-
played via a Tektronix 4014 graphic terminal. The sampling
takes place with a 1.250 sec. window at a sampling frequency
of 200 Hz. The maximum number of examples that can be sampled
is 17, but if there are more, they can be stored in two files
and combined during the averaging procedure.

A preliminary sampling of most of the subjects was undertaken
in 1977, and a write-out was inspected by a team consisting of
H. Hirose, Jørgen Rischel, Birgit Hutters and the present
writer. Some artefacts in the EMG-curves had been removed by
moving or shortening the sampling window (this could be done
if the artefact was found outside the relevant word). Some
curves had to be rejected, but the programme made it possible
to retain most of the material, i.e. not rejecting all curves
of a whole word because of an artefact in one of them. Each
of the curves (EMG, Fo, intensity, etc.) can be left out indi-
vidually, and a special programme permits to cut out small sec-
tions in one of the curves only. Later it turned out that a
number of curves had been disturbed during the sampling. Thus
in 1984-1985 a new sampling was undertaken for all curves rel-
evant to the stød-analysis. The integration time used for the
EMG-signals was 25 ms and for the intensity curves 13 ms.
The 1977 and 1979 recordings of BF and the recordings of JR,
which had not been sampled earlier, were also sampled at this
occasion. P. Dømler and Sv. E. Lystlund took care of the
technical aspect of the sampling.

The final corrections and the averaging were performed by Jens
Bechsgaard-Christensen and Niels Jørn Dyhr according to my in-
structions. Two examples of average curves are shown in Fig.
4. The line-up point was in all cases the start of the stres-
sed vowel. The time scale is in cs. The scale of the ampli-
tude of the curves is linear (except for intensity), but all
scale values are arbitrary except for Herz in the case of Fo.
A percentual standard deviation curve is given below each
average curve. It should be kept in mind that a good deal of
the apparent deviation is due to timing differences. Cases with
hesitation or large tempo differences were left out, but there
are, of course, a good deal of tempo differences left, and the
farther you come from the line-up point, the more the individual
tokens will deviate on the time line. Time differences are
thus transposed into deviations of amplitude, which may be some-
what misleading.

This is particularly true of the Fo curve, which, in stød words,
contains rather abrupt falls and rises which may not come exact-
ly at the same time.

Averaging Fo curves of stød words by computer is, on the whole,
a somewhat dubious procedure, particularly because the stød
sometimes turns up as an abrupt fall in pitch, sometimes as
irregularities, and sometimes simply as a gap in the curve
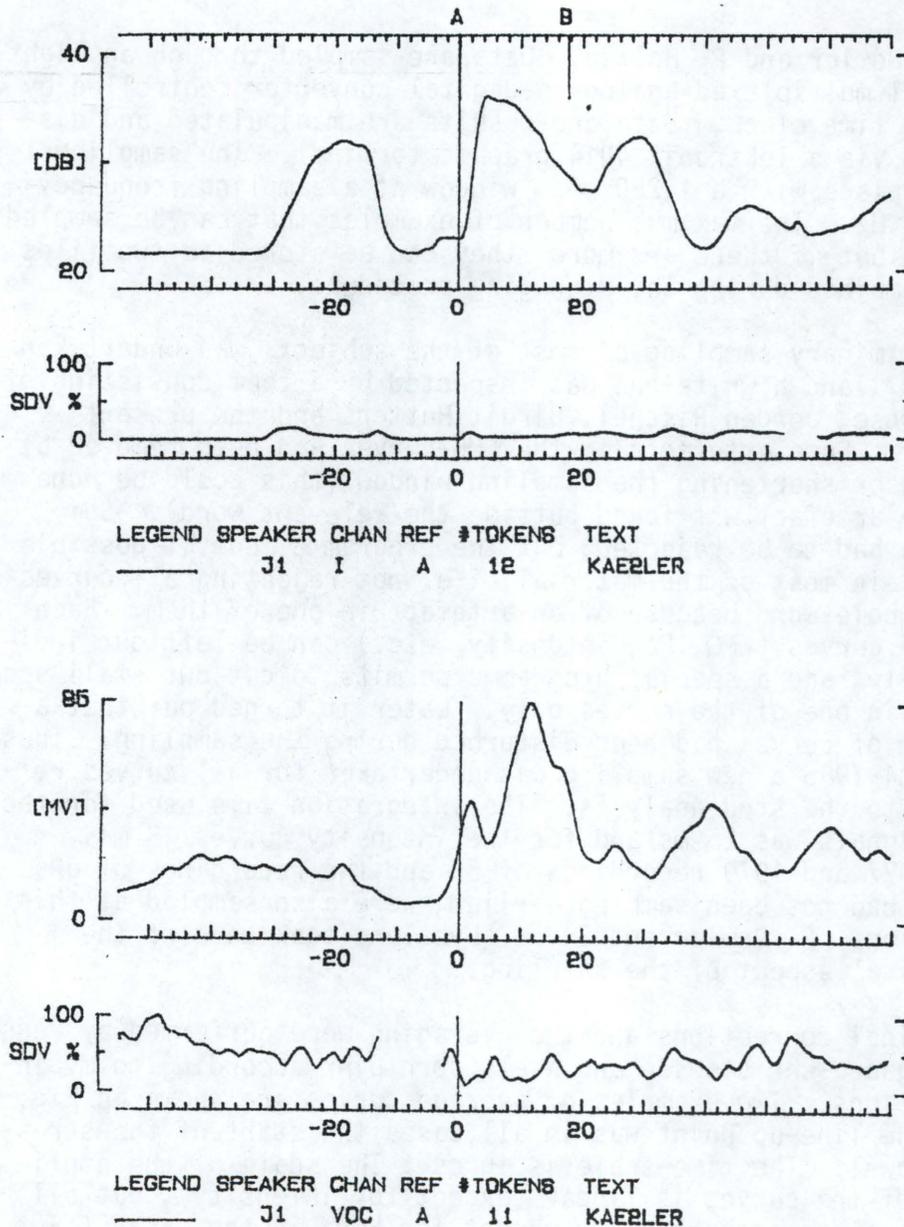
Figure 4

*Print-out from computer; average curves of intensity and VOC
with standard deviation. A (0): start of vowel, line-up point.
B: end of vowel. Duration in cs (MV and OB are not real). Sub-
ject BF 1977; text: [de: kʰɛ:'lɒ di siɳ].*

because the signal may be rather weak. When these possibilities
are all realized for different tokens of the same word, the aver-
age is not very informative. In the cases where only a few tokens
had irregular vibrations and others a dip in frequency, the former
were left out (this was the case for BM, JJ, and in most words for
HU), but when there were many cases they were included. An example
with much irregularity is shown in Fig. 5. Since the irregular
vibrations are often of rather low intensity it also depends on the
sensitivity setting of the pitchmeter whether they will show up in
the curves, and the setting was not quite the same for all subjects,

so that some have more gaps. This, then, does not mean that
there was a closure during the stød, but only that there were
irregularities and that they were of low amplitude. Averaging
the fundamental frequency of curves with such irregular vibra-
tions is a problematic matter anyhow.
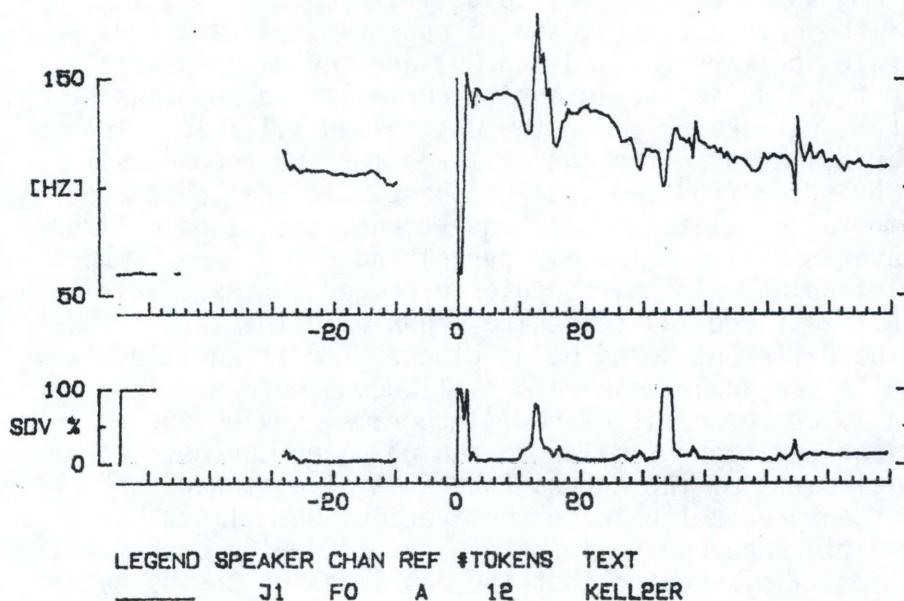
Figure 5

*Example of dubious average curve of Fo.
Subject: BF 1977, text: [de: kʰɛl'ɒ di
siŋ]; line-up point = start of [ɛ].*

Octave jumps also give problems. A particular programme per-
mits the correction of evident jumps, but sometimes the sam-
pling has caught the octave jump on its way up or down, so that
it only shows up as a small jump. Some irregularities of this
kind have been cut out. In some cases averaging had to be given
up. For this reason only a restricted number of Fo-curves aver-
aged by computer are reproduced in Appendix IV.

Airflow, intensity, and Fo-curves of the 1985-86 recordings
(lists 8-12) were not averaged by means of the computer, but
superposed tracings of the 8 tokens were made by hand, and an
average line drawn on this basis. In this case octave jumps
do not give problems, and irregular vibrations were left out,
but this means that the average curve of the latter half of
the syllable in words with stød may be based on a smaller num-
ber of individual tokens than the start of the syllable or the
following syllable. If it is based on a small number of in-
dividual curves, this is indicated by using points instead of

broken lines (see Appendix IV). BH's curves (1974) were also
averaged manually, and the same is true of the words [pʰiːbɒ]
and [pʰiːˈbɒ] read by subjects JJ, HU and BM, because [pʰiːbɒ]
had been forgotten in the sampling procedure.

The exactitude of these average curves may differ according to
the variability of the readings. Very often the individual
curves were very close together, and the exactitude was less
than ± 0.5 mm, which corresponds to a little more than ± 1 Hz
for most of the male speakers, and to approximately ± 2.5 Hz
for the female speakers (HU, FJ and BH) and the male speaker
BRP (and to ± 0.5 dB in the intensity curves). In some cases
it was higher, particularly for the unstressed syllable. The
temporal variation was often rather large for the second syl-
lable, which is far from the line-up point. In this case a
certain temporal equalization was undertaken, i.e. a case like
⌒⌒ was averaged as ⌒ (the mid curve) and not as ⌒⌒ , which
would be misleading. In the computer-averaged curves of air-
flow for BF 1974 there was something wrong with the zero-line,
the curves of different words being placed at different levels
in relation to the scale. Therefore all words were averaged
again manually on the basis of new mingograms, trying to
achieve height relations similar to the computer curves. For
the essential parts of the curves (the initial consonant and
the vowel) the agreement between the averages was almost per-
fect, most differences being less than one mm, which corre-
sponds to 1-2 1/min., showing that the baselines of the computer
curves themselves were OK, only the placement relative to the
scale was wrong. The computer averages were therefore used,
the baselines being adjusted to the same level. At the same
time the comparison showed the rather good accuracy of the
manually produced average curves. (Examples of manually aver-
aged curves are given in Fig. 6.)

To the inaccuracies of the average curves should of course be
added the uncertainty of the measurements, which was around
0.5 mm.

b. Significance tests   Significance tests for the durational
                         differences were made by means of Stu-
dent's t-test or (in some cases) the Mann-Whitney U-test.
For manually traced curves it was generally possible to super-
pose the two words with and without stød and state the over-
lappings at the relevant points. Very often there were no
overlappings, or just a single overlapping between the 8-10
examples of the two words, and it was easy to state by the
Mann-Whitney test that the significance was below the 0.1 level.
In some cases there was almost complete overlapping, and thus
no significance. In the relatively few examples of doubt con-
cerning the number of overlappings the lower significance level
was chosen (see Fig. 6).

For the average curves produced by computer it was more prob-
lematic. In the Haskins programme it is possible to get a
print-out of all values with standard deviation, and then cal-
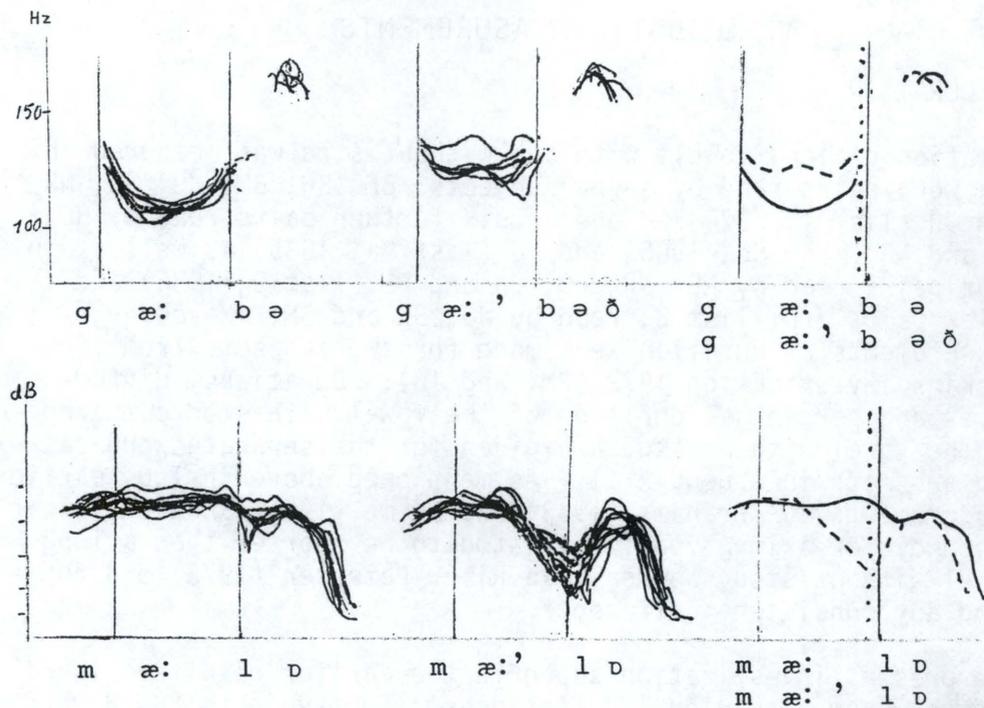
Figure 6

*Examples of manually superposed and averaged
curves. a: Fo curves (NR, list 8, 1985);
b: intensity curves (NR, list 9, 1986).* ⌐ *5 dB*

culate the significance at selected points. This was not pos-
sible with the present programme. Moreover, the standard de-
viation curve printed below the average curve has a very narrow
scale, one mm corresponding to approximately 8%, so that it can-
not be calculated exactly. In some cases, i.e. rather often
for the intensity curves, the standard deviation is very small,
so that the inexactitude does not matter so much; in other
cases, i.e. very often in the EMG-curves, the standard devia-
tion is large. It also often happens that the percentual
standard deviation is very similar for the two words to be com-
pared, but the averages very different, so that the absolute
standard deviations are too different to permit the application
of a t-test. In these cases a non-parametric test should be
used, but this would require measurements of the individual
curves. Therefore, for lists 1-3 (1974-79) significance tests
were applied to all word pairs of one subject taken together.
It was, however, often possible to state that there was no
overlapping between the maxima of the individual tokens of
corresponding words with and without stød.

III. RESULTS

A. ACOUSTIC MEASUREMENTS

1. DURATION

Duration of long vowels with and without stød was measured in
six word pairs read by seven subjects: BF, BH, BM, HU, JJ, NR
and JR (list 1, 1974-79) and in six further pairs read by HU,
JR and NR (list 8b, 1985) and FJ (list 8a, 1985) as well as in
four pairs read by ND, NR, PD, OB and PM (list 9, 1986) and in
a few pairs from list 3, read by JJ, JR and BM. Moreover,
measurements of duration were made for two subjects from the
Haskins investigation 1972 (PMi and TB). Durations, differ-
ences and percentual duration of the vowel with stød compared
to the vowel without stød are given for the separate word pairs
and subjects in Appendix II. As mentioned above in I,D, earlier
measurements by Abrahams (1943) and by me (1955) showed a clear
tendency for a long vowel with stød to be shorter than a long
vowel without stød, whereas Pia Riber Petersen (1973) did not
find any consistent difference.

The present investigation supports the earlier results. There
are, however, individual differences. Two subjects (BH 3 word
pairs) and BM (6 word pairs) do not show any difference, where-
as 12 subjects (BF, FJ, HU, JJ, JR, ND, NR, OB, PD, PM, TB and
PMi) have a clear difference, the vowel with stød being shorter.
In Table I a concentrated survey of the results is given, all
lists and pairs combined for each subject. (Averages of indi-
vidual word pairs are given in Appendix II, 2a-c), and dura-
tions are also indicated in the graphs for intensity (Appendix
III), Fo (Appendix IV) and airflow (Appendix VI). The pairs
[pʰiː'bɒ/pʰiːbɒ] and [lɛː'sɒ/lɛːsɒ] were read by eight subjects
and [kʰɛː'lɒ/kʰɛːlə] by six subjects. These main examples were
read in two different sessions and frames by HU, JR, NR and FJ
and five times in different sessions and frames by BF. These
readings in different sessions and frames are counted as sepa-
rate pairs in the survey.

Table I

*Differences (in cs) between long vowels with and with-
out stød (V: - V:') and percentual duration of [V:']
compared to [V:]. N = number of word pairs (averages).*

	BH	BM	BF	FJ	HU	JJ	JR	ND	NR	PD	PM	PMi	TB	OB
N	3	6	15	8	12	6	16	4	16	4	4	2	2	4
diff. (cs)	-0.1	0.2	2.9	3.6	3.3	3.9	1.7	5.1	3.1	3.1	2.7	2.6	4.3	2.1
%	102	99	85	83	84	81	90	80	85	82	87·	86	78	88

The percentage is very similar for the different subjects, ex-
cept that JR has a higher percentage (and a smaller difference)

than the other subjects. For BH and BM 5 of the 9 pairs have
a shorter vowel in words with stød and 4 a longer vowel, and
none of the differences are significant; but for the other 12
subjects the difference is consistent in the sense that 92 out
of 93 pairs of averages show a shortening of the vowel with
stød, the difference being significant at the 1 or (more often)
0.1% level in 74 out of the 93 pairs. In 5 pairs it is only
significant at the 5% level, in 1 it is non-significant, and
in 3 (JR) the significance cannot be calculated because there
were only three readings, but there is some overlapping.

Although the tendency to shortening is clear, vowels with stød
remain longer than short vowels. In list 8 the two words
[pʰibɒ] and [lɛsɒ] were also recorded. The relation between
short and long vowel compared to the relation between long
vowel with and without stød is shown in Table II.

Table II

Duration of long vowel with stød and of short vowel,
both of them in percentage of long vowel without
stød (N = 8)

	FJ	HU	JR	NR	av.
pʰibɒ/pʰi:bɒ	50	34	56	61	50.3
pʰi:'bɒ/pʰi:bɒ	75	85	88	79	81.8
lɛsɒ/lɛ:sɒ	61	56	61	67	61.3
lɛ:'sɒ/lɛ:sɒ	88	93	82	93	89.0

The averages of long vowels with stød and of short vowels are
clearly different, and there is only overlapping in one indi-
vidual case.

Almost all examples without statistically significant differ-
ence concern the pair [lɛ:'sɒ/lɛ:sɒ], and on the whole there
seems to be a certain tendency to shorten high vowels with stød
more than low vowels and a more pronounced tendency to shorten
vowels before sonorants more than before obstruents (partic-
ularly s). The pairs [kʰɛ:'lɒ/kʰɛ:lə], [pʰi:'bɒ/pʰi:bɒ] and
[lɛ:'sɒ/lɛ:sɒ] can be compared in 13 different cases (5 dif-
ferent subjects in different sessions or frames) and in 11
cases (for the percentual shortening 10 cases) [kʰɛ:'lɒ] is
shortened most, and [lɛ:'sɒ] least. But a number of the other
examples (from lists 8 and 9) do not fit into this pattern; it
is thus only a tendency.

It is a problem why Riber Petersen did not find the same dif-
ference between long vowels with and without stød. None of
her six subjects had a consistent shortening, and on the whole
it is only found in 50% of the cases. The difference can hard-
ly be due to age or dialectal background. All Riber Petersen's

subjects were Copenhageners (of two different generations),
and most of the subjects in my 1955 investigation were also
from Copenhagen or North Zealand (and only a few of them were
somewhat older than the subjects of the older generation in
Riber Petersen's investigation). Of the subjects in the pres-
ent investigation from Copenhagen or North Zealand seven had a
consistent difference, and two none.

It is more probable that the difference has something to do
with the sentence types used. Riber Petersen's corpus consisted
of small, real sentences. The 1955 material comprised mostly
isolated words but also some small sentences, and in the latter
case the difference between words with and without stød was very
small and hardly significant. In the present investigation the
test words were placed in frame sentences. In 1974 there was
only one stress group, but in 1985 and 1986 three. This did
not make any difference. Perhaps words in frame sentences are
pronounced more distinctly than in real sentences, so that
small differences come out more clearly. This assumption may
be supported by the observation that the subjects with small or
no differences (JR, BH, BM) read the sentences in a relatively
fast tempo, and the subject with the largest difference read
the sentences slowly.

In order to test this assumption a new recording was made of
three subjects (HU, NR and OB) reading three of the same word
pairs in small sentences (for HU and NR Riber Petersen's sen-
tences were used, see Appendix I, lists 10 and 11, and Appendix
I, 2f). The result supported the assumption. In the sentences
(with 3-4 stresses) there is less difference than in the test
words in frames (with 4 stresses). There are still 7 positive
cases out of 9 (i.e. shorter vowel in words with stød), but
only 4 differences are significant at the 1 or 0.1% level, one
case at the 5% level, and two non-significant. None of the
three subjects have a significant difference in all three pairs.
The difference between vowels with and without stød is thus
still there as a tendency, but it is not consistent. All vowels
are shortened in the sentences compared to the corresponding
words in frames (with the exception of NR's [kʰɛ:'lɒ]),the aver-
age shortening being 4.6 cs, but vowels without stød are
shortened about 1 cs more than vowels with stød. A new record-
ing of sentences read by Pia Riber Petersen's subject BRP was
also undertaken. He had a significantly shorter vowel in
[mæ:'lɒ] and [må:'lɒ] than in [mæ:lɒ] and [må:lɒ], respectively,
but the opposite (without significance) in [lɛ:'sɒ] vs. [lɛ:sɒ].

The consonant following a long vowel was measured for list 8
(4 subjects, 31 word pairs) and the consonant [l] was measured
for 5 subjects reading list 1 (10 pairs) and for one subject
reading list 3 (4 pairs). Of these 45 pairs 24 had a longer
consonant in words with stød, 17 a shorter consonant, and 4 had
no difference. There is thus no consistent difference.

As for words with short vowel plus sonorant consonant both
Lauritzen and Riber Petersen found the vowel to be shorter and
the consonant to be longer in words with stød. The difference

in consonant length was significant in all Riber Petersen's
four word pairs (all subjects combined), but the difference in
vowel length in only two of the four word pairs. These find-
ings are fully confirmed by the present investigation. The
lengthening of consonants in words with short vowel and stød
in the consonant is consistent for all subjects, and in only
one out of 20 pairs the difference is non-significant. But
the shortening of the vowel is only a tendency, and it is only
found in disyllables, where 23 out of 28 pairs have shortening
(17 with significance at the 1 or 0.1% level), whereas the
monosyllabic pairs have shortening in only 50% of the pairs
(7 out of 14 pairs). Durations and differences for the sepa-
rate pairs are given in Appendix II, 3a,b and 4a,b. A survey
of the absolute and relative lengthening of the consonant in
words with stød is given in table III, both lists (1 and 8) com-
bined. In list 8 all consonants were measured, in list 1 only
[1]. A survey of vowel duration is given in table IV.

Table III

*Absolute and relative lengthening of consonants in
words with short vowel and stød (N indicates number
of word pairs (averages)) (VC' - VC)*

	BF	BM	FJ	HU	JJ	JR	NR
N	1	1	5	4	1	4	4
cs	+1.3	+1.6	+3.0	+2.6	+2.2	+1.9	+1.9
%	121	129	150	134	132	136	133

Table IV

*Shortening of vowels in words with short vowel plus
stød in consonant (N = Number of word pairs (aver-
ages)) (VC' - VC)*

		BH	BM	BF	FJ	HU	JJ	JR	NR
disyll.	N	2	2	5	4	4	2	4	4
	cs	+0.7	-1.9	-2.7	-0.5	-2.1	-0.2	-1.5	-2.3
monosyll.	N	1	1	5	2	2	1	2	2
	cs	+3.0	-0.1	-0.5	-0.1	-1.1	+0.8	+1.0	+0.7

Duration of initial consonants in words with and without stød
was measured for four speakers (FJ, HU, JR and NR) on the basis
of four selected word pairs from list 8 with different types of
consonants ([pʰ, b-, s-, l-]). FJ had a longer consonant in
words with stød in all four pairs (and she showed the same tend-
ency in list 7), but the difference was not significant, and the
other three speakers had no consistent difference.

2. IRREGULARITY AND CLOSURE

The most conspicuous acoustic characteristic of words with stød
is the presence of irregular vibrations in the latter part of
a long vowel or in a sonorant consonant following a short vowel.
i.e. in what Smith calls the "second phase" of the stød, gener-
ally considered as the real stød phase. Smith considers this
as a "non-normative" stød because, as a speech therapist, he
does not find this way of pronouncing the stød recommendable.
But as a matter of fact this is quite a normal pronunciation
of the stød in distinct speech. In the present investigation
irregularities were found in 70.8% of all cases. The analysis
was based on about 1700 words with stød. The irregularity con-
cerns both frequency and intensity and is seen very clearly in
the duplex oscillogram and also in intensity and Fo curves.
However, it is not always visible in the Fo curves which, de-
pending on the sensitivity level of the pitch analyser, may
show a gap instead. All recordings from 1985-86 (comprising
almost half of the examples) contained a duplex oscillogram
plus either an intensity curve or an airflow curve, besides
the Fo curve. All cases with gap in the Fo curve showed irre-
gularity in the other curves. There were only two or three
cases where it may have been due simply to a weak signal. As
for the older computer-analysed recordings (lists 1-2), the
analysis was based on the sampled signals, which did not com-
prise any duplex oscillogram. Here a gap in the Fo curve was
taken as a sign of irregularity.

Some examples of different degree of irregularity are shown in
Fig. 7 (see also Riber Petersen 1973, p. 201-204). The degree
of irregularity is very variable. There is a certain tendency
to more irregularity in consonants and in high vowels than in
low vowels ([vɛn'] and [vɛn'n̩] show irregularity in almost all
cases and, for instance, BM has much more irregularity in the
[bibibibi]-series than in the other words, although they were
read in the same session). There are also individual differ-
ences (OB and BM having fewer cases of irregularity than the
other speakers, and JR and BRP often having somewhat weaker
irregularity than most of the other speakers), but the largest
differences are found between different readings by the same
speaker. This is only partly dependent on the character of
the list (HU and OB have less irregularity in the words in
sentences than in the words in frames, but this is not the
case for NR; and BRP, who did not have irregularities in Riber
Petersen's investigation, has irregularity (though sometimes
rather weak) in 76% of the cases in the present investigation,
although both texts consisted in normal (and partly in the
same) sentences. It seems mainly to be a question of the dis-
tinctness level chosen by the speaker in the session in quest-
ion. Table V gives the percentage of words with irregular
vibrations for the individual speakers and sessions. In a few
cases with weak irregularity the decision depended on a sub-
jective estimate, but generally there was no doubt. (Lists
10, 11, 12 contained words in sentences).
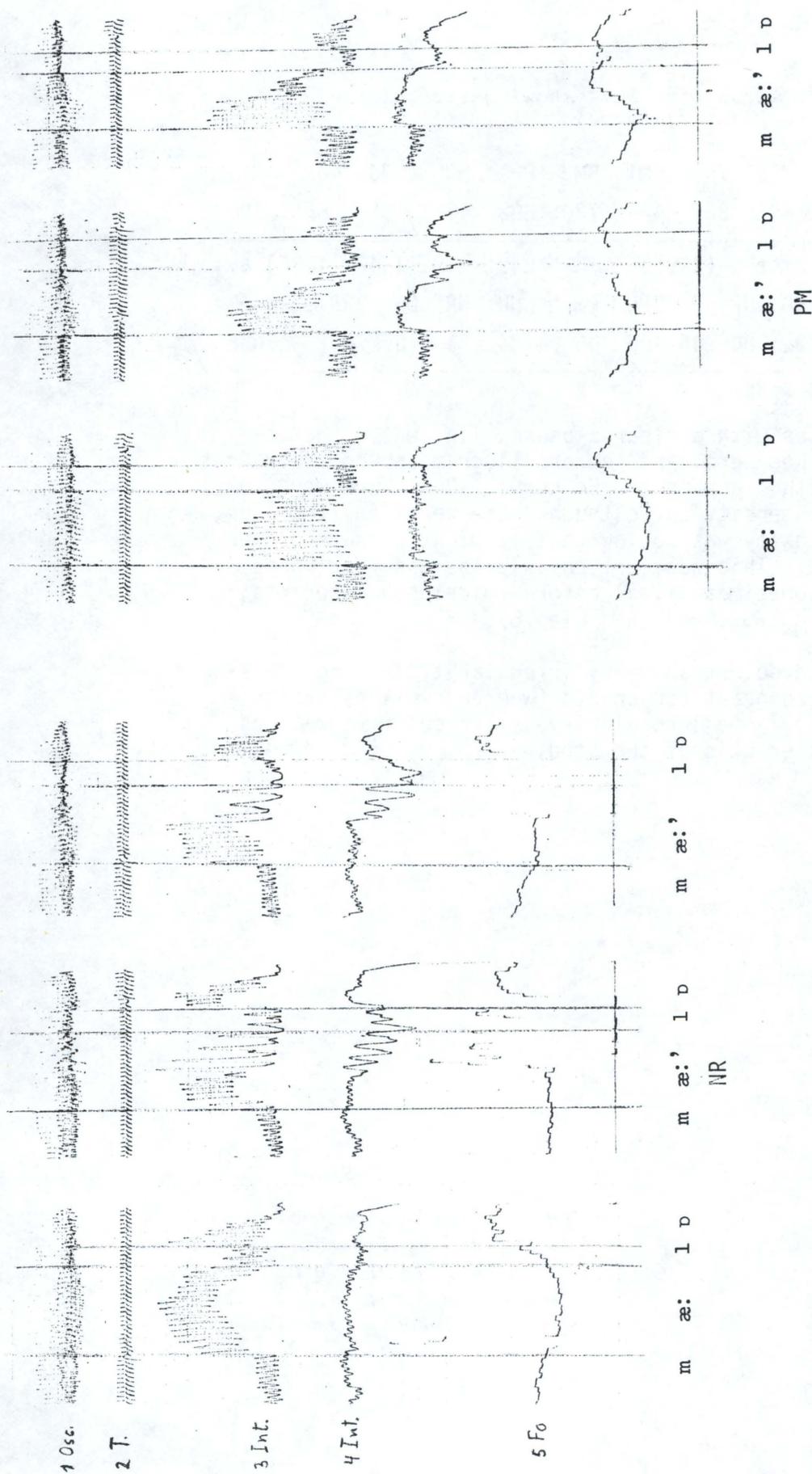
Figure 7

One example of [mɛ:lɒ] and two of [mɛ:'lɒ] read by NR and PM and showing varying degree of irregularity in [mɛ:'lɒ]. 1: duplex oscillogram, 2: time, 3: Intensity, HP 500 Hz, integr. time 5 ms, 4: Log. intensity, integr. time 10 ms, 5: Fo.

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Table V

Percentage of words with stød showing irregular vi-brations. Lists 1-2 (1974-79).

BF 74	77a	77b	79a	79b	BM1	BM2	BH	HU	JJ	JR	NR
53	73	90	80	82	44	72	88	46	52	86	90

List 8 (1985)				List 9 (1986)					Lists 10,11,12 (1986) av.				
FJ	HU	JR	NR	ND	NR	OB	PD	PM	HU	NR	OB	BRP	
75	94	63	41	98	100	46	100	96	34	81	8	76	70.8

There were no cases with a clear closure, i.e. where the intensity line reached zero and the oscillogram showed a straight line combined with a gap in the Fo curve. But there were some cases where the intensity curve touched the zero-line for a cs, or where the intensity was so low that it might perhaps be perceived as a pause. This was particularly the case for words with [u:ʔ] (and sometimes [i:ʔ]) before voiceless consonants, e.g. [mu:'sən] and [sbi:ʔsɒ] (see Fig. 8).

Words without stød do not show any irregularity in long stressed vowels or in sonorant consonants (whereas weak syllables with schwa may show some irregularity). Irregular vibrations are thus a characteristic of the stød.
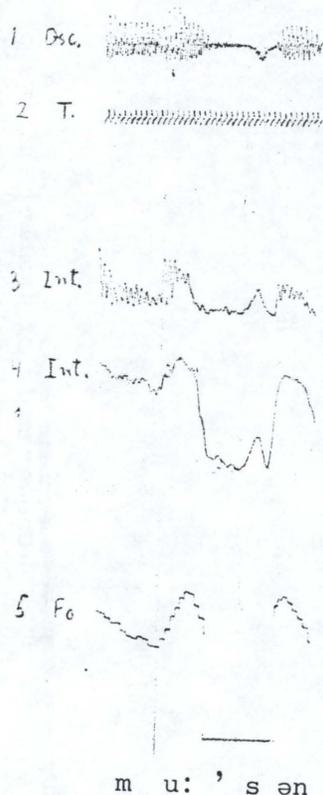
Figure 8

PM [mu:'sən]; almost closure.
1: duplex oscillogram; 2: time;
3: intensity HP 500 Hz, integr. time 5 ms; 4: log. intensity, integr. time 10 ms;
5: Fo.

3. INTENSITY

The intensity contour of syllables with and without stød was analysed on the basis of 74 pairs of averages from list 1 read by 6 different subjects, 8 pairs of averages from list 3 read by two different subjects, and 32 pairs from lists 9, 10, 11 and 12 (1986) read by 7 different subjects, two of whom also read list 1 (see Appendix III, p. 225). (Intensity was not measured for list 8, because it might be affected by the mask used for the recording of airflow.) The pairs from lists 1 and 3 (1974), which were computer-averaged, could not be analysed quantitatively (see above, p. 90). But for the pairs from 1986 two points of interest in the beginning and end of the syllable were measured in dB.

The result was that the intensity contours of syllables with and without stød differ in a very consistent way (see Appendix III, Figs. 1-2, pp. 226-231.

There is, in the first place, a tendency for words with stød to reach a higher level of intensity in the beginning of the vowel, i.e. in what Smith (1943) calls the first phase of the stød (Smith also observed a tendency to a steeper rise in the start). This is true of 59 out of 82 pairs from lists 1 and 3 (with 15 opposite cases and 8 of equal height). Similarly, in the 1986-recordings, 23 out of 32 pairs show a higher level in words with stød (with 7 opposite cases and 2 of equal height). However, the difference is small, for the 1986-pairs 1.7 dB on the average, and it is only rarely significant (11 cases out of 32). There are also individual differences, OB showing a consistent difference, NR, JR and BRP no difference.

In the second place, in words with stød the contour reaches a lower point at the end of the vowel (or after a short vowel in the sonorant consonant), i.e. the second phase (the stød phase) than in words without stød, and this difference is consistent. It is valid for all the analysed 78 pairs from lists 1 and 3 and for 31 out of 32 pairs in the 1986-recordings, the only pair without any difference belonging to list 11 (sentences).

Significance could be calculated for each individual subject reading list 1 or 3, all pairs and the two unpaired words taken together. It was 0.1% for BH, BM, JJ, NR, BF 1977 and 1979 (a and b), 1% for HU, and 5% for BF 1974 and for JR. For the 1986-recordings significance could be calculated for each word pair. The words with stød reached a lower level in all 32 pairs, and the difference was significant at the 0.1% level for 31 of the 32 pairs, and at the 5% level for one pair (from the sentences), the average difference in dB being 10.1 dB in list 9 (test words in frame) and 6.7 dB in lists 10, 11 and 12 (sentences), differences which are well above the measurement uncertainty.

There is thus a deeper drop in intensity from the start of the vowel to the lowest point in words with stød. This is the case in 77 out of 78 pairs in lists 1 and 3, and in 31 out of 32 pairs in the 1986-recordings (the only exception belonging to the sentence examples).

The occurrence of a deeper drop in intensity in words with stød
in pairs from lists 1-3 (1974-79) is indicated in table VI for
the different subjects, whereas the intensity decrease (in dB)
in words with and without stød and the difference between them
for the individual subjects in the 1986-recordings are given
in table VII.

Table VI

Number of averages with deeper (+) or smaller (-)
drop in intensity in words with stød than in words
without stød. (List 1)

	BF	BH	BM	HU	JJ	JR	NR	sum
+	33	6	10	7	7	5	7	75
-	0	1	0	0	0	0	0	1

Table VII

Intensity decrease (in dB) in long vowels with and
without stød. A: 4 pairs, each comprising 10 tokens;
B: 3 pairs, each comprising 8 tokens.

A. Words in frame (list 9)

	ND	NR	OB	PD	PM	av.
V:'	14.0	13.8	13.6	14.6	14.8	14.2
V:	3.9	3.1	0.4	1.6	2.8	2.4
diff.	10.1	10.7	13.2	13.0	12.0	11.8

B. Words in sentences (lists 10, 11, 12)

	HU	NR	OB	BRP	av.
V:'	11.5	11.0	8.2	10.3	10.3
V:	4.0	3.8	4.3	1.0	3.3
diff.	7.5	7.2	3.9	9.3	7.0

The difference is very clear in all cases but somewhat smaller
in sentences than in frames.

The decrease starts early in the vowel, the average distance
from the start of the vowel being 4.8 cs in the 1986-recordings
with the individual means rather close (4.2 - 5.8 cs). All ex-
amples in these recordings contained long vowels. In list 1
it is possible to compare the start in long vowels with stød
with the start in short vowels followed by a consonant with
stød. It is interesting to find that the fall starts at the

same point in both cases, which is a further indication that the stød is a syllabic phenomenon and does not belong to a definite segment. This can be seen for the individual subjects in table VIII (here also unpaired words with long vowel are included.

Table VIII

Distance from vowel start to start of intensity decrease (in cs) in words with stød. List 1. N = Number of averages.

A. V:'

	BF	BH	BM	HU	JJ	NR	av.
N	27	7	7	7	7	7	
cs	5.8	6.4	7.0	10.1	4.5	6.3	6.7

B. VC'

	BF	BH	BM	HU	JJ	NR	av.
N	11	3	3	3	3	3	
cs	5.2	6.5	5.7	8.7	5.2	6.5	6.3

The distance to the end of the decrease is also almost the same in the two cases. It is in almost all cases at the very end of the long vowel (in only three averages a small rise is found after the lowest point) and in the sonorant consonant after a short vowel, but somewhat dependent on the duration of the vowel (see also Figs. 1-2 in Appendix III). In long vowels without stød the lowest point is also normally at the end, but the small decrease may start at different points, often at the beginning, but also later, so that it does not make sense to calculate an average.

Thus the intensity decrease starts in the vowel in the case of "stød in the consonant" and, moreover, the decrease of intensity continues into a following sonorant consonant after "stød in the vowel". A sonorant consonant like [l] normally has lower intensity than the preceding vowel, but it is much lower after a long vowel with stød than after a long vowel without stød, the difference for 10 averages of the words [kʰɛ:lə] and [kʰɛ:'lɒ] in the 1986-recordings being 7.3 dB, all statistically significant.

4. FUNDAMENTAL FREQUENCY

a. First part of the stressed syllable

The frequency contour of the first part of the syllable in words with and without stød was analysed on the basis of 75 word pairs

from list 1, read by 6 different subjects (1974-79), 8 from
list 3 read by 2 different subjects (1974), 62 from list 8,
read by 4 subjects (1985), and 32 from lists 9, 10, 11 and 12
(1986), read by seven different subjects, i.e. 178 word pairs
in all, each word comprising 8-10 tokens (see Appendix IV, p.
232). The Fo contour was in almost all cases different for
words with and without stød.

The most stable difference consists in a higher level of Fo in
the start of words with stød (the first phase) compared to
words without stød. The differences in Hz for each subject
are given in Table IX for lists 1 and 3, and in Table X for
lists 8-12 (i.e. 1985-86). BH's curves were not calibrated,
and in this case a "+" indicates a positive difference. The
difference was measured as the largest difference within the
first 10 cs of the word (see also the graphs in Appendix IV).

Table IX

*Difference (in Hz) between the levels of Fo within the first
10 cs of the vowel in words with and without stød (maximum dif-
ference). Lists 1-3 (N = number of pairs (averages)).
A: Disyllables with long vowel; B: Disyllables with short vowel;
C: bibibi-words; D: monosyllables.*

	BF 1974	1977a	1977b	1979a	1979b	BM	BH	HU	JJ	JR	NR
A N	4	4	4	4	4	4	4	4	4		4
V:'-V:	27.0	28.5	13.0	17.0	8.3	17.0	+	30.0	22.0		12.6
B N	2	1	1	1	1	2	2	2	2		2
VC'-VC	19.5	31.0	13.0	11.0	7.0	13.5	+	20.0	15.0		4.5
C N						3			5		
V:'-V:						21.3			22.0		
D N	2	2	2	2	2	2	2	2	2		2
mon.	19.0	15.0	7.5	11.0	8.0	10.5	+	17.5	14.5		3.5

It is apparent from the tables that words with "stød in the
consonant" have a higher Fo level in the vowel than their stød-
less counterparts, just as words with "stød in the vowel", thus
again indicating that the stød is a syllabic phenomenon.

The difference is smaller in monosyllables than in disyllables,
the main reason being that the monosyllables without stød have
a relatively high Fo level approaching the words with stød. It
is tempting to guess that this could be due to the fact that
they are old accent 1 words. However, in two of the three pairs
read by a larger number of speakers (viz. [du / du:'] and [tʰa/
tʰæ:'] there is also a difference in vowel duration, and the
short vowel might favour a higher Fo. In comparable disyllables
[kʰɛlɒ] has a slightly higher Fo in the vowel than [kʰɛ:lə] and
[pʰibɒ] a clearly higher Fo than [pʰi:bɒ] for most speakers,

Table X

Difference (in Hz) between the levels of Fo within the first 10 cs of the vowel in words with and without stød (maximum difference). N = number of pairs (averages) (Lists 8, 9, 10, 11, 12). A: Disyllables with long vowel; B: Disyllables with short vowel; C: Monosyllables; D: Disyllables with long vowel in sentences.

		List 8				List 9				List 12
	FJ	HU	JR	NR	ND	PD	OB	PM	NR	BRP
A. dis. N	7	10	10	10	4	4	4	4	4	
V:'-V:	20.6	11.2	24.9	24.1	18.3	12.5	26.0	26.5	26.2	
B. dis. N	5	2	2	2						
VC'-VC	9.0	11.0	26.5	18.5						
C. N	5	3	3	3						
mon.	-2.8	7.3	13.0	13.0						
sent. N		3		3			3			3
V:'-V:		5.7		3.3			11.7			21.0

whereas there is no difference between [lɛsɒ] and [lɛ:sɒ]. The only monosyllabic pair without any difference in vowel duration is [vɛn / vɛn']. [vɛn] is in between [vɛnɒ] and [vɛ:n'] in Fo level but clearly lower than [vɛn'] in most cases. Only one of the speakers (FJ), who read five pairs of monosyllables, has no difference between the words without and with stød in this case, on the average the words without stød are even higher. But in four of the five pairs the word without stød has a short vowel and the word with stød a long vowel (she has a slightly higher Fo in [kʰɛlɒ] than in [kʰɛ:lə] and has not read the other two disyllabic pairs with short and long vowel). Thus there is not much evidence to support the assumption of a higher accent 1. BF has much less difference between Fo in words with and without stød in recordings 1977b and 1979b than in the other recordings, the reason being that in these two recordings the test words were in final position after a word with emphasis. The difference, though smaller, is, however, retained even in this position.

In all, 171 out of 178 pairs (96%) show a positive difference. As for the significance of the differences it could not be calculated for lists 1 and 3 for the individual pairs, but it is evidently significant for all subjects, since it is positive in 74 out of 76 pairs. In the 1985-86 recordings significance could be calculated by comparing the overlappings. Disyllables in frames show a significant difference at the 1% or 0.1% level (generally 0.1%) in 42 out of 48 pairs of averages (1 at the 5% level, 5 not significant). In sentences 9 out of 12 pairs are significant at the 1% or 0.1% level, and 3 non-significant.

For monosyllables only 4 out of 14 pairs are significant at the
1% or 0.1% level, 2 at the 5% level, and 8 non-significant (of
these 4 are due to subject FJ).

This difference is thus much more consistent than the corre-
sponding difference in intensity, where the difference was
positive in only 72% of the cases, and in the 32 pairs where
significance could be calculated only one third showed signif-
icance.

b. Second part of the syllable   In the second part of a long
                                  vowel (or in the sonorant con-
sonant after a short vowel) (the second phase) most authors
have found a tendency to decrease of Fo in words with stød,
though neither Smith nor Riber Petersen found this decrease
to be a consistent phenomenon.

In the present investigation such a decrease was found in ap-
proximately half of the examples (53.8%). As was the case
with the presence of irregularity this analysis could not be
based on average curves, since average curves based on cases
of which some show irregularity and some not, are not very
informative. It was therefore based on individual inspection
of the 1700 words with stød mentioned in the section on irreg-
ularity. - It turns out that lack of decrease in Fo is not
a well defined parameter since it may mean two quite different
things: (1) the whole second half of the vowel may be charac-
terized by irregular vibrations, so that a description of the
direction of Fo does not make any sense. (2) The Fo curve may
be smooth, showing an even or rising direction. (1) is by far
the most common case. Very often the same speaker may show
either irregular vibrations, falling Fo mixed with irregular
vibrations, or simply a fall or a dip in Fo in examples of the
same word in the same session, depending on how distinctly or
forcefully he has pronounced the word at that moment. Irreg-
ularity is characteristic of a strong stød, Fo dip of a weak
stød as pronounced by the same speaker. An example is given
in Figure 9.

The second case, an even or rising Fo, is extremely rare for
almost all subjects, with a few exceptions. In table XI the
cases are divided into four types: A: only irregularity; B:
a (larger or smaller) decrease in Fo mixed with irregularity;
C: only decrease of Fo; D: neither-nor, i.e. even or rising Fo.
The numbers are percentages (the sum of A+B+C+D is in some
cases slightly above 100, because the decimals have been left
out and the preceding integer raised if the decimal was above
0.5). - The actual number of cases on which the percentages
are based are, on the average, 70, reaching from 21 to 143,
for each column.

d ʁ æ ŋ' n̩ 'l ɛ: ' s ɒ
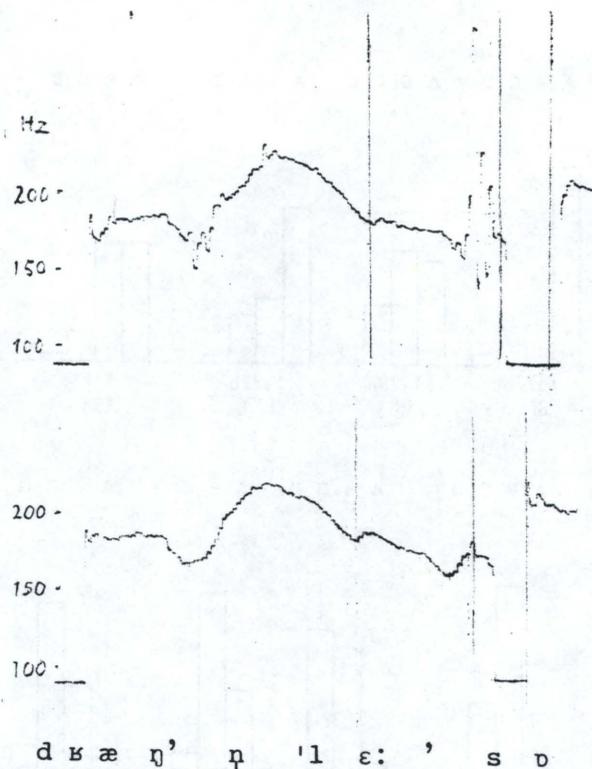
Figure 9

Two examples of Fo from the same reading by HU,
one with irregularity, one with Fo drop; text:
[dʁæŋ'n̩ lɛ:'sɒ].

Table XI

Percentage of words with stød showing A: only irregularity in
the second half of the syllable; B: irregularity and decrease
of Fo; C: only decrease of Fo: D: neither-nor.

Lists 1-2 (1974-79)

	BF 74	77a	77b	79a	79b	BM1	BM2	BH	HU	JJ	JR	NR
A.	3	22	74	38	58	7	41	44	3	6	69	80
B.	50	51	15	42	24	37	31	44	43	46	17	10
C.	44	22	8	22	18	52	28	11	52	47	10	3
D.	2	5	4	1	3	4	0	3	2	1	3	7

	List 8 (1985)				List 9 (1986)					Lists 10,11,13 (1986)				
	FJ	HU	JR	NR	ND	NR	OB	PD	PM	HU	NR	OB	BRP	av.
A.	6	29	49	7	66	92	15	79	73	4	10	8	76	38.4
B.	69	65	14	34	32	8	32	21	23	30	71	0	0	32.4
C.	25	6	19	48	0	0	54	0	4	61	19	31	0	23.4
D.	0	1	18	11	2	0	0	0	0	8	0	62	23	6.4
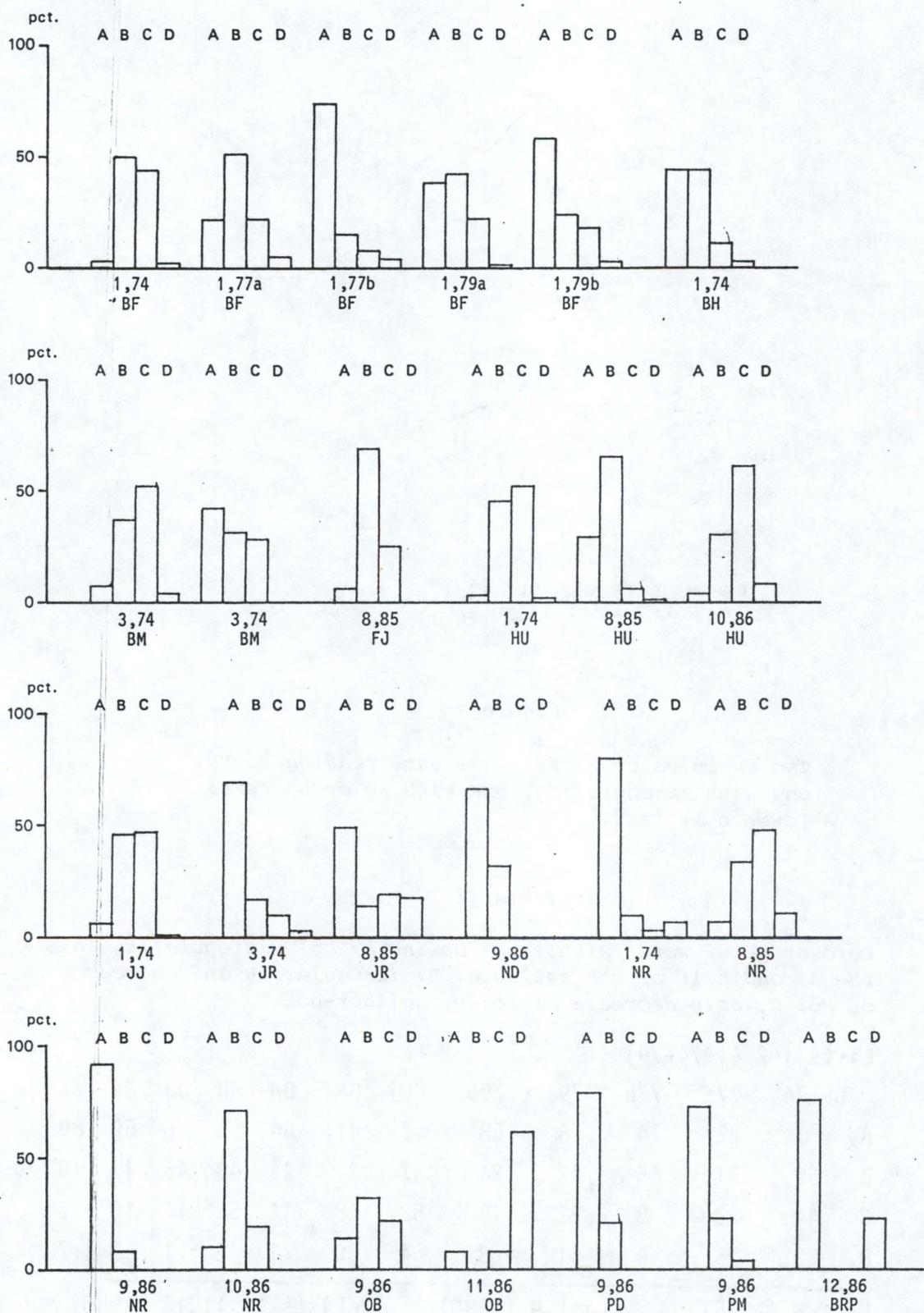
Figure 10

*Relative number of examples of words with stød having A: only
irregularity, B: irregularity and Fo fall, C: only Fo fall,
D: neither-nor, for individual speakers and lists. The numbers
below the columns indicate list and year.*

The same facts are represented graphically in figure 10. Here different sessions with the same subject are grouped together to demonstrate the large intra-individual variation more clearly. BF has less Fo-decrease and more irregularity in 77b and 79b than in the other recordings because in these two cases the test word was placed at the end of a frame after a word with emphasis, i.e. on a low Fo-level. BM has more irregularity and less fall in list 2, where all words contained the vowel [i:'],than in list 1. - NR has less irregularity and more cases with Fo-drop in lists 8 and 10 than in list 1. In list 10 the words are placed in real sentences. In list 8 the test word is one of three stressed syllables, whereas in list 1 it is the only stressed word. HU also has less cases with irregularity and more Fo-drop in the sentence list No. 10, but in contradistinction to NR she has more irregularity in list 8 than in list 1, which is surprising.

The distance from the start of the vowel to the Fo-fall is rather variable and sometimes somewhat dubious. HU has, for instance, generally a slow fall from the very start as in vowels without stød, but the later point of abrupt fall is generally clear. FJ has a strong fall from the start after voiceless consonants, which may continue almost directly into the fall for the stød. But in most cases it is possible to see where the fall for the stød starts. In table XII the approximate averages for the different speakers are given, based on lists without too much irregularity.

Table XII

*Average distance (in cs) from start of the vowel
to start of Fo drop.*

BF	BH	BM	FJ	HU	JJ	JR	OB	NR
9.2	10.0	10.8	7.5	10.3	10.5	11.0	9.5	7.7

Sometimes there is a small rise again at the end of the long vowel (generally accompanied by a small rise in intensity). - This happens particularly often in the monosyllable [du:'] where the vowel with stød is final, and in [lɛ:'sɒ] (see Fig. 9, HU [lɛ:'sɒ]). In other words, this occurs only occasionally, and never in [pʰi:'bɒ], probably because the vowel in this word is rather short. In the monosyllable [vɛn'] with stød in the final [n] there is generally great irregularity, but the vibrations may reappear after a while. In the word [hu:'ən] (often pronounced [hu:'un]) there is generally a clear drop followed by a rise, but as no delimitation is possible, this rise may belong to the second syllable.

In words with long vowel and stød plus [l] the drop in Fo (or irregularity) very often continues into the [l] (see, e.g., Fig. 7 above, p.101), whereas in words without stød it is the final rise of the vowel which continues into the [l]. The Fo

contour of the sonorant is thus very different in the two cases,
see e.g. Fig. 7 above and Fig. 11 (NR). Here most of the drop
or irregularity is in fact in the [l]. It may even happen that
it does not start until the [l] (see Fig. 15 below (JR)). On
the other hand, the Fo contour of [kʰɛ:'lɒ] and [kʰɛl'ɒ] may be
almost exactly alike (see, e.g., the average curves of BM 1974
in Appendix IV, p. 235).
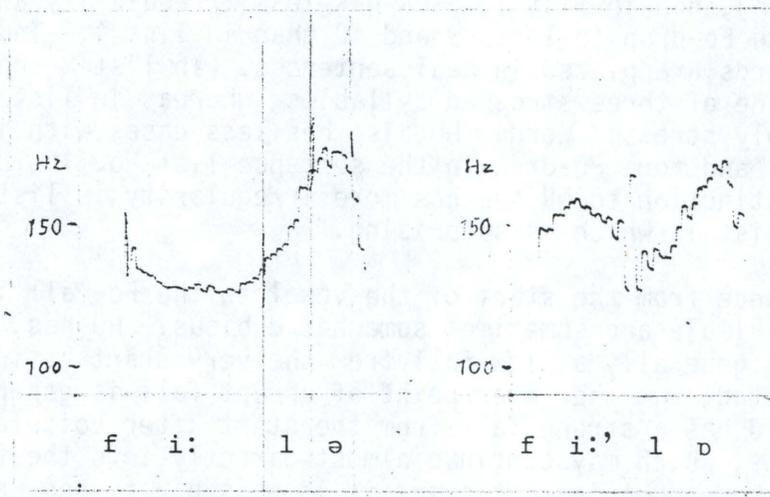
Figure 11

NR. Fo of [fi:lə] and [fi:'lɒ]
showing the different contour
of both [i:] and [l].

Words with stød which have neither Fo drop nor irregularity
are rare. It appears from table XI that for most of the speak-
ers (viz. BF, BM, BH, HU, JJ, FJ, ND, PD, PM) this happens in
only 0-5% of the cases, which corresponds to 0-4 individual
words, 23 examples in all, of which 13 concern the word [pʰi:'
bɒ], probably because the vowel may be so short that there is
no time for Fo drop or irregularity to develop (the four ex-
amples from BM have, for instance, a duration of around 10 cs).

But for four speakers: BRP, JR, NR and OB there are more ex-
amples. For BRP it is very clear. He never has any Fo drop,
but rising pitch throughout the vowel with stød. (This was
also the case in Riber Petersen's recording of this subject.)
JR (list 8, 1985) has 18% (or 21 examples) without either Fo
drop or irregularity (see, e.g., Fig. 12 [lɛ:'sɒ]. The [s] is
partly voiced. The delimitation is quite clear in the oscil-
logram, which is left out here). Moreover, the irregularity is
rather weak, and in many of the examples with "only irregularity"
it is possible to state that there is no Fo drop, and in four
examples of [hu:'ən] listed as fall it may be a fall in the
second syllable. The irregularity in this word is on the top
of a rising-falling curve, quite different from the falling-
rising curve of the other speakers (see Fig. 13 and the aver-
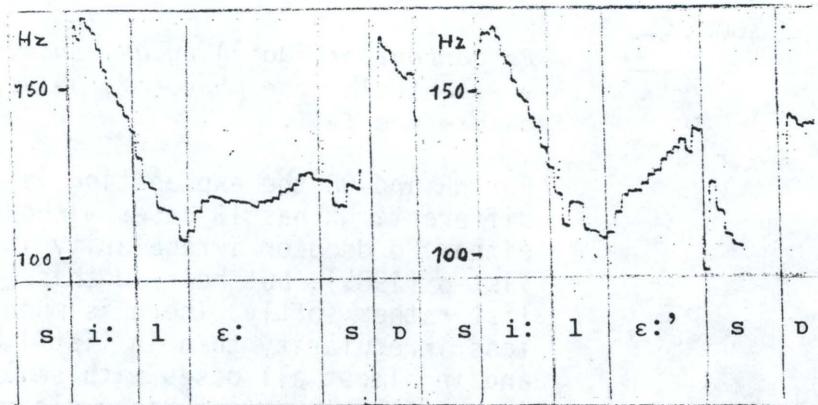
Figure 12

*JR. Fo of [lɛ:sɒ] and [lɛ:'sɒ]
showing rising Fo of the word
with stød.*

age curves, Appendix IV). However, in other cases he has a fall,
particularly in the words [ɖu:', bu:'sɒ, gæ:'bəð, tʰæ:'bəð] and
in half of the examples of [lɛ:'sɒ], thus finally and before a
voiceless consonant, and there is often a rise before the fall,
starting when the intensity goes down, e.g. in [ɖu:'] (see Fig.
14). Before [l] and [n] there are only a few cases with fall,
but in [fi:'lɒ, kʰɛ:'lɒ, be:'nəð] (but not in [sæ:'lən]) there
may be a fall in the following sonorant consonant in contra-
distinction to the corresponding words without stød, which have
a rise in the consonant (see Fig. 15). Thus, this speaker does
not have a consistent pattern.
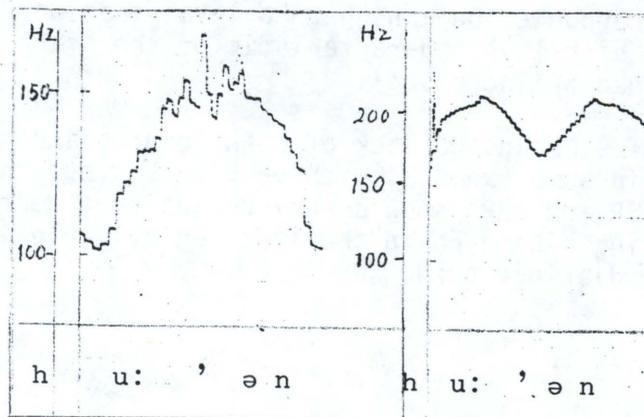
Figure 13

*Fo contour of [hu:'ən] by JR and by
FJ (the latter contour is the typical
one).*
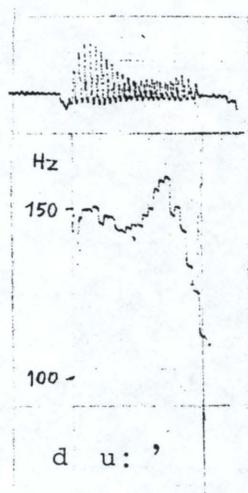
Figure 14

Fo contour of [du:'] *by JR, showing a rise during the phase of the stød before the fall.*

For NR and OB the explanation is different. NR has 13 cases without either Fo drop or irregularity in list 8 (1985), but he read this list rather softly. There is much less irregularity than in list 1, and in almost all cases with small or no irregularity he has a clear drop in Fo. The cases without this drop are simply pronounced with a very weak stød, which also appears from the intensity and airflow curves.

The same is the case for OB. He has, on the whole, a relatively weak stød, but in list 9, which was read distinctly, there is always a clear rising-falling Fo in words with stød, whereas in list 11 (the sentences), which was read quickly and somewhat slovenly, there are relatively many cases with neither fall nor irregularity (list 11 was a short list, so that 62% corresponds to 16 examples out of 26). In 8 examples of [mæ:'lɒ] there is a drop in the following [l]; and 3 examples of [pʰi:'bɒ] without Fo drop or irregularity are pronounced on a considerably higher Fo level than [pʰi:bə]. But 5 examples of [mu:'sən] look very much like [mu:sən]. There is no clear difference in the Fo contour of the stressed syllable, but the unstressed syllable is somewhat lower than in [mu:sən], and the decrease in the intensity contour starts earlier. For the other three subjects (BPR, JR and NR) all cases with neither Fo drop nor irregularity are pronounced on a higher Fo level than words without stød (i.e. the high level characteristic of the start of the vowel is retained or increased).

Thus, whereas for NR and OB lack of both Fo drop and irregularity is only found in some examples with very weak stød, the other two speakers, JR and BRP, show a real deviation from the general pattern by having rising Fo in the stressed syllable in many cases of quite distinct stød.
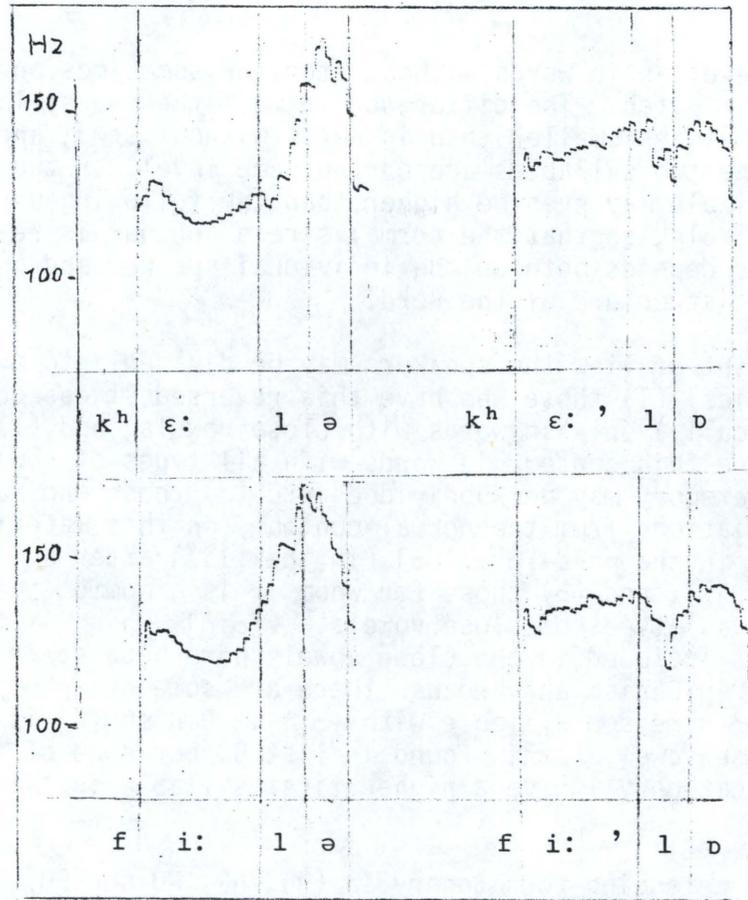
Figure 15

Fo contour of JR [kʰɛ:lə, kʰɛ:'lɒ] *and* [fi:lə, fi:'lɒ]*, showing a rise in the vowel and a fall in the consonant in words with stød.*

c. The word contour   In words without stød all subjects have
   (= stress contour)   the contour described in a number of
                          papers by Nina Thorsen (e.g. 1978 and
1983) as the typical Copenhagen stress contour (this contour is
generally taken over by people who have moved to Copenhagen from
other parts of the country): i.e. a low stressed syllable, from
which the pitch glides or jumps up to the first posttonic syl-
lable with following unstressed syllables pronounced on a grad-
ually falling pitch. The stressed syllable often has a falling-
rising pitch contour, particularly if it has a low vowel (typical
examples can be seen in the average curves of NR, Appendix IV).

In words with stød the first part of the stressed vowel is
higher than in words without stød (see above, p. 106), whereas
the following unstressed syllable is generally said on the

same pitch level as in words without stød, or sometimes on a
slightly lower pitch. The difference between the two syllables
is therefore always smaller than in words without stød, and in
some cases the two syllables are on the same level, or the
stressed syllable may even be higher than the following un-
stressed syllable, so that the normal stress contour is re-
versed. This depends both on the individual speaker and on
the segmental structure of the word.

From this point of view the speakers may be divided into two
main categories: (I) those who have this reversed stress con-
tour (practically) only in words with close vowels, and (II)
those who have this contour in words with all types of vowels.
The former category may be subdivided into (a) those who have
very few deviations from the normal contour (in this material
particularly in the word [pʰiːˈbɒ] (in the [iː] after an
aspirated [pʰ])), and (b) those for whom it is a common phe-
nomenon with all types of close vowels. ([oː], which is found
in list 9, is included in the close vowels here because it is
rather close in Danish and because there are some examples
with a higher stressed syllable with [oː]. Danish [e] is also
a rather close vowel. It is found in list 8, but none of the
speakers of category I have a higher first syllable in this
case.)

The speakers belonging to category Ia (HU, NR, ND and PD) are
all from Copenhagen or Zealand. They have the normal low-high
contour in 82% of the words with close vowel and in all words
with more open vowels. The speakers belonging to category Ib
(BH, BM, FJ) are dialectally a more heterogeneous group: BH is
from Copenhagen, BM lived in Jutland until he was seven and
from then on in Copenhagen, and FJ is from Funen and speaks a
standard language which in various respects is rather conser-
vative; she has, however, adopted the Copenhagen pitch contour.
For these three subjects only 27% of the words with close vowels
have the normal low-high contour, and in a few exceptional
cases also words with [ɛː] or [ɛlʔ] have an even or falling
contour (one example for FJ, two for BH and BM), but in an
extra reading of list 9, pronounced with particular force in
order to see what happens to the airflow, FJ has four more
examples with open vowels.

Category II comprises JR, who is from Funen but speaks a rather
conservative Standard Danish, and PM, OB and BF, who all have
a perceptible Jutlandish rhythm. However, they all have high
unstressed syllables after stressed syllables without stød.
But in words with stød JR has this type in only 51% of the
cases, PM in 41%, OB in 24%, and BF in only 18%. They have a
clearly high-low pattern in 32, 44, 61 and 74 percent of the
cases, respectively. In Appendix IV, Table I and II the number
of cases is indicated for different speakers and words. (The
analysis is based on individual tokens, not on averages). The
average curves in Appendix IV also show the differences between
speakers. Fig. 16 shows two sentences read by OB. In A there
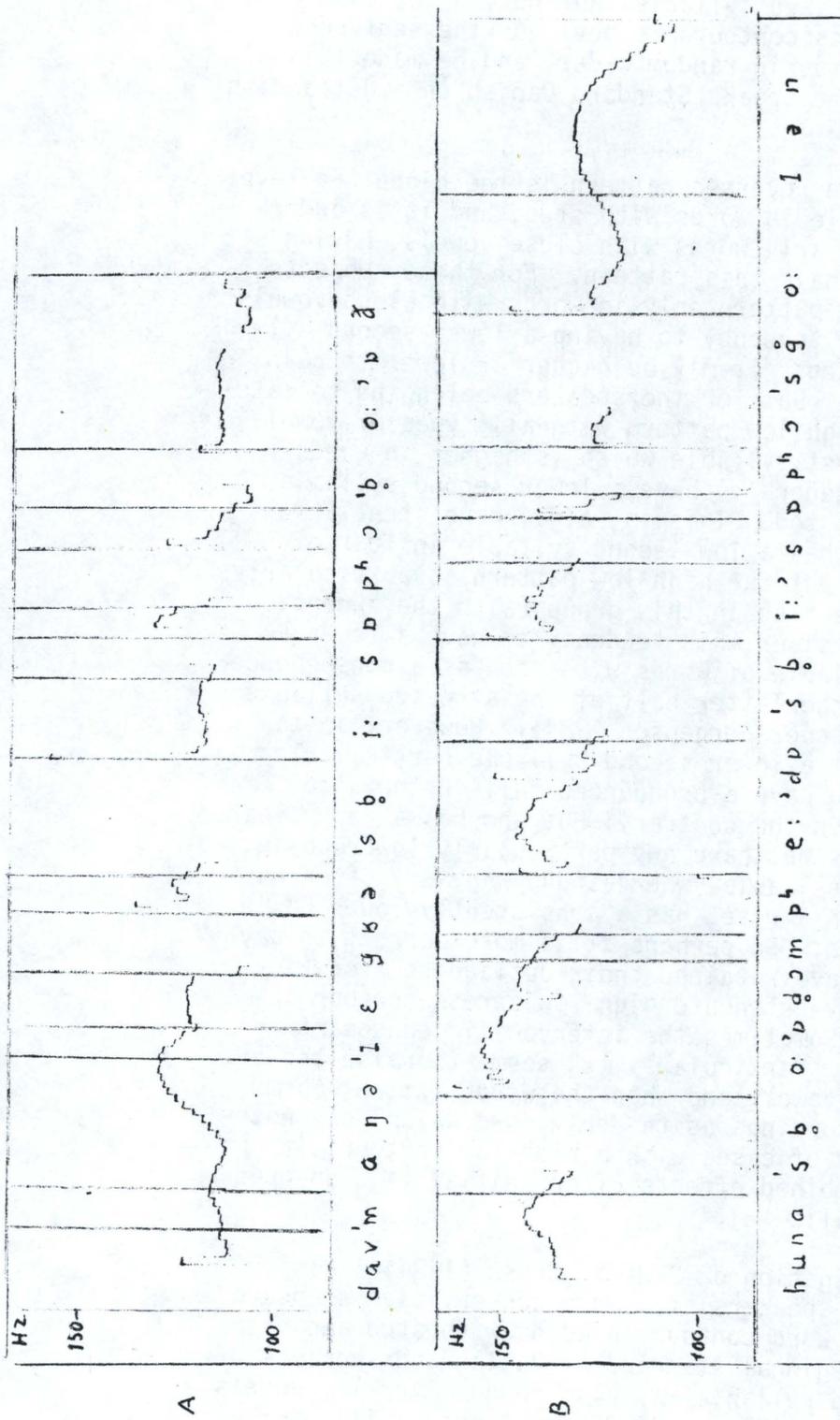
Figure 16

Two sentences read by OB, showing different contours for words with and without stød.
A: the first three stressed words (without stød) showing a low-high contour.
B: the first three stressed words (with stød) showing a high-low contour.

is only stød in the last stressed syllable, in B there is stød
in the first three stressed syllables but not in the last one.
The difference in stress contours is obvious (the sentences
were repeated eight times in random order, and he made this
difference each time; he speaks Standard Danish on a Jutlandish
background).

The main reason for the reversed pattern is the higher Fo level
of the stressed syllable in words with stød, and it is under-
standable that particularly words with close vowels, having
an intrinsic high Fo, have this pattern. For those subjects
who have this high-low pattern only in words with close vowels
there is no pronounced tendency to having a lower second syl-
lable in words with stød. It may be higher or lower than in
words without stød. - But for the speakers belonging to cate-
gory II, having the high-low pattern with all types of vowels,
it is not only the first syllable which is higher in words
with stød, they also generally have a lower second syllable
than in words without stød. This is, e.g., consistently so
for JR and OB, and BF has a low second syllable in four of
his five recordings. But the high-low pattern is particularly
clear for close vowels also in this group (with the exception
of JR). One might consider this tendency to have a lower Fo
in the unstressed syllable of words with stød as a consequence
of the falling Fo in the latter half of the stressed syllable
(as I have done in Fischer-Jørgensen 1984). However, in that
case one should expect a lower second syllable particularly
for those speakers who have a pronounced fall in the stød.
And this is not so. On the contrary: HU, who has a very clear
fall in the stød, does not have any particularly lower Fo in
following unstressed syllable, whereas JR, who very often has
no fall and even often a rise, has a consistently lower Fo in
the following syllable. So perhaps it is more correct to say
that these speakers have retained their Jutlandish - or (in
JR's case) conservative standard high-low stress contour in
words with stød. - Sometimes the intervocalic consonant
seems to play a role. Particularly [s] seems to raise the
following unstressed vowel, and when the word [lɛ:'sɒ] forms
exception in BF's recordings as the only word which does not
have a large majority of cases with a high-low contour, it
may be due to the combined effects of an initial [l], an open
vowel, and a postvocalic [s].

In my earlier investigation on Danish stress (1984) I also
found a tendency for speakers of a more conservative standard
to have the high-low word contour in words with stød and high
vowels; and in the regional standard of Jutlandish speakers
this lower unstressed syllable was also found after low vowels
(cf. Fischer-Jørgensen 1984, p. 84-86 and Appendix III of the
1984-paper, 3, 6, 7).

Corresponding differences are found in unstressed words after
monosyllabic words with and without stød (e.g. after [du] and
[du:'], see Fig. 16a).   It is thus a question of stress
contours, not specifically word contours.

In list 1 (1974-79), where the test word was the only stressed word, it may be influenced by sentence intonation, e.g. the use of non-final intonation might favour a rise in the second unstressed syllable of the test word. HU has generally used this intonation, but she has just the same rise in the unstressed syllable of words with stød in other recordings without non-final sentence intonation. In BF's 1974-recording there is, however, an influence from sentence intonation, then he shifts to non-final intonation with retained high pitch at the end. This has influenced the words with stød and open vowel, so that they get more rising contours in the last four recordings. Four of the five cases of [vɛːˈnɒn], four of the eight cases of [lɛːˈsɒ], and four of the six cases of [kʰɛːˈlɒ] with high unstressed syllable are found in the last four readings. But the final intonation of the preceding readings have not changed the normal rising contour of words with stød, except for two cases of [huːən] with level contour.

In the Haskins recording 1972 the test word was in final position, the frame being [di sæː ...]. Here Fj has non-final intonation, but nevertheless [huːˈən], [pʰiːˈbɒ] and [kʰɛlˈɒ] have a lower second syllable or (in some cases) equal height, whereas [lɛːˈsɒ] and [kʰɛːˈlɒ] have a higher second syllable. Of the two other speakers PMi, who is from Copenhagen, has a pronounced non-final intonation with a strong rise in the last syllable of all words, whereas TB, who is from southern Jutland but speaks Standard Danish, has a small fall at the end of the sentence and makes a clear distinction between words with and without stød, the final syllable being on a higher level in words without stød but in almost all cases lower in words with stød, irrespective of vowel height.
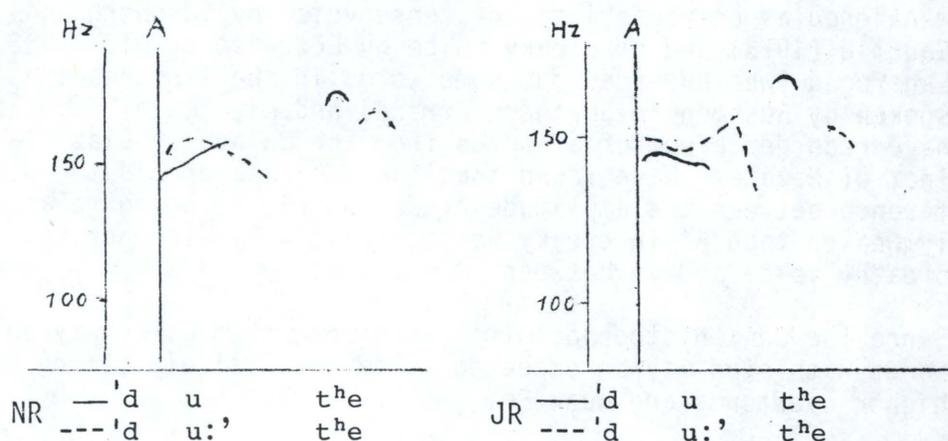
Figure 16a

Fo curves of the words [du] and [duː'] followed by
[tʰe] in the sentence [ja ka ˈgɔd siː ˈ[du (duː')] tʰe
ˈpʰalə], read by NR and JR.

5. SPECTROGRAPHIC ANALYSIS

The spectrographic analysis is rather restricted. It comprises
56 word pairs in all (only words from the same reading were
compared). For 12 pairs only wide band spectrograms were pro-
duced (BRP 1, HU 3, JJ 2, ND 2, NR 2, PD 1, PM 1). For the
other 44 pairs both wide band spectrograms (300 Hz), narrow
band spectrograms (45 Hz) and power spectra (45 Hz) were pro-
duced. The sections (power spectra) were placed in the first
and the last third of the vowel, generally 3-5 cs from the
boundary, and in the case of the second measuring point as close
as possible to the dip in fundamental frequency and intensity
in vowels with stød. 25 of the word pairs contained the open
vowels [æ: / æ:'] and [ɛ: / ɛ:']. They were read by BF (4),
BM (2), BH (2), BRP (6), FJ (6), JR (2) and OB (3). The other
19 pairs contained the close vowels [i:] and [i:']. They were
read by BF (3), BH (1), BM (4), JR (8), FJ (1) and OB (2).

In the first place the spectrographic analysis demonstrates
the same characteristic features of vowels with stød as those
described in the preceding chapters, i.e. shorter duration, de-
crease in intensity and fundamental frequency and in many cases
irregular vibrations, features which (except for duration)
could be measured more precisely by means of other types of
display. Fig. 17 shows wide band spectrograms of the pair
[mæ:lᴅ / mæ:'lᴅ] read by three different speakers with de-
creasing distinctness of the stød.

The power display may, however, also show measurable differ-
ences in relative intensity of different parts of the spectrum.
Such differences have been mentioned as characteristic of par-
ticular phonation types, and might therefore be relevant for
the stød. Greater energy in the upper part of the spectrum is
mentioned by Laver (1980, p. 149) as characteristic of tense
voice, and relatively strong higher overtones and weak Fo are
mentioned as characteristic of tense voice by Sundberg and
Gauffin (1978) and of creaky voice by Löfqvist et al. (1983).
Ladefoged (who has recorded some words in the language !Xoõ,
spoken by Bushmen in Southern Africa) and Kirk et al. 1984 (who
have recorded a number of words from the Jalapa de Diaz dia-
lect of Mazatec) have found that the best measure is the dif-
ference between the amplitude of Fo and F1, Fo being relative-
ly weaker than F1 in creaky voice, relatively stronger in
breathy voice and in between in modal voice.

Since the Danish stød has often been described as creaky voice,
words with stød may be expected to have relatively strong
higher overtones and weak Fo.

Lauritsen (1968) published 33 wide band spectrograms of Danish
words with and without stød read by one informant. In a few
cases vowels with stød show higher intensity, particularly in
F4 and F5. Riber Petersen (1973) published only one pair of
spectrograms, but she recorded quite a number, which I have
had occasion to see. There were 16 comparable pairs, of which
6 showed somewhat more intensity in higher formants at the
start of the vowel in words with stød.
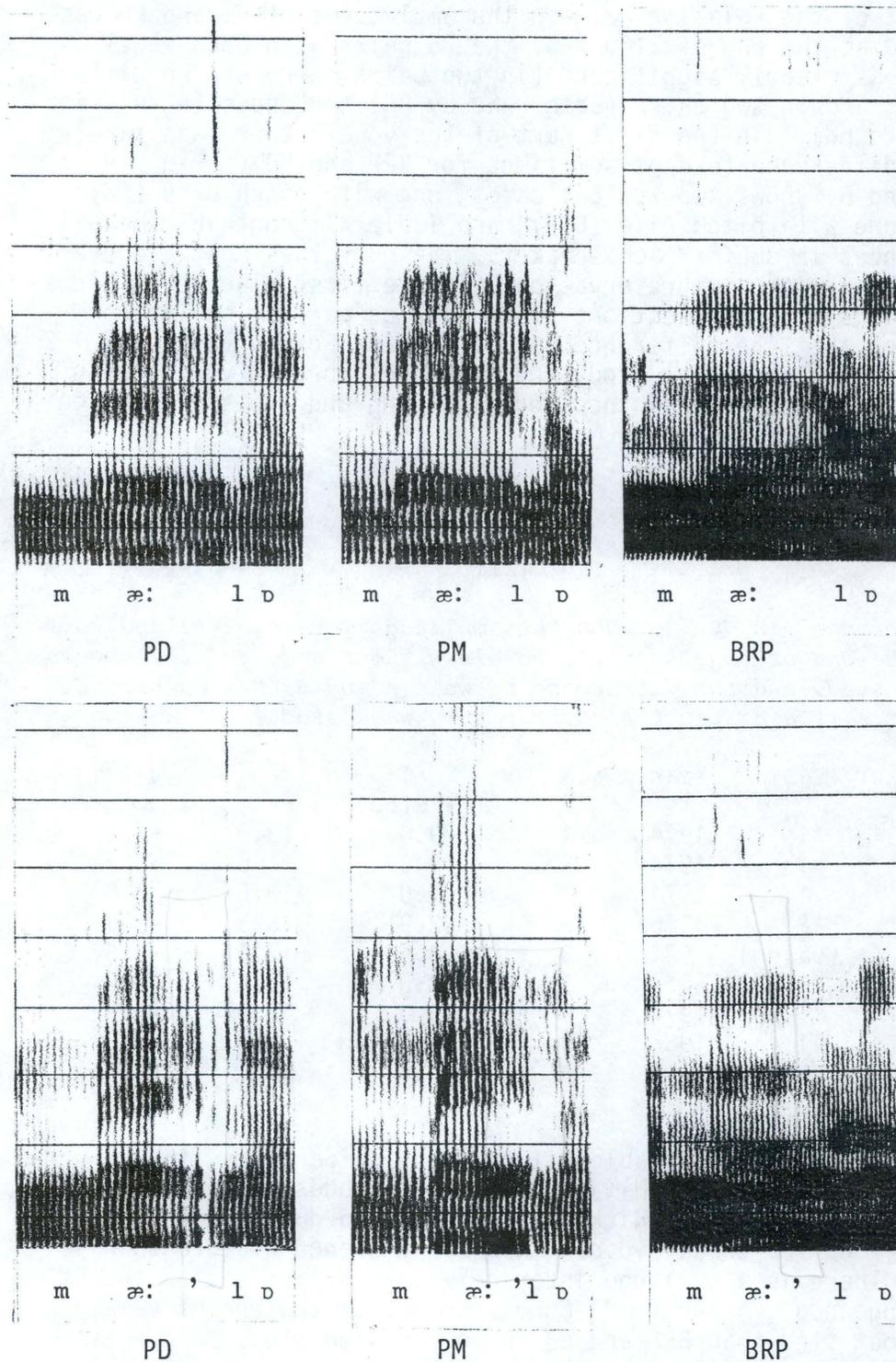
Figure 17

Spectrograms of [mæːlɒ] *and* [mæːˈlɒ] *with strong, weaker and very weak stød.*

In the present corpus higher intensity in F4 and F5 was visible
for some speakers (BF, BH, HU, JJ and ·JR) but rarely found for
other speakers (BM, BRP, FJ, ND, NR, OB).

A clear difference between words with and without stød in re-
spect of the relation between the amplitudes of F1 and Fo was
found at the end of 21 out of the 25 pairs with open vowels.
This is clearly significant (in two pairs there was no differ-
ence, and in two pairs (both read by BH) the opposite relation
was found). In the first part of the vowels there was rarely
any difference (except sometimes for BRP and FJ). Fig. 18
(A and B) shows two typical cases, one with pitch drop (FJ)
and one with pitch rise (BRP), and Table XII contains the dif-
ferences in dB for each speaker. The dB values must, however,
be taken with some reservation. In the first place control re-
cordings with the sections placed 1-2 cs earlier or later
showed that the difference between F1 and Fo may vary some 1-2
dB in vowels without stød, and sometimes more in vowels with
stød, particularly if the stød is strong and the spectrum con-
sequently irregular.

Table XII

*Difference (in dB) between the amplitude levels of F1 and Fo
at the end of vowels in (A) vowels without stød and (B) vowels
with stød, and the difference between A and B; N = number of
pairs. (FJa distinct stød, FJb very weak stød.)*

Speaker	List	Year	N	F1 - Fo A (- stød)	F1 - Fo B (+ stød)	diff.
BF	1	1974	4	9.8	13.0	-3.2
BH	1	1974	2	15.3	11.6	+3.7
BM	1	1974	2	7.0	13.5	-6.5
BRP	12	1986	6	2.9	6.3	-3.4
FJa	(valen)	1981	3	8.5	17.0	-8.5
FJb		"	3	8.0	10.2	-2.2
JR	1	1974	2	9.0	13.0	-4.0
OB	11	1986	3	2.2	6.0	-3.8

It is apparent from Table XII that the differences, though con-
sistent (except for BH), are relatively modest compared to the
differences found by Kirk et al., viz. 6.6 dB for modal voice
and 17 dB for creaky voice, thus a difference of more than 10
dB. There is also large interindividual variation, BF and BM
having, e.g., a larger F1-Fo difference at the end of vowels
without stød than BRP and OB in vowels with stød. There is
also overlapping between the two categories for each individual
speaker, in spite of the small number of pairs. Only BM (with
two pairs) does not show any overlapping. FJ shows a clear
difference according to the distinctness of the stød, very
weak stød showing a smaller F1-Fo difference than distinct stød.

Figure 18 a-b

Power spectra (45 Hz) taken at the end of the vowels. ⊢———⊣ 10 dB.
(a) [væ:lən] and [væ:'lən] (speaker FJ, distinct stød)
(b) [må:lɒ] and [må:'lɒ] (speaker BRP, normal stød).

No corresponding difference was visible for the other speakers
(in FJ's case the difference between distinct and weak stød
was made intentionally).

In spite of these overlappings, the F1-Fo measure functions
quite well for open vowels. But it cannot be used for close
vowels. This is obvious for female speakers, whose Fo partici-
pates in F1 in close vowels. But, at least for the Danish
stød, it cannot be used for male speakers either. It works
for BM, but not for BF, JR and OB. For JR and BM the measure
F2-Fo can be used (see Fig. 18C), and it also gives a clear
difference for BH's [ε: / ε:'], but it does not work for BF's
and OB's [i: / i:'], and it only works in half of the pairs
with open vowels. All speakers (except OB) have, however, a
clear decrease in amplitude in lower harmonics, including F1
and sometimes F2 at the end of vowels with stød, whereas in
most cases the higher harmonics (particularly around 3-5 KHz)
remain unchanged. OB has more decrease in Fo than in F1 but
also decrease in all higher harmonics. The difference between
stød and no stød is obviously not a question of formants but
of glottal spectrum, and of course Ladefoged and Kirk et al.
only meant the F1-Fo difference to be a practical criterion,
which, however, cannot be used in all cases.

bi:lə   bi:'lən
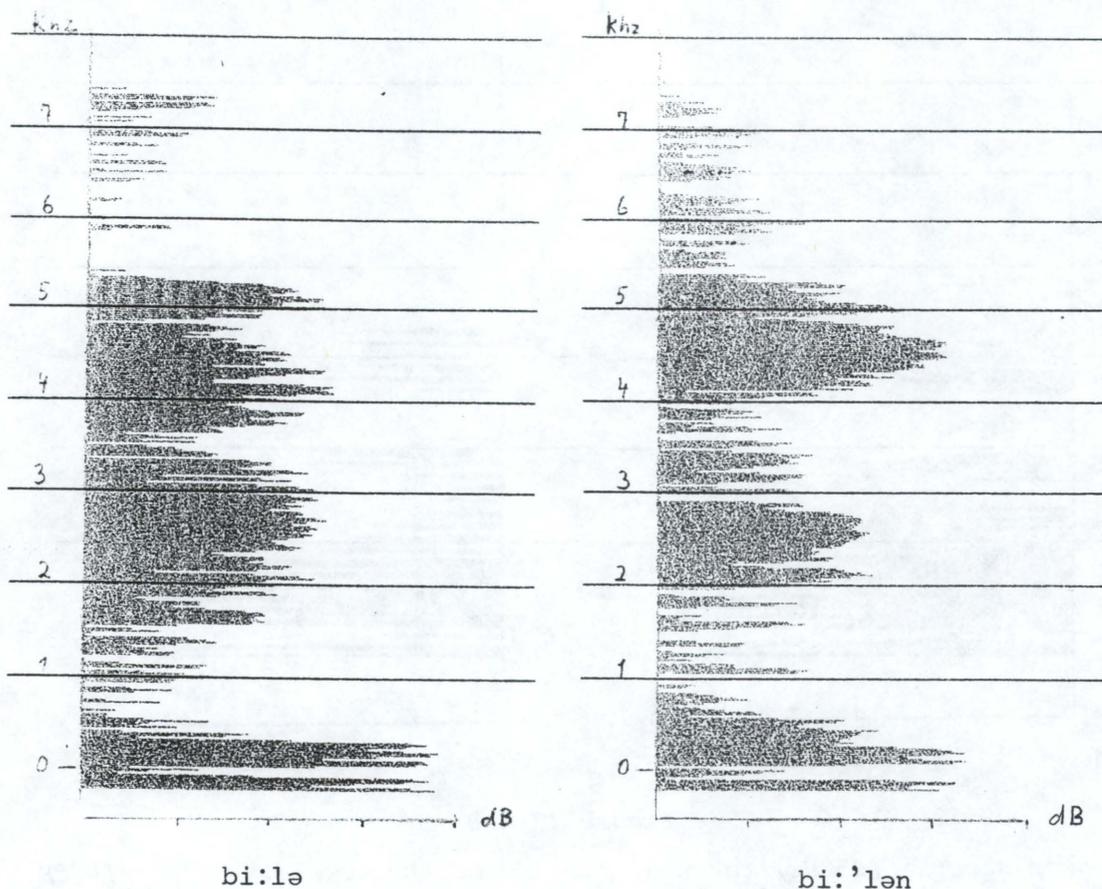
Figure 18 c
Power spectra (45 Hz) of [bi:lə] *and* [bi:'lən] *taken at the end*
of the vowels (speaker JR). ⊢————⊣*10 dB.*

6. INVERSE FILTERING

An inverse filtering analysis of a number of words with and
without stød was undertaken by Inger Karlsson, Stockholm (see
above, p. 90). By inverse filtering the formants are removed
(as far as possible), so that the curve should show the wave-
form at the glottis. The integral of the filtered oscillogram
is supposed to reflect the airflow at the glottis (for the
technique and its use, see, e.g., Fant (1983) and Javkin et al.
(1983).

In 1985 FJ read six examples of the words [væːlən] and [væːʹlən]
half of them with distinct stød, the other half with very weak
stød. Three words from this list were selected for inverse
filtering; one example of [væːlən] and two of [væːʹlən], one
with distinct stød and one with very weak stød (see Fig. 19a-c).
Moreover, some words were selected from a reading of list 12
(sentences) by BRP, viz. [væːlən / væːʹlən, mæːlᴅ / mæːʹlᴅ,
måːlᴅ / måːʹlᴅ] and [lɛːsᴅ / lɛːʹsᴅ], all from his fourth read-
ing. As mentioned above p. 79, BRP, who was one of Pia Riber
Petersen's subjects, had rising Fo, no irregularity and some-
times no decrease in intensity in stød words in the recording
she undertook in 1973, but nevertheless he had a clearly per-
ceptible stød. It would therefore be interesting to see whether
a difference between vowels with this type of stød and vowels
without stød would appear from inverse filtering. Unfortunate-
ly BRP spoke much more distinctly in the Stockholm recording
(1986, list 12). In the four pairs which were filtered first
he had both intensity decrease and irregularity, although the
irregularity was very weak in [måːʹlᴅ]. Therefore some further
words with stød were filtered. The word [måːʹlᴅ] from his first
reading was the one that came closest to the pronunciation used
in his 1973-recording. It has no irregularity and only a small
decrease of intensity at the end of the vowel. Fig. 20a-c
shows this word compared to [måːlᴅ] and to [måːʹlᴅ] from the
fourth reading with a somewhat stronger stød. The pairs
[væːlən / væːʹlən], [mæːlᴅ / mæːʹlᴅ] and [lɛːsᴅ / lɛːʹsᴅ] from
the fourth reading are presented in Appendix V.

For reasons of space Figs. 19 and 20 are arranged differently
which may be confusing; but in all cases the numbers 1, 2 and
3 are used to indicate (1) words without stød, (2) words with
normal stød, and (3) words with weak stød, and the letters
A, B and C indicate (A) normal oscillogram, (B) inverse filter-
ed oscillogram, and (C) integral of the inverse filtering.
The sampling frequency was 16 KHz for FJ and 10 KHz for BRP.

In all words with distinct stød both spectrograms and normal
oscillograms as well as inverse filtered curves show the ex-
pected decrease of intensity in the stød phase and sometimes
irregular vibrations, as well as a shorter duration of vowels
with stød, and - for FJ - decrease of Fo. - But the filtered
curves show further differences. The most conspicuous feature
of the oscillogram with inverse filtering is the decrease in
amplitude of the negative spikes in the latter half of the
vowel with stød. This is seen clearly in all examples, although
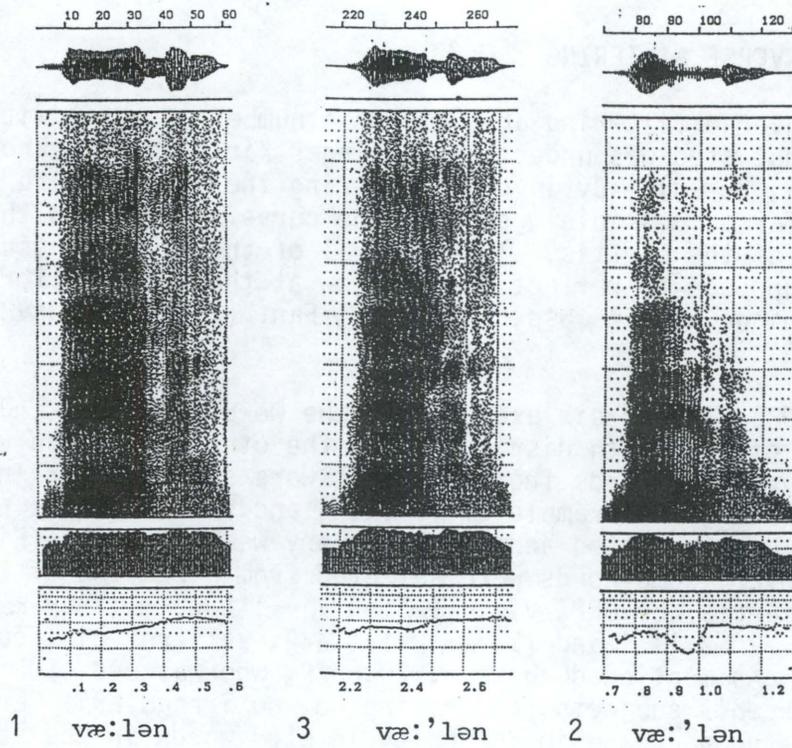
Figure 19 a
Spectrograms of 1 [væ:lən], 2 [væ:'lən] with distinct
stød and 3[væ:'lən] with weak stød, read by FJ.
From above: oscillogram, spectrogram, intensity, Fo.
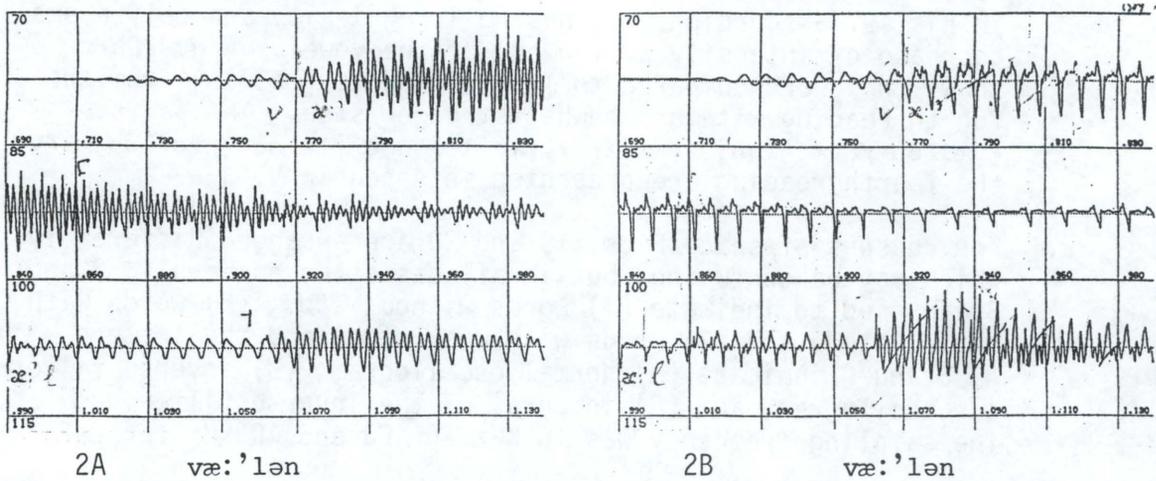
Figure 19 b

2A: Normal oscillogram, 2B: inverse filtering of 2 [væ:'lən] with
distinct stød, read by FJ.

1A væ:lən

3A væ:'lən

1B væ:lən

3B væ:'lən

1C væ:lən
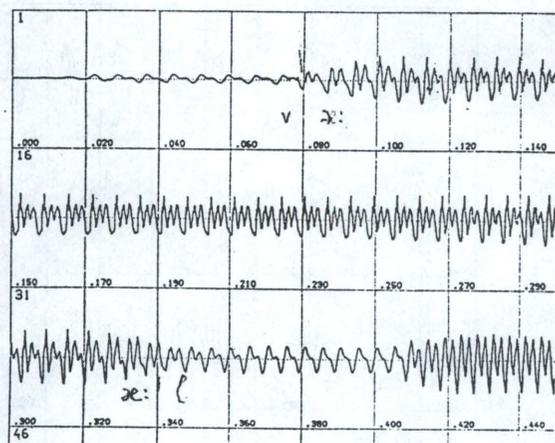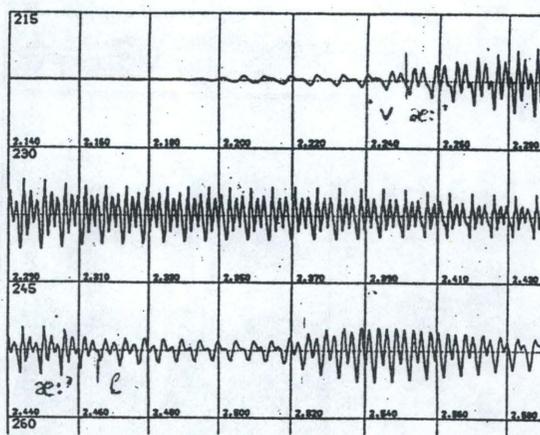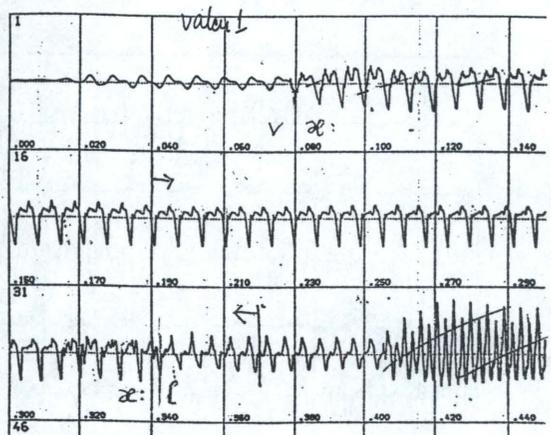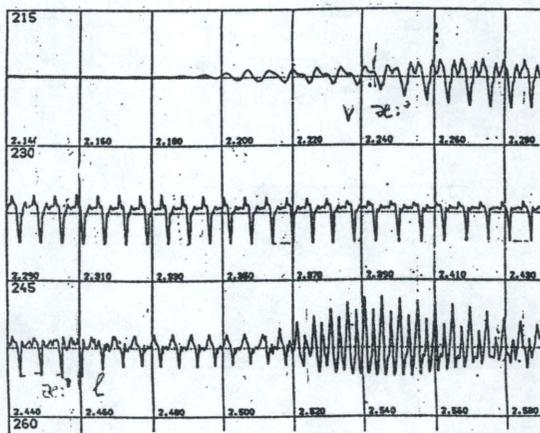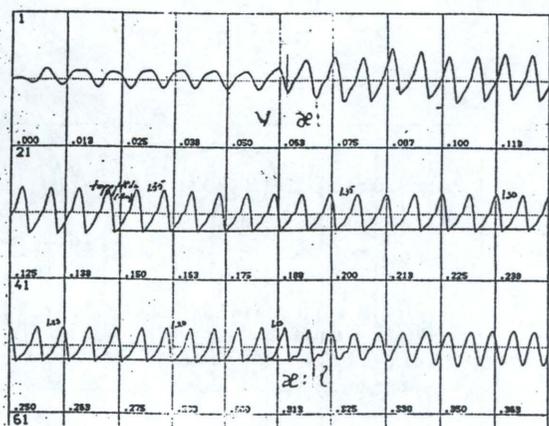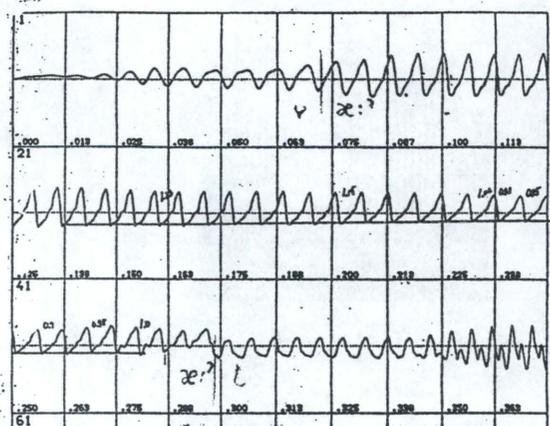
3C væ:'lən

Figure 19 c

A: *Normal oscillogram, B: inverse filtering, C: integral of inverse filtering
of 1* [væ:lən] *and 3* [væ:'lən] *with weak stød, read by FJ.*
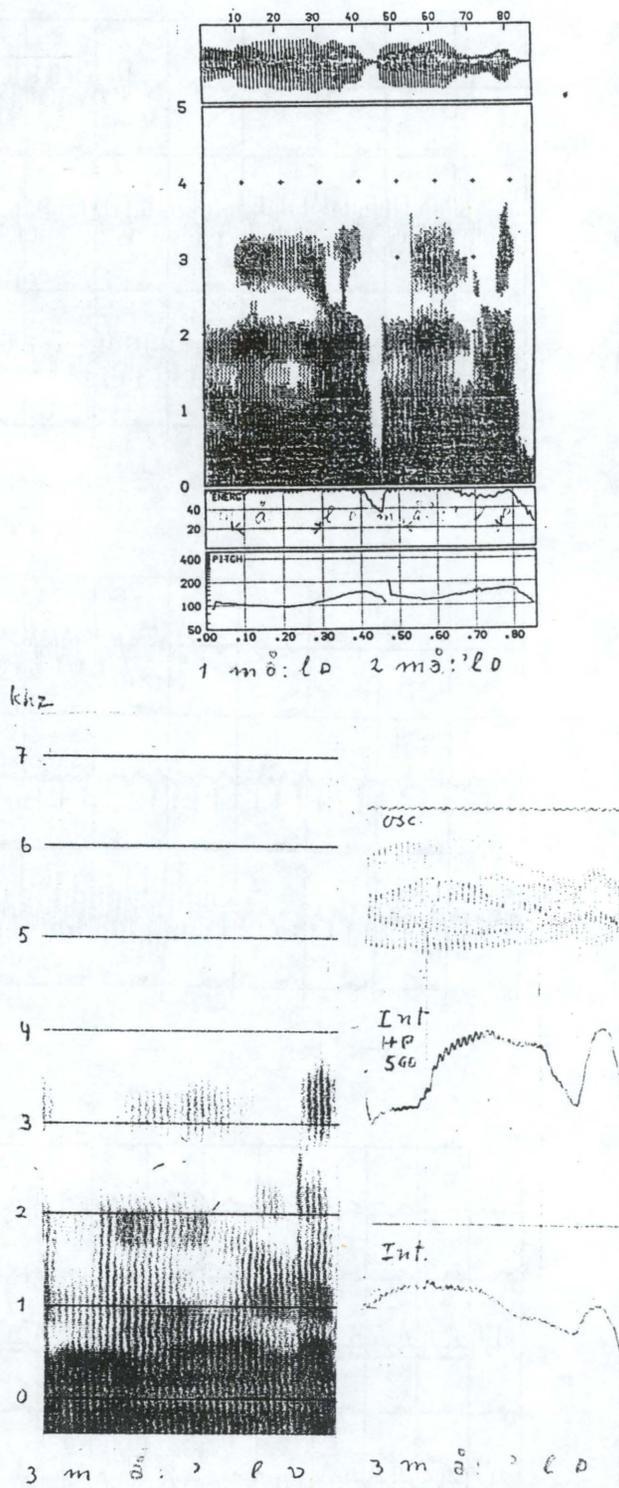
Figure 20 a

Spectrograms of 1 [må:lᴅ], 2 [må:'lᴅ] with
normal stød, and 3 [må:'lᴅ] with weak stød,
and mingogram of [må:'lᴅ]3, read by BRP.

1A   må:1ᴅ

2A   må:'1ᴅ

3A   må:'1ᴅ
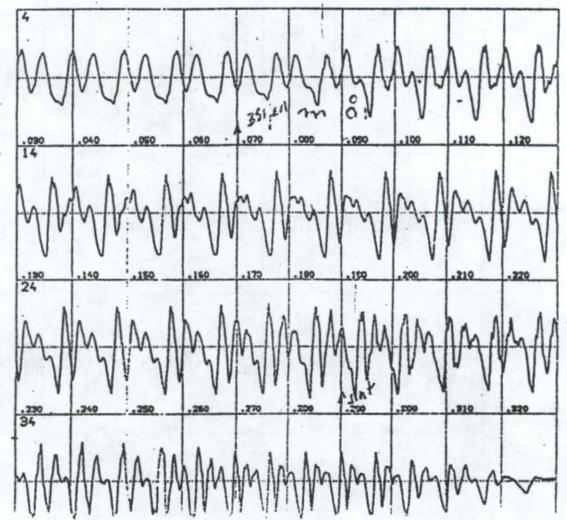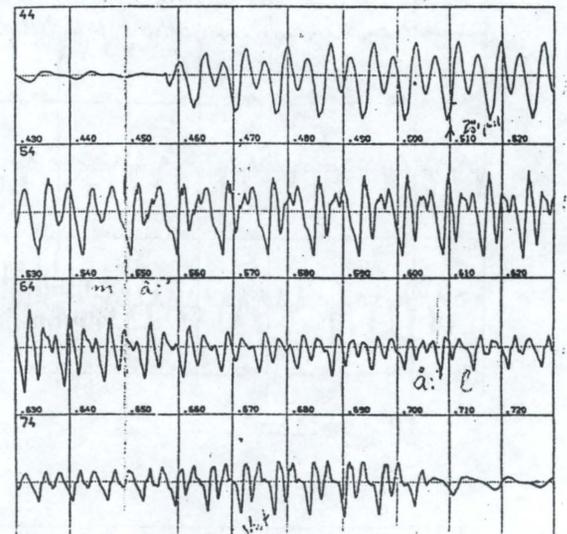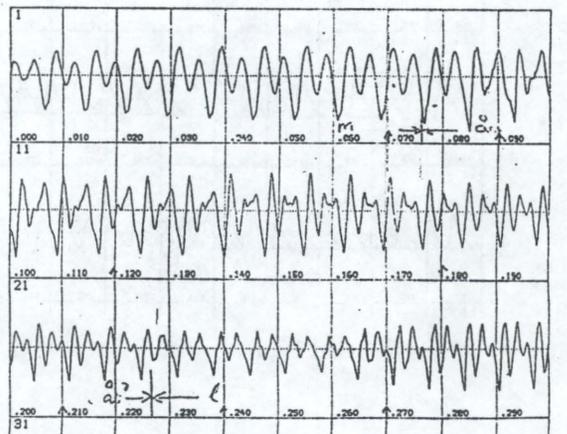
Figure 20 b

Normal oscillogram of 1A [må:1ᴅ],
2A [må:'1ᴅ] and 3A [må:'1ᴅ].
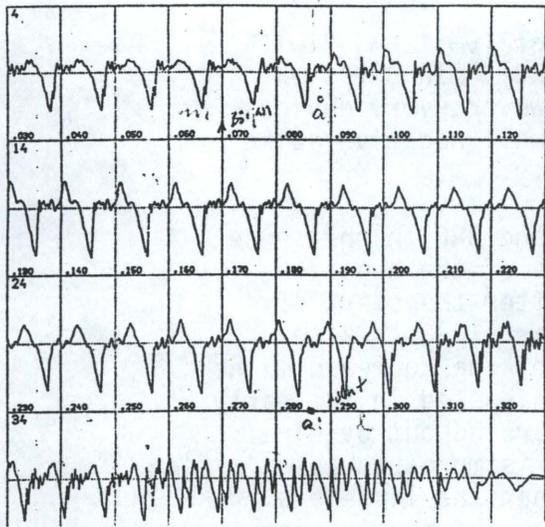
1B   må:lᴅ
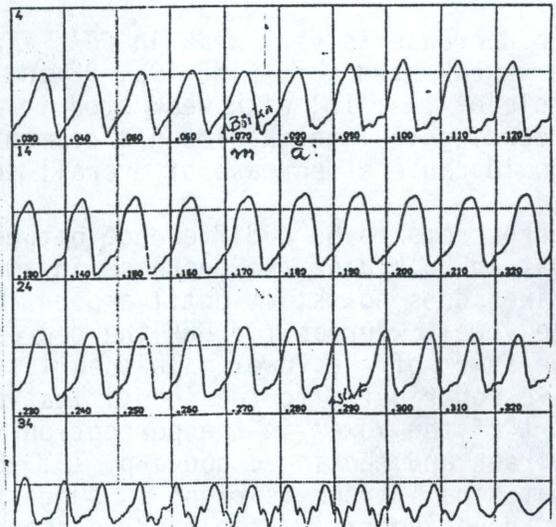
1C   må:lᴅ
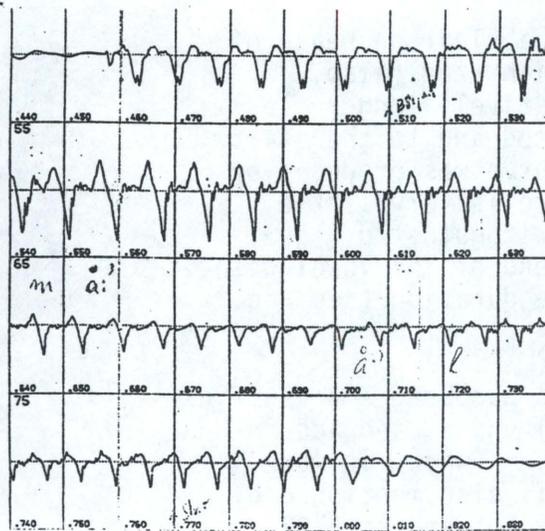
2B   må:'lᴅ
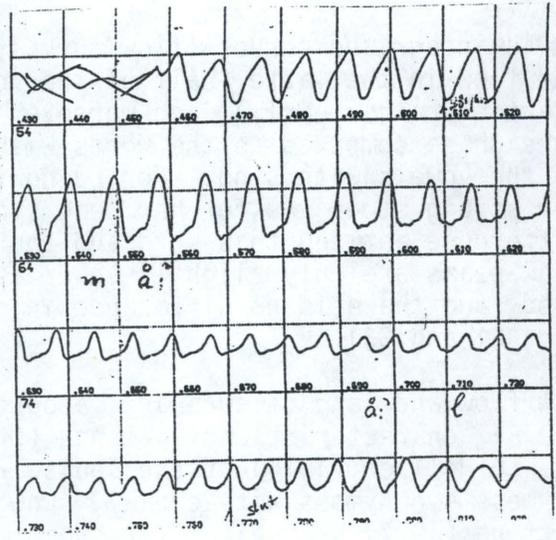
2C   må:'lᴅ
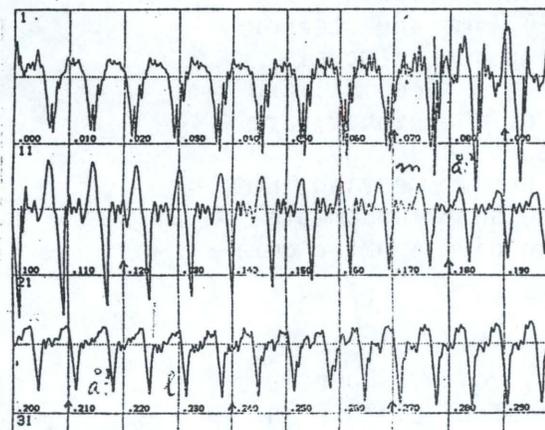
3B   må:'lᴅ
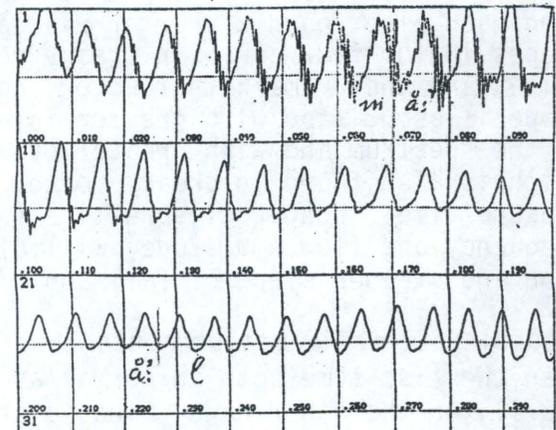
3C   må:'lᴅ

Figure 20 c

Inverse filtering (B) and integral of inverse filtering (C) of 1 [må:lᴅ],
2 [må:'lᴅ] (normal stød) and 3 [må:'lᴅ] (weak stød), read by BRP.

the decrease is very weak in FJ's example of [væ:'lən] 3 with
very weak stød (cf. Fig. 19b, B2 and 19c, B3). In BRP's ex-
ample of [må:'lɒ] with weak stød it is, however, very obvious.
According to Inger Karlsson's comments a small negative spike
should cause a decrease of overall intensity.

There seems to be a difference between FJ and BRP in the sense
that in FJ's case the decrease in amplitude of the negative
spikes does not start until around 10 cs after the start of
the vowel, whereas for BRP the decrease starts 2-3 cs after
the start of the vowel. This early start of the decrease might
have contributed to the identification of his stød in the early
part of the vowel in the perception test carried out by Nina
Thorsen and mentioned above p. 79. But it is more probable
that Nina Thorsen is right in suggesting that the listeners
may have identified the stød on the basis of the high rising
Fo, since they had heard a word pair before the start of the
test.

BRP's integrated curves (flow curves) show a clear decrease of
the flow in the latter half of the vowel with stød (also
starting rather early), and moreover a relatively longer clo-
sure phase compared to the words without stød and to the start
of the vowels with stød. For FJ no flow curve was produced of
her strong stød. As for her weak stød there is very little
difference between this word and the word without stød (the
flow peaks are only slightly lower at the end of the vowel with
stød, and there is no difference in closure duration (see Fig.
19c, C1 and C3).

Low flow and long closure are, according to Sundberg and Gauffin
(1978), characteristic of a tense (pressed) voice, and accord-
ing to Hollien (1974) of the "pulse register" (which is more
or less synonymous with creak). Low flow is also mentioned by
Catford (1977) as typical for creak, and by Rothenberg (1972)
as signalling "tight voice"; and both Javkin and Maddieson
(1983) and Zemlin (1981) mention a long closure period as char-
acteristic of creaky voice. In a study of Burmese Javkin and
Maddieson also found a shorter rise and fall time and steeper
slopes in the flow curve in creaky voice compared to modal
voice, and they remark that according to Fant a steep falling
slope is associated with greater intensity of the higher part
of the spectrum and with greater overall acoustic energy,
which is also found in creaky voice. They do not mention the
closure time. Longer closure time (with the same fundamental
frequency and flow amplitude) will of course give shorter dura-
tion and steeper slope of fall and rise.

According to their measurements the fall time is shorter
than the rise time both in normal and creaky voice. Fourcin
(1974), on the other hand, finds a sharp onset of closure and
a slow opening as characteristic of creaky voice. He bases
this observation on laryngographic recordings. Roach and
Hardcastle (1979) and Esling (1984) have also investigated
various phonation types (as pronounced by the authors) by means
of the laryngograph. They find that the rising part of the

laryngogram (interpreted as approximately indicating the closing
movement of the vocal folds) is relatively short in creaky voice
and that it gets longer with decreasing stricture of the glottis
in different phonation types.

As mentioned by Javkin and Maddieson, a comparison between nor-
mal and creaky voice presupposes similar fundamental frequency
and amplitude of the glottal flow. - In [væ:'lən] read with
weak stød by FJ amplitude and fundamental frequency are almost
the same as in [væ:lən], and the peaks slightly lower at the
end, which should give less steep slopes, but only the rising
slope (which in these curves represents the opening movement)
is somewhat less steep. In the examples read by BRP a compari-
son between words with and without stød is difficult because
vowels with stød have longer closure, higher pitch and a smaller
amplitude. Combined this seems to give shorter and lower but
less steep slopes in words with stød. In 6 out of 8 examples
there is a tendency for the closing movement to have a steeper
slope than the opening movement, a tendency which is less pro-
nounced at the start of the vowel and in vowels without stød.
But since the pulses are of much lower amplitude in the stød
vowels, this does not give increased intensity.

B. PHYSIOLOGICAL ANALYSIS

1. LARYNX POSITION AND MOVEMENT

Position and movement of the larynx in vowels with stød compared
to vowels without stød was investigated by means of a videofilm
(see p. 88 above) for five speakers (ND, PD, NR, OB, PM) reading
list 9 containing four different word pairs in the frame *"Jeg
kan let sige ... fem gange"* 'I can easily say ... five times',
each word occurring ten times. Two of the ten repetitions were
subjected to a more thorough analysis, consisting in a frame by
frame tracing from the videoscreen on transparent paper. Words
with and without stød from the same reading, or at least two
consecutive readings, were compared in detail.

It was not possible to detect any consistent pattern apart from
the fact that the larynx tends to move more in vowels with stød
than in vowels without stød, this being the case in about half
of the 40 pairs with only 1-2 countercases. But in many pairs
the movement was of the same extent in words with and without
stød, or there was practically no movement. There were both
individual differences and differences between vowel types.
PD had more movement in the vowel with stød in six out of eight
pairs, OB and PM only in two out of eight pairs, and there was
a difference between [u:] and [u:'] in eight out of ten pairs,
whereas for [i: / i:'] a difference was only found in two out
of ten pairs. On the whole, [i:] and [i:'] showed very little
movement.

In about one third of the pairs the starting position was prac-
tically the same for vowels with and without stød, but in most
pairs there was a certain difference. The larynx had a lower

and more fronted position in [uː'] than in [uː] for PD and ND;
otherwise there were no clear tendencies, and as for the move-
ments, they differed in a non-consistent way; thus PD showed a
forward and downward movement of the larynx in [uː'], whereas
for ND the direction of the movement was backward and upward.

On the basis of this preliminary analysis it was concluded that
it would not be worth while to undertake a quantitative in-
vestigation on a larger scale.

The generally observed tendency for [u] to have a lower position
of the larynx than [i] and [a] was confirmed for all five
speakers.

2. FIBEROPTIC ANALYSIS OF THE VOCAL FOLDS

A fiberoptic analysis of the vocal folds by means of a video-
tape-recording (50 frames per sec., see p. 89 above) was under-
taken for seven speakers (BF, BM, BH, FJ, HU, JR and ND) read-
ing list 13 which contained four word pairs (one of them oc-
curring twice), all with the vowel [i], which is best suited
for fiberoptic research. BF also read some examples of the
sentence [si 'ʔiːlə] with hard attack.

The recording of FJ was not quite successful since only part
of her vocal folds were visible, but this recording could be
supplemented with an analysis of a fiberscope film made in
the Research Institute of Logopedics and Phoniatrics in Tokyo
in 1976. This film contained four words with stød: [pʰiː'l,
biː'l, fiː'l, viː'l] repeated four times, and a number of
words in [-iːlə]. In this recording the vocal folds were
visible in their full length.

The video-recordings were played back several times, and a
number of the readings were inspected frame by frame. 109
frames were selected as typical for the speakers (8-24 for
each speaker) and photographed from the screen. The film
from Tokyo was inspected frame by frame by means of a motion
film viewer, and 12 frames were traced manually on transparent
paper. It was not possible to make usable copies.

Most of the selected frames show the vocal folds a few cs
after the start and before the end of the vowel, the exact
point being chosen on the basis of a comparison with mingo-
graphic recordings comprising a duplex oscillogram and intensity
and Fo-curves, so that the picture illustrating the last part
of the vowels with stød corresponded, as far as possible, to
the moment of minimum Fo and intensity. Moreover, four series
of successive frames of words with stød (read by BF, BH, HU
and JR) were photographed, the individual frames being corre-
lated with the mingograms.

A number of photographs are reproduced in Figs. 21-32. Since
the speed of the film was 50 frames per second and the shutter
was closed half of the time, the pictures represent an average
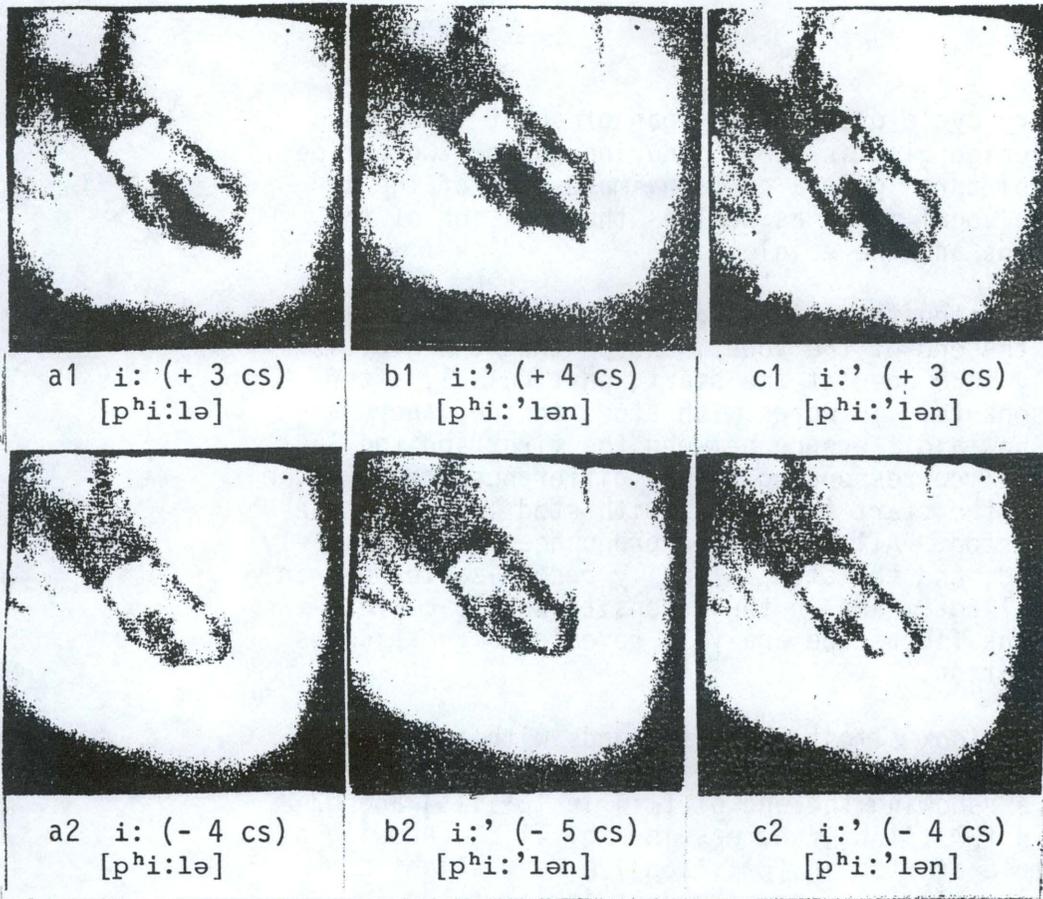
Figure 21
Frames from a fiberoptic film of the vocal folds. (1) first part of vowel, (2) second part of vowel. + = distance from vowel onset, - = distance from vowel end. Speaker FJ.
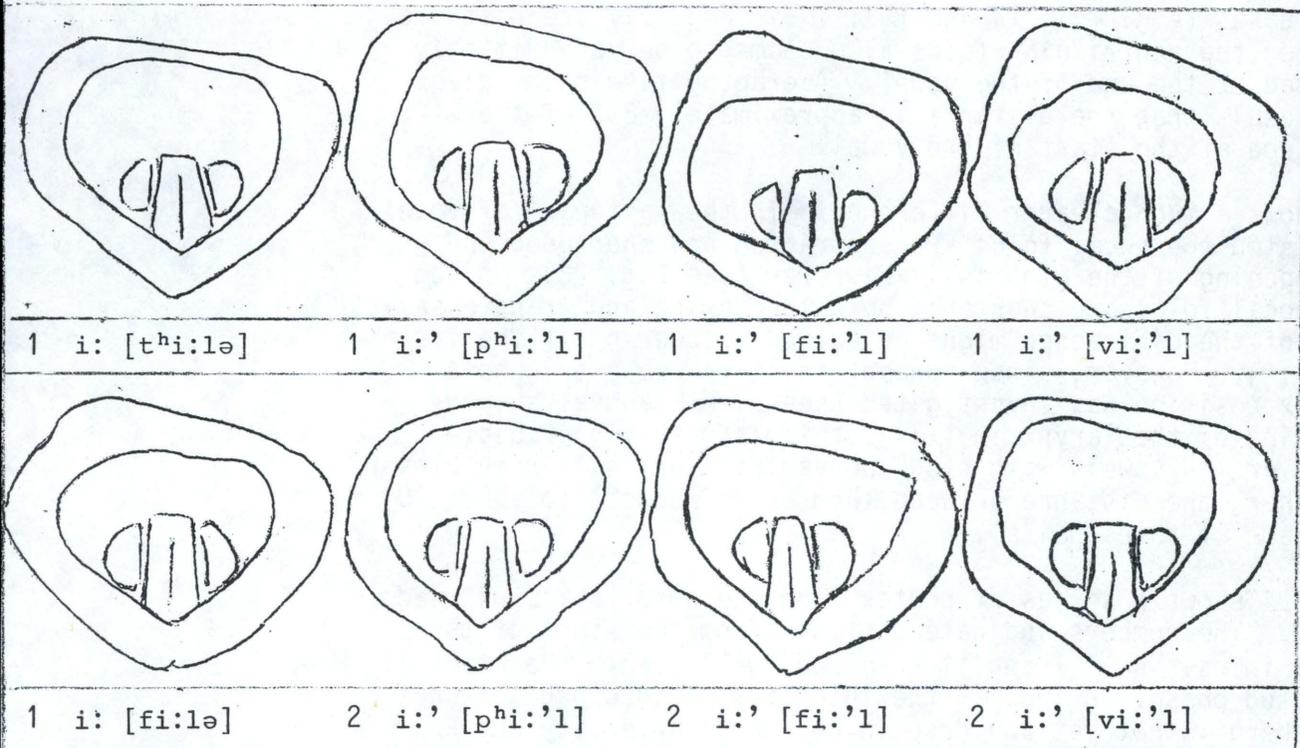
Figure 22
Frames from a fiberoptic film of the vocal folds (Tokyo), traced manually from a viewer. 1 first part of vowel, 2 second part of vowel. Speaker FJ.

of the vibratory cycle over a time span of about 1 cs, thus
showing the average glottis opening during one or two periods.
Moreover, the pictures give a certain impression of the con-
traction of the vocal folds as well as the position of the
ventricular folds and the epiglottis.

In words without stød there is hardly any difference between
the start and the end of the vowel, except that the glottis
may be slightly more open at the start, particularly after
voiceless consonants. In words with stød, on the other hand,
all subjects show a difference between the first and the last
part of the vowel corresponding to the differences seen in the
mingograms. At the start the vowels with stød look like the
vowels without stød. All words were pronounced with a clearly
perceptible stød, and the stød is easily recognizable both in
the duplex oscillogram and in the intensity and Fo-curves.
Nevertheless, the fiberscope analysis revealed a conspicuous
individual variation.

FJ's vocal folds look almost alike in words with and without
stød. It is, e.g., hardly possible to see any difference be-
tween Fig. 21 a2 showing the end of [i:] in [pʰi:lə] and b2
showing stød in [pʰi:'lən], whereas in Fig. 21 c2 (showing a
different example of stød in [pʰi:'lən]) a very slight con-
traction of the vocal folds and the ventricular folds is
visible. As for the recordings made in Tokyo, the vocal folds
are close together in all vowels with only a narrow slit in
the middle, but there is a consistent, though very small dif-
ference, the vocal folds showing a slight contraction looking
as medial compression in words with stød (see Fig. 22). In
some cases (e.g. [ɪi:'l] and [vi:'l] in Fig. 22) the distance
between the ventricular folds also seems to be very slightly
reduced at the end of the vowel. Averaging five pairs gives
the result that the distance is approximately 85% of the
distance at the start of the vowel.

HU shows a much clearer difference. In the last part of vowels
with stød the vocal folds are contracted and shortened and
the opening of the glottis is narrower (see Fig. 23). Since
the vocal folds are shortened both lengthwise and transversally,
some of the difference might be due to a lowering of the larynx
in [i:']. However, since none of the five subjects, whose
larynx position was investigated (see p. 131 above) showed
lowering of the larynx in [i:'], this is not very probable.
Moreover, in vowels with stød the ventricular folds come closer
together, the distance between them being reduced to about 70%
(average of three pairs).

Fig. 24 shows a series of photos from the word [bi:'lən] read
by HU. The numbers indicate distance from the start of the
vowel in cs. No.s 7 and 11 are taken well before the start of
the stød phase. At No. 15 the intensity has dropped somewhat,
but there is not yet any drop in Fo. Both intensity and Fo
decrease rapidly from No. 15 to 21. At 21 both have reached
their minimum value, and the vocal folds have reached their
maximum contraction. There is very little change in Fo and

a1   i: (+ 5 cs)   b1   i:' (+ 6 cs)   c1   i:' (+ 3 cs)
     [bi:lə]   [pʰi:'lən]   [mi:'lən]

a2   i: (- 4 cs)   b2   i:' (- 4 cs)   c2   i:' (- 2 cs)
     [bi:lə]   [pʰi:'lən]   [mi:'lən]
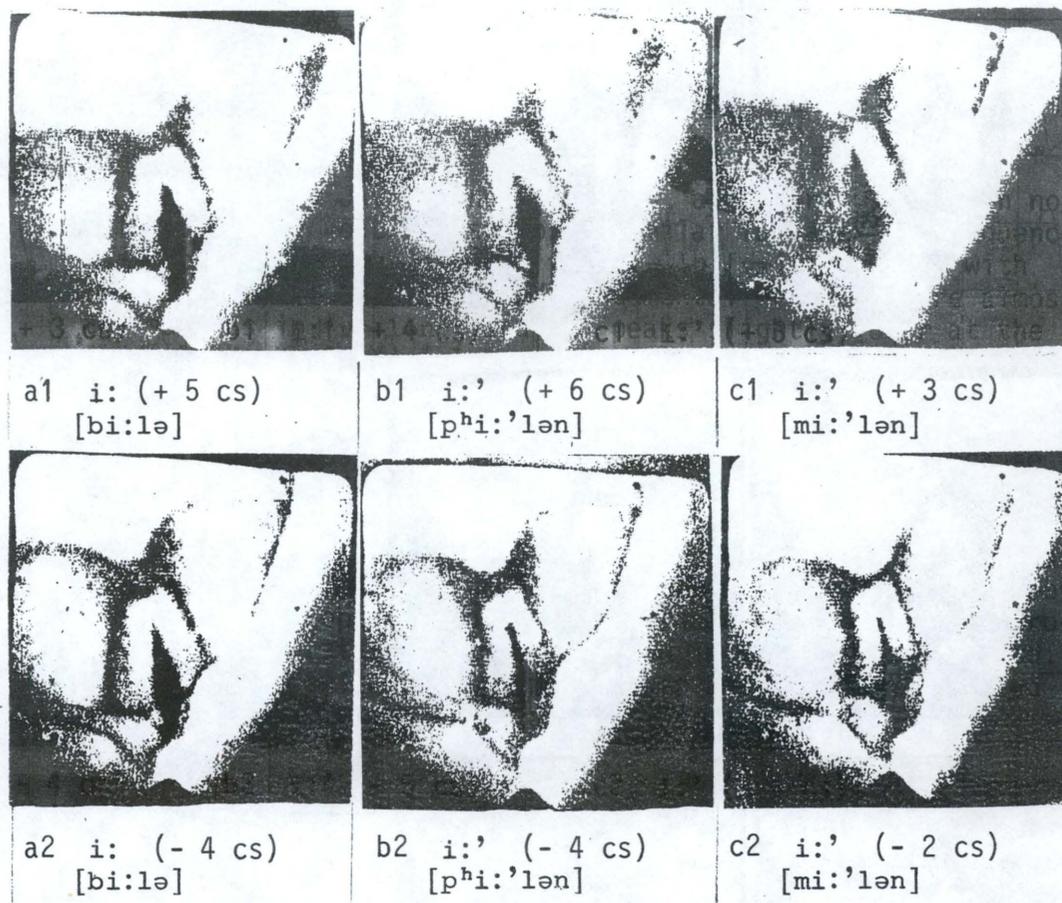
Figure 23

Frames from a fiberoptic film of the vocal folds. 1. first part of
vowel, 2. second part of vowel. + = distance from vowel onset,
- = distance from vowel end. Speaker HU.

intensity from 21 to 25, and the vocal folds keep their con-
traction. Immediately after No. 25, Fo and intensity start
rising. At 29 (in [l]), they have reached the maximum again,
and there is a clear relaxation of the vocal folds.

ND (Fig. 25) also has an adduction of the ventricular folds at
the end of vowels with stød, their distance being reduced to
approximately 70% (average of three pairs). (This is not seen
very clearly in the copies in Fig. 25; the measurements were
made in the original photos.) At the end of vowels with stød
his right vocal fold is almost covered by the ventricular fold,
so that it is difficult to see the glottis, but pictures taken
just at the start of the stød (Fig. 25c-1a) and at the end
where the glottis appears again (Fig. 25c-2a) show a very nar-
row glottis. Vowels with stød also have a slight depression
of the epiglottis.

I   duplex oscillogram
II   Intensity
III Fo
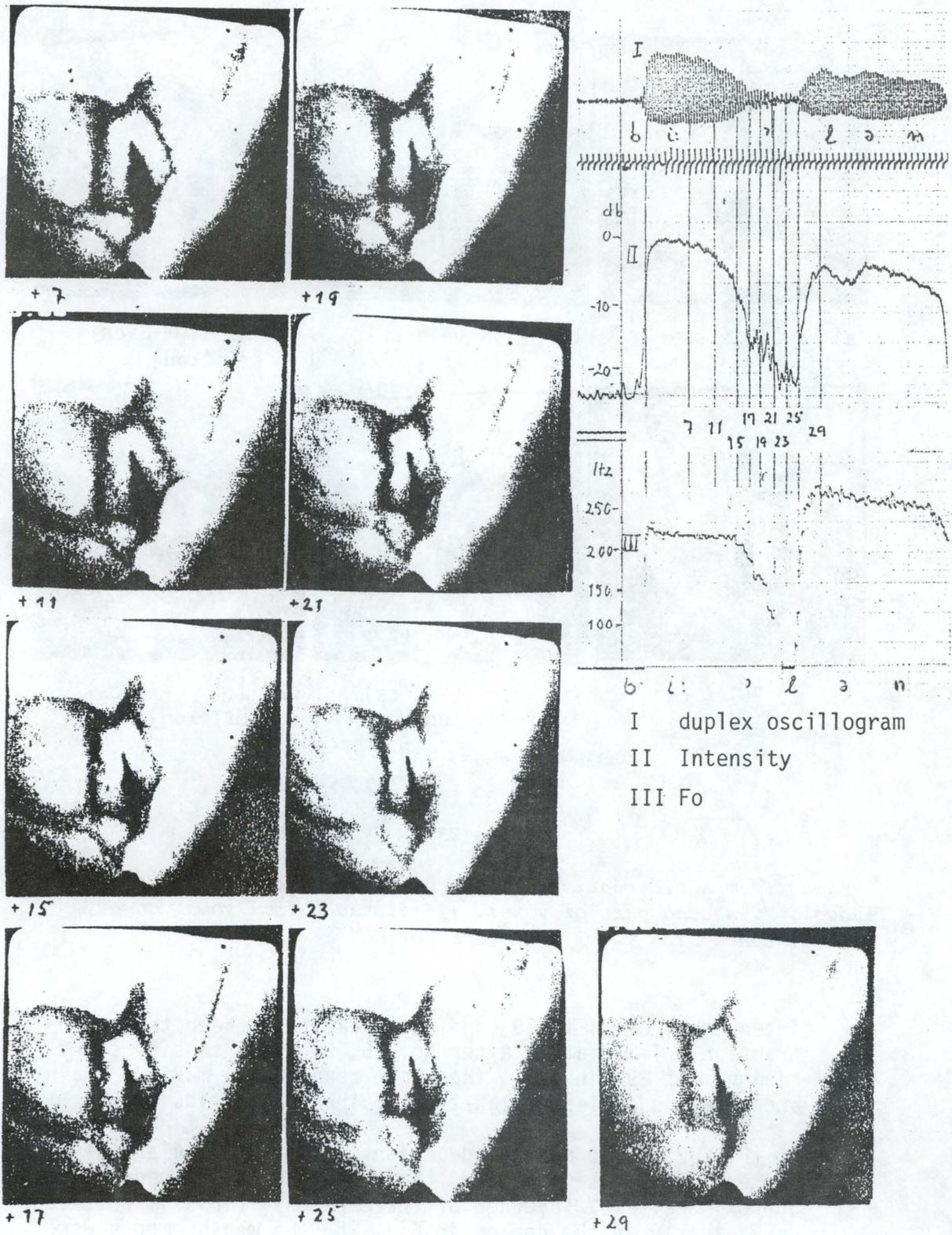
Figure 24

*Frames from a fiberoptic film of the vocal folds. Successive frames showing
the vowel [i:'] in [bi:'lən], compared to a mingographic recording. The
numbers indicate distance in cs from vowel onset (the last picture is from
the following [l]). Speaker HU.*

a1 i: (+ 3 cs)
    [mi:lə]

b1 i:' (+ 1 cs)
    [mi:'lən]

c1 i:' (+ 3 cs)
    [mi:'lən]

a2 i: (– 6 cs)
    [mi:lə]

b2 i:' (– 7 cs)
    [mi:'lən]

c2 i:' (– 6 cs)
    [mi:'lən]

c 1a i:' (+13 –15 cs)
      [mi:'lən]

c 2a i:'l(end + 1 cs)
      [mi:'lən]
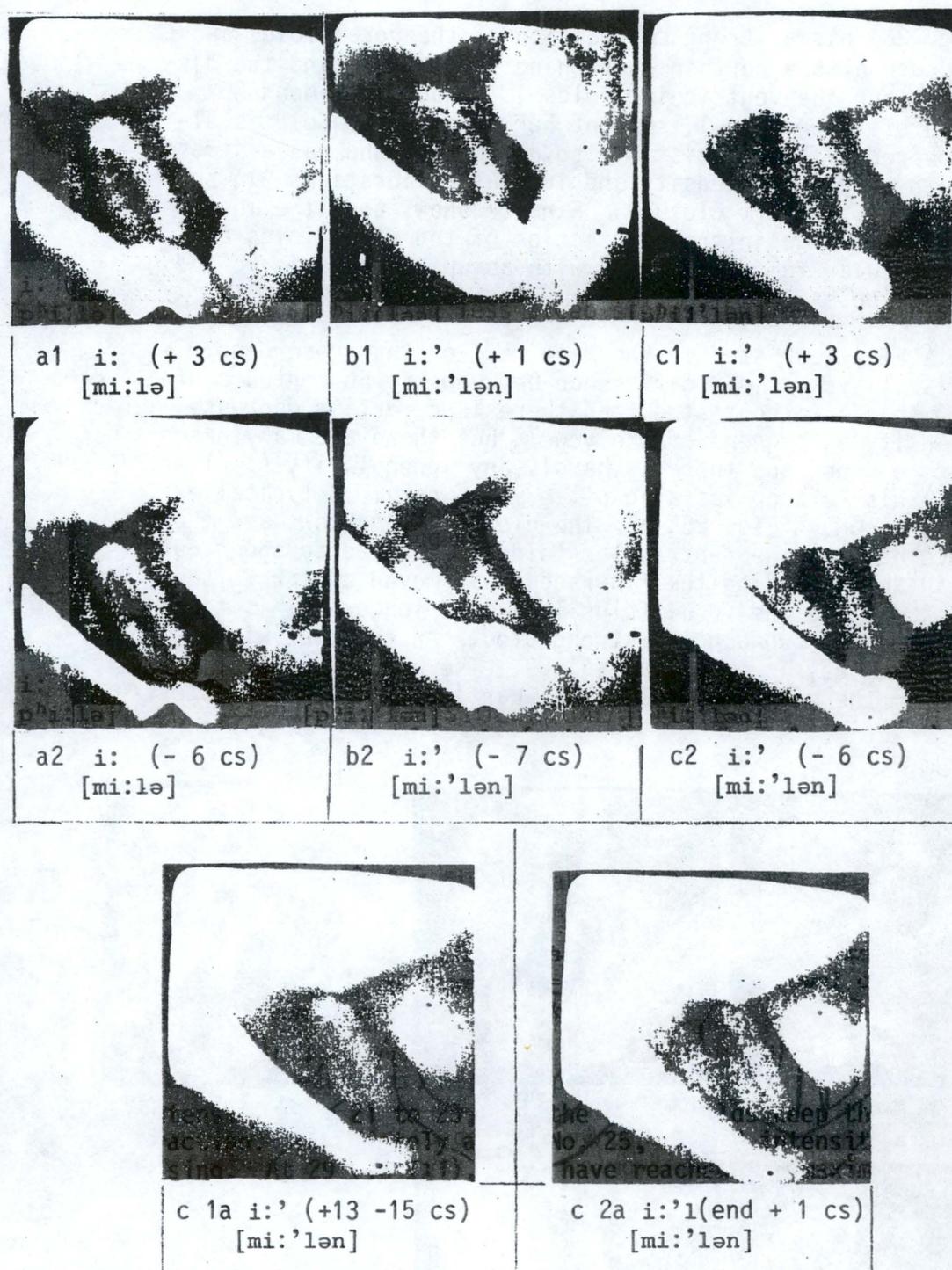
Figure 25

Frames from a fiberoptic film of the vocal folds. 1. first part of vowel, 2. second part of vowel. c 1a start of the stød in [mi:'lən], c 2a start of [l]. + = distance from vowel onset, – = distance from vowel end. Speaker ND.

BH (Fig. 26) has a strong contraction of the vocal folds and
in one case also a certain shortening lengthwise, and the dis-
tance between the ventricular folds is reduced to about 55%
(average of three cases), so that her right vocal fold is al-
most covered. The glottis is also narrowed. She has a strong
stød with very low intensity and irregular vibrations, in some
cases perhaps a short closure. Fig. 27 shows that the most
conspicuous change in the contraction of the vocal folds and
the ventricular folds coincides with abrupt changes in Fo and
intensity (No.s 31-35 of Fig. 27).

BF has a very weak stød in the main part of this recording.
There is always a clear difference between the Fo contours of
words with and without stød, and there is a certain decrease
of intensity at the end of the vowel, but there are many cases
without Fo drop, and there is hardly any irregularity (in list
1 (1974) his Fo drop was also often very weak). A typical ex-
ample is shown in Fig. 28, b2. The glottis is narrow, and the
distance between the ventricular folds is reduced to about 60%.
Later in the recording the fiberscope was moved closer to the
glottis, so that the vocal folds look much longer. This time
he was asked to pronounce a strong stød. An example (with a
closure of 5 cs) is given in Fig. 29. The glottis gets nar-
rower from the middle of the vowel, particularly in the poste-

a1 i: (+ 11 cs)   b1 i:' (+ 5 cs)   c1 i:' (+ 2 cs)
    [bi lə]   [bi 'lən]   [bi 'lən]

a2 i: (- 6 cs)   b2 i:' (- 7 cs)   c2 i:' (- 0 cs)
    [bi:lə]   [bi:'lən]   [bi:'lən]
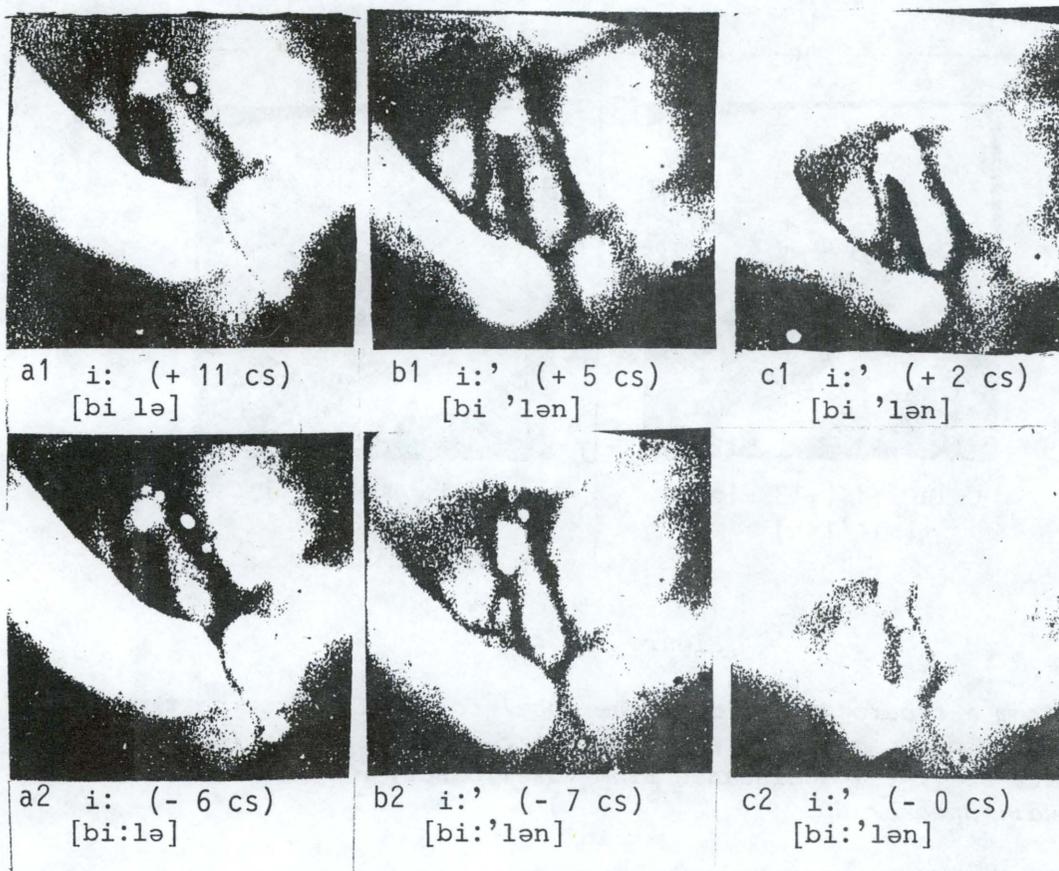
Figure 26

*Frames from a fiberoptic film of the vocal folds. 1. first part of
vowel, 2. second part of vowel. + = distance from vowel onset,
- = distance from vowel end. Speaker BH.*
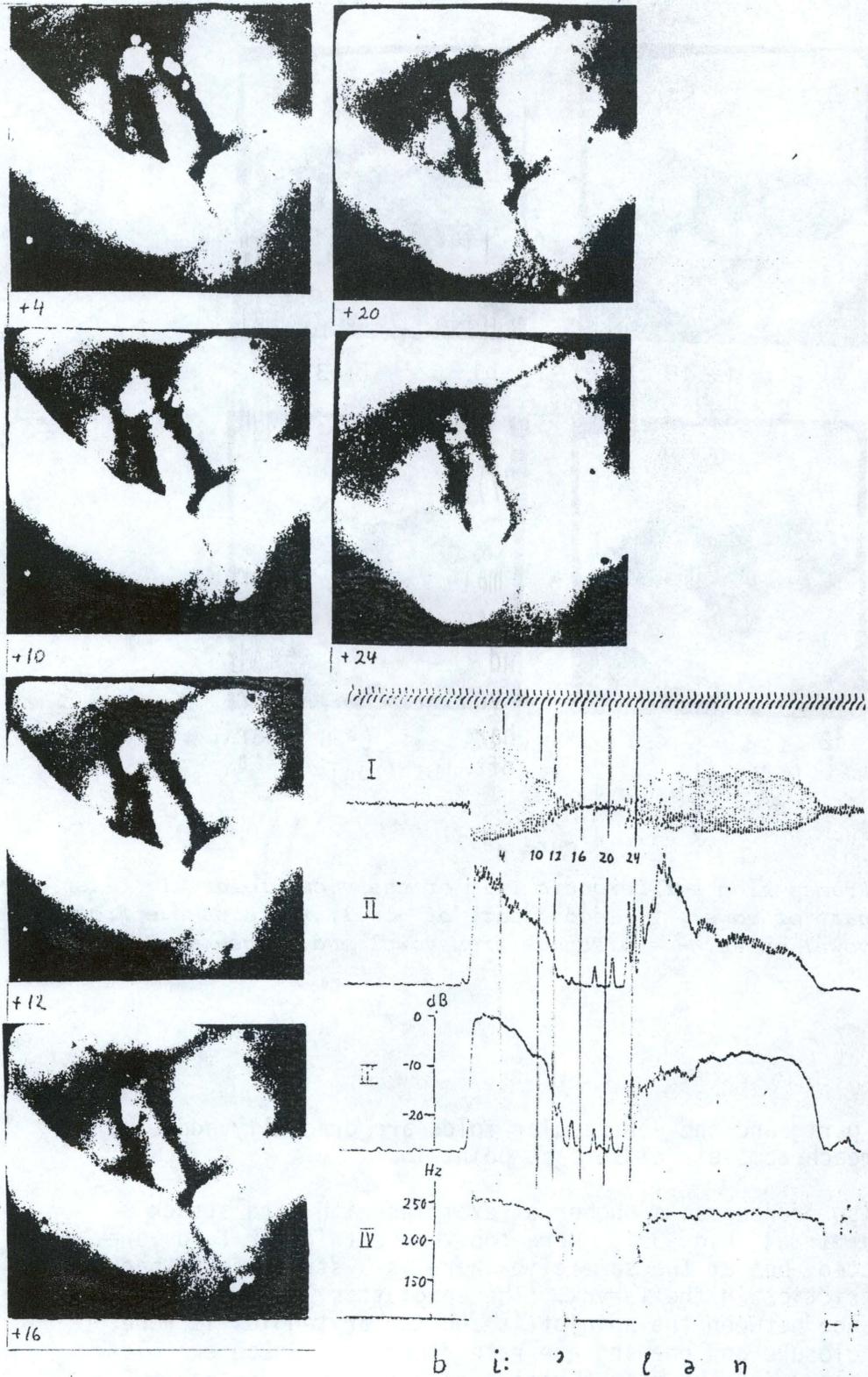
I   Duplex oscillogram; II Intensity HP 500
III Intensity; IV Fo.

Figure 27

Frames from a fiberoptic film of the vocal folds. Successive
frames showing the [i:'] in [bi:'lən], compared to a mingo-
graphic recording. The numbers indicate distance in cs from
vowel onset. Speaker BH.

a1   i: (+ 16 cs)   b1   i:'   (+ 3 cs)
     [pʰi:lə]   [bi̠:'lən]

a2   i: (- 7 cs)   b2   i:'   (- 8 cs)
     [pʰi:lə]   [bi:'lən]
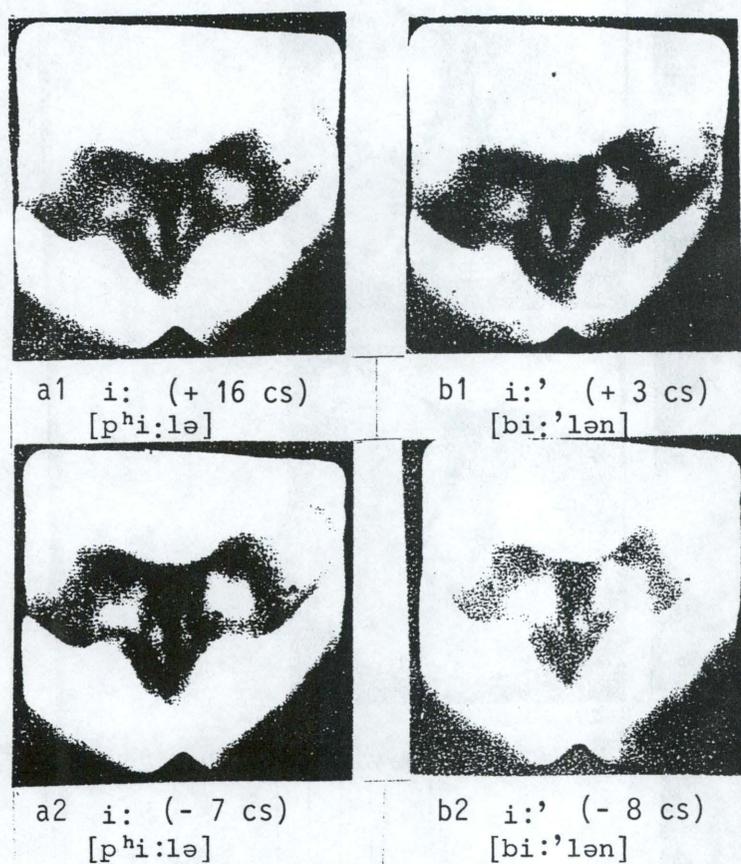
Figure 28

Frames from a fiberoptic film of the vocal folds. 1. first
part of vowel, 2. second part of vowel. + = distance from
vowel onset. - = distance from vowel end.   Speaker BF.

rior part, and the ventricular folds are gradually adducted
and reach complete closure at point 16.

BF also pronounced a number of examples with hard attack
([si ˈʔi:lə], Fig. 30). Here too the ventricular folds are
adducted, but at the same time there is a strong front-back
constriction in the larynx. The epiglottis goes down and the
distance between the epiglottis and the arytenoids is reduced.
Both closure and opening are rather abrupt. These examples
were read with the same position of the fiberscope as in Fig.
27.

JR (Fig. 31) uses a more normal stød from an acoustic and per-
ceptual point of view, although often without Fo-drop (see
above p. 112-113), but the fiberscope pictures show a very
strong adduction of the ventricular folds, on the average (5
examples) to 25%, and in one case even to 15% of the distance
at the start. Because of this movement very little of the
vocal folds is visible. The successive frames in Fig. 32 show
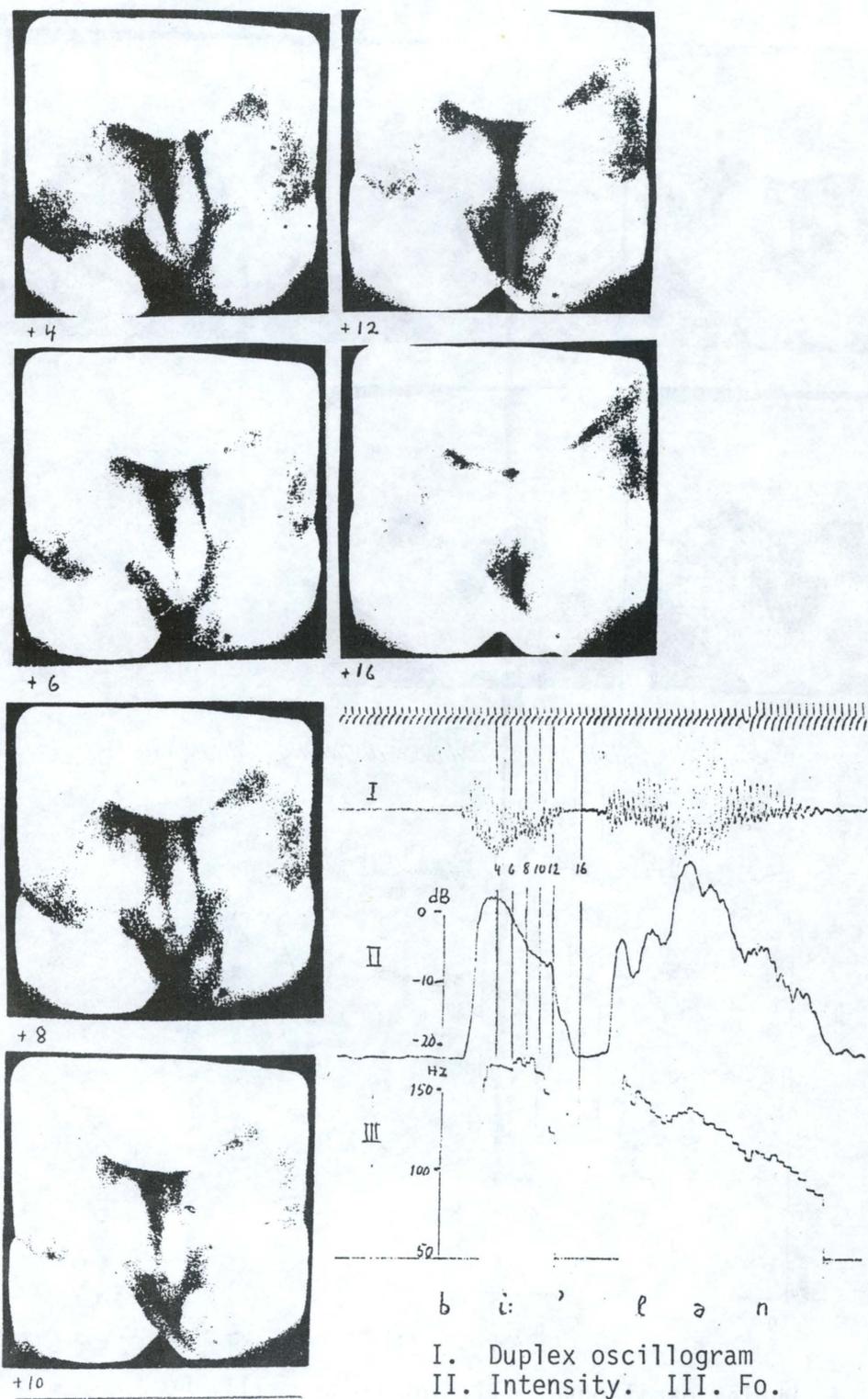
Figure 29

Frames from a fiberoptic film of the vocal folds. Successive
frames showing the [i:'] in [bi:'lən] (very strong stød), com-
pared to a mingographic recording. The numbers indicate dis-
tance in cs from the start of the vowel. Speaker BF.
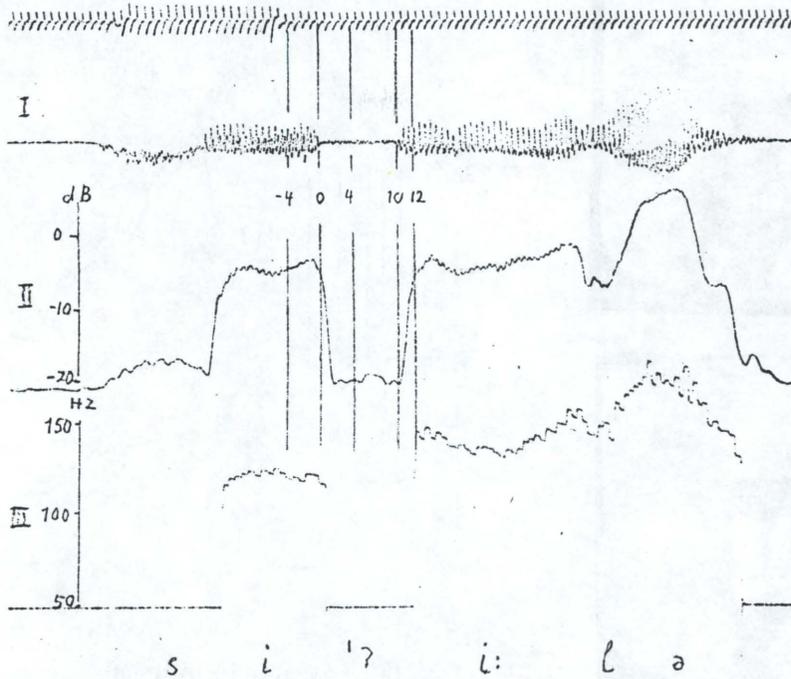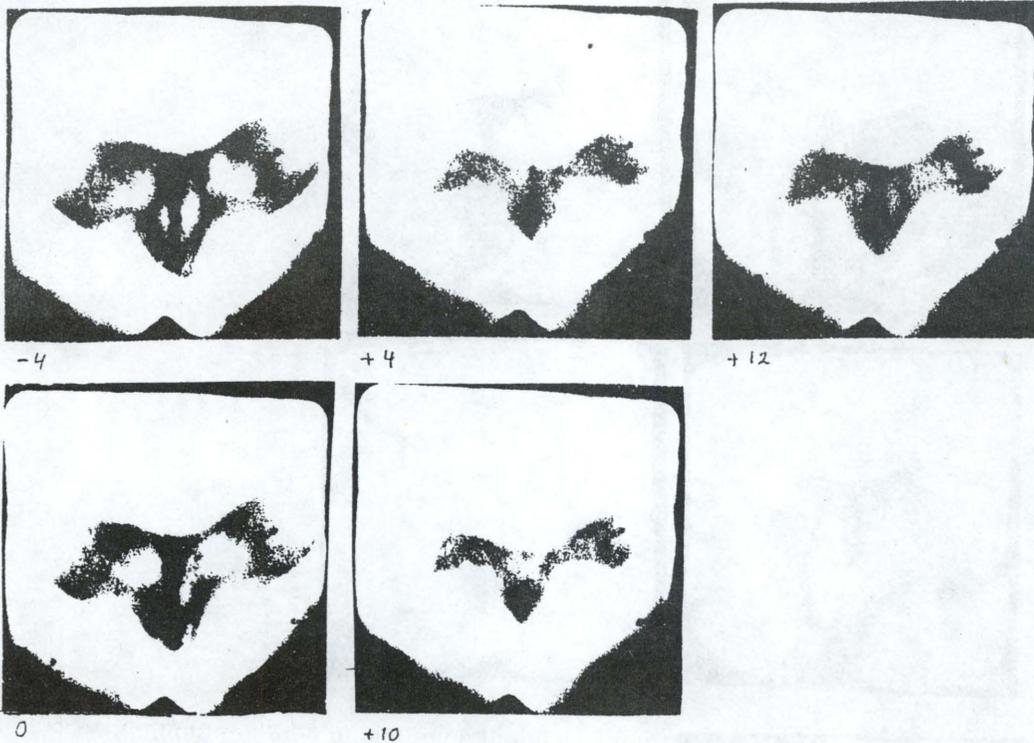
I. Duplex oscillogram, II. Intensity, III. Fo.

Figure 30

Frames from a fiberoptic film of the vocal folds. Successive
frames showing hard attack in the sentence [si '?i:lə]. Numbers
indicate distance in cs from the end of the first [i]. Speaker
BF.

|		
a1 i: (+ 6 cs) [bi:lə]	b1 i:' (+ 1 cs) [bi:'lən]	c1 i:' (+ 6 cs) [mi:'lən]
a2 i: (- 6 cs) [bi:lə]	b2 i:' (- 4 cs) [bi:'lən]	c2 i:' (- 4 cs) [mi:'lən]
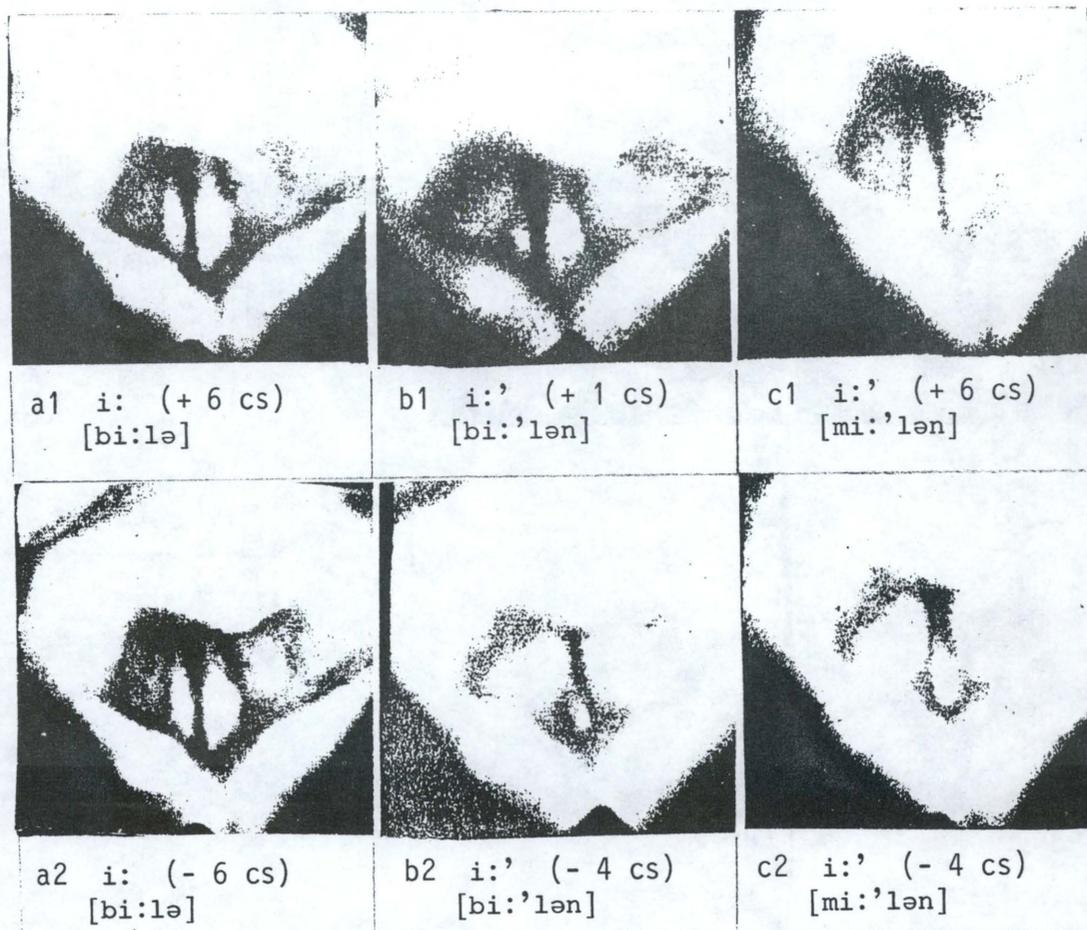
Figure 31

Frames from a fiberoptic film of the vocal folds. Speaker JR.
1. first part of vowel; 2. second part of vowel. + : distance
*from vowel onset, - : distance from vowel end.*

that it is the right fold which disappears completely. What
happens to the glottis is therefore uncertain. It does not
seem to be very narrow when it appears again (Fig. 32, No. 22);
his glottis is generally more open in the anterior than in the
posterior part, and in the start of the stød the posterior part
is closed first.

BM has (according to Hirose, personal communication) a slight-
ly twisted supralaryngeal structure extending from the base of
the epiglottis to the ventricular fold. When he starts phonat-
ing the distance between the epiglottis and the arytenoids is
reduced, and the picture of the vocal folds gets very dark so
that it is difficult and sometimes impossible to distinguish
the glottis. It is therefore not possible to say what happens
to the vocal folds, and copies of the photos only show a dark
area, but the ventricular folds seem to be considerably more
adducted at the end of words with stød than in the beginning,
the distance being reduced to almost 25% in the two examples
which have been photographed.
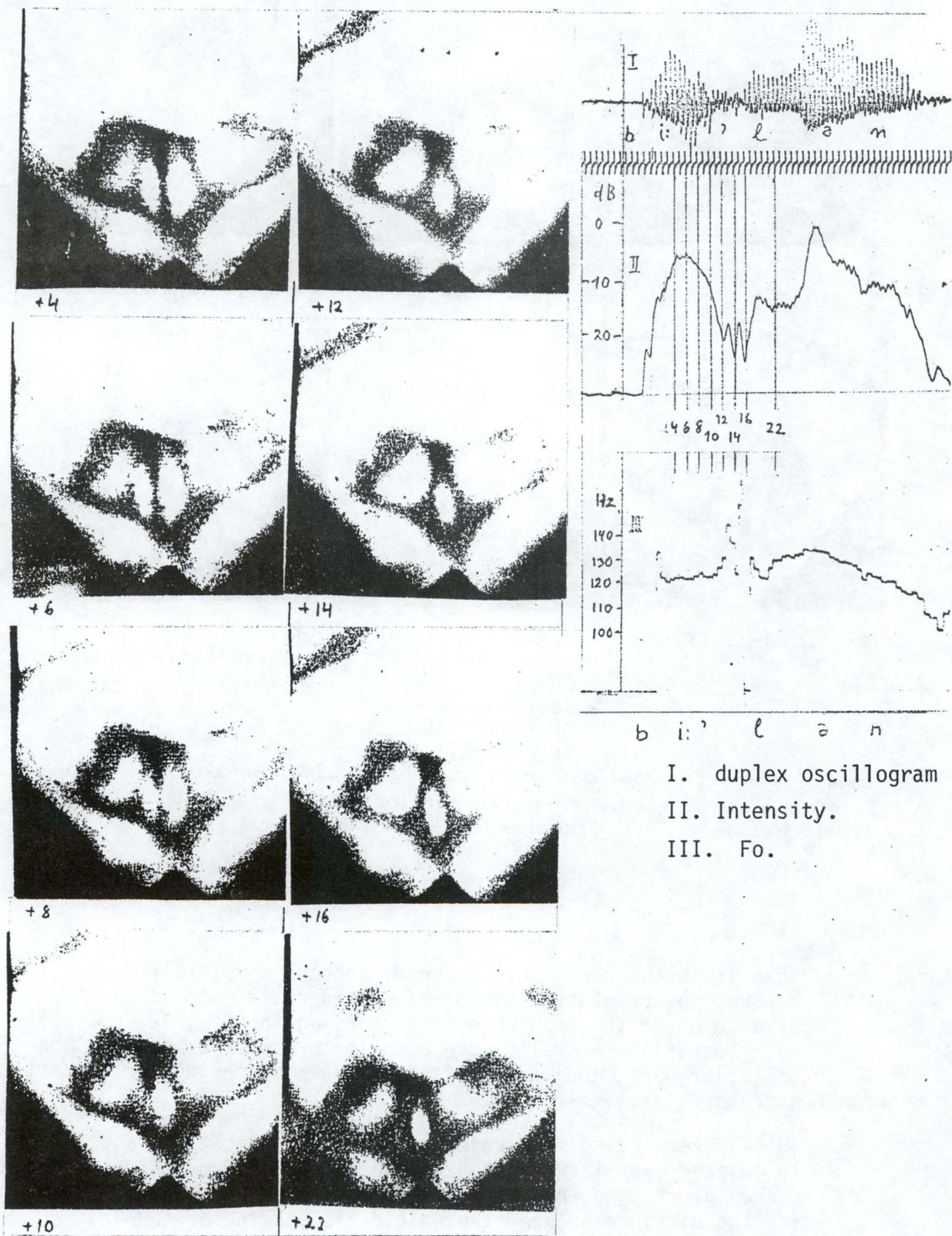
I. duplex oscillogram
II. Intensity.
III. Fo.

Figure 32

Frames from a fiberoptic film of the vocal folds. Speaker JR. Successive
frames showing the vowel [i:'] *in* [bi:'lən], *compared to a mingographic*
recording. The numbers indicate distance in cs from the start of the vowel,
the last picture showing the following consonant [l].

There is thus much interindividual variation, and it seems pos-
sible to produce the stød in different ways. The extremes are
FJ and JR, although both are from Funen, and both speak a some-
what conservative Standard Danish. FJ has hardly any adduction
of her ventricular folds in vowels with stød, whereas JR has a
very strong adduction; and the difference is very consistent,
the range for the 5 examples measured being 81-94% of the dis-
tance at the start of the vowel for FJ, and 15-38% for JR.
There is also an acoustic difference: In the 1985 recording FJ
had pitch decrease in 94% of the cases, JR in only 33%. But
whether there is any causal relation between these two findings
is very dubious. Both speakers have approximately the same
percentage of irregular vibrations.

Closure of the ventricular folds was found by Ringgaard (1960
and 1962) in the so-called West-Jutlandish stød, and by Fujimura
and Sawashima (1971) in the very similar phenomenon in English
postvocalic stop consonants (e.g. *fat teeth*).

In section IV B (p.179) the question of constrictions in the
larynx will be taken up again in connection with a discussion
of the stød as a phonation type.

3. AIRFLOW

Oral airflow was recorded for one subject (BF 1974, reading
list 1) and a combination of oral and nasal airflow for 4 sub-
jects reading list 8. The material comprised 70 different word
pairs with 8 (for BF 10) repetitions, i.e. 566 word pairs in
all (but BF's two pairs with postvocalic [n] could only be used
for analysis of the first part of the vowel, because the mask
did not cover the nose). Average curves are found in Appendix
VI.

a. First phase   As was the case for intensity and Fo, it is
                 practical to consider the first and the second
phase of the stød separately. Since both intensity and Fo tend
to reach a higher level in words with stød than in words with-
out stød in the first part of the vowel, the same might be ex-
pected for airflow. A glance at the 54 average curves in the
appendix shows that this is only rarely the case. More often
in words with stød the airflow rises more quickly and higher
for the initial consonant and falls more quickly down to the
vowel.

Smith (1944) found a steeper rise in the start of the open
phase of an initial voiceless consonant and in the vowel after
a voiced consonant in words with stød and a larger area under
the first part of the curve, but the delimitation was quite
arbitrary. - He used traditional kymographic recordings with
a very lax membrane and a valve in the tube. With this lax
membrane a peak of a [d]-explosion may be delayed up to 5 cs
after the start of the vowel. It might be of interest to re-
peat his analysis with more modern instruments and using a
larger corpus.

Preliminary inspection showed that an analysis of the area was
problematic since a consistent delimitåtion after consonants
would be impossible and since the effects of a higher rise and
quicker fall might cancel each other. Instead steepness and
peak were analyzed. Steepness was measured as the horizontal
distance in ms between the start of the rise and a point corre-
sponding to vertical height close to the peak. - Both measures
were undertaken on the individual curves, not on the average
curves, and only as relations between corresponding words with
and without stød within the same reading of the list, because
the airflow might be expected to change in the course of the
recording. Partly due to the quicker reaction of the instru-
ments used (see p. 88) it was often difficult to see any dif-
ference in steepness in the case of *bdg* and the rise of the
vowel after [l] and [v], and there were thus many judgements
of "same". For the strongly aspirated *ptk* it was simpler.
For *fsh* the start was sometimes problematic.

Smith found no difference for monosyllables. The material is
therefore divided into disyllables and monosyllables. Tables
XIII and XIV give a survey of the results, and Tables I and II
in Appendix VI contain the results for (A) *ptk*, (B) *fshbdg*,
and (C) vowel after *l* and *v* separately for disyllables.

Table XIII

Disyllables.
A. *Number of pairs in which the word with stød has a steeper*
   (+) or slower (-) or the same (0) rise in airflow at the
   start of the word compared to the corresponding word with-
   out stød in the same reading.

B. *Number of pairs in which the word with stød has a higher (+)*
   or lower (-) or the same (0) airflow peak at the start of
   the word compared to the corresponding word without stød in
   the same reading.
   *Significance: * <5%, ** <1%, *** <0.1%.*

	A. steepness				B. height			
	+	0	-	sf.	+	0	-	sf.
BF	43	8	10	***	42	9	10	***
FJ	30	31	23		46	8	30	
HU	41	34	21	*(*)	67	9	20	***
JR	45	26	25	*	58	9	29	**
NR	52	28	16	***	66	9	21	***
sum	211	127	95	***	279	44	110	***
%	48.7	29.3	21.9		64.4	10.2	25.3	

Table XIV

Monosyllables.
A. *Steepness of rise, and B. peak airflow in words with and without stød. See legend to Table XIII.*

	A. steepness				B. height		
	+	0	-		+	0	-
BF	11	8	3		8	4	10
FJ	7	18	15		14	5	21
HU	9	3	12		12	2	10
JR	9	8	7		12	1	11
NR	8	8	8		11	2	11
sum	44	45	45		57	14	63
%	32.8	33.6	33.6		% 42.5	10.5	47.0

There is a clear tendency to a steeper rise and a still more evident tendency to higher peaks in disyllables with stød, but there are some individual differences, the tendencies being particularly strong, and significant at the 0.1% level, for BF and NR, and very weak and not significant for FJ. But for all speakers there are negative cases, also in individual word pairs, except for [sæ:lə / sæ:'lən] and [vɛnɒ / vɛn'n̩] for HU.

The test used for calculation of significance was the sign test (Siegel 1956, p. 68-75) which is applicable to the relation between members of pairs. But its application to steepness may be somewhat problematic because it presupposes that the number of "same" cases can be disregarded. If these cases are distributed on + and -, the significance is sometimes smaller. This is indicated by parentheses around the stars.

The tables in the appendix show that the tendencies are most pronounced for *ptk*.

Whereas there is a clear tendency to a steeper rise and a higher peak in disyllables with stød, there is no difference in the monosyllabic words, and thus Smith's observations are confirmed. However, it is highly problematic whether this is really due to the difference between disyllabicity and monosyllabicity. In section A.4 above (see p. 106-107) a similar difference was found for the Fo peak in the start of the vowel, but it was argued that the difference might also be due to differences in vowel length. This argument is also valid for the airflow, and the argument has even more weight in this case. - Only one of the monosyllabic word pairs has the same vowel length in the words with and without stød, viz. [vɛn / vɛn'], and this pair shows the same difference as the disyllabic pairs. The height differ-

ence is exactly the same (63% of the cases have a higher peak
after the [v] in [vɛn']), and as for the steepness the percent-
age is even higher than in the disyllabic words (viz. 61% vs.
49%). In all the other monosyllabic pairs investigated the
word without stød has a short vowel, and the word with stød a
long vowel ([du / du:', tʰa / tʰæ:'] and (for one speaker)
[pʰib / pʰi:'b] and [føl / fø:'l]). For these words there is
no significant difference, and the tendency is rather reversed.
The pairs investigated by Smith also had a difference in length
(the examples were in fact taken over from him in order to
verify his observations with better instruments, but they should
have been supplemented with pairs without this length differ-
ence). The assumption that words with short vowels may have a
stronger and steeper airflow than words with long vowels is
supported by a comparison of the examples [pʰi:bɒ / pʰi:'bɒ /
pʰibɒ] and [lɛ:sɒ / lɛ:'sɒ / lɛsɒ]. Whereas the words with
long vowel and stød have a significantly steeper rise and higher
peak than the words with long vowel without stød, there is no
significant difference between the words with long vowel and
stød and the words with short vowel, and for [pʰi:'bɒ / pʰibɒ]
the tendency is even reversed as far as the height is concerned.
- A comparison between [kʰɛ:lə] and [kʰɛlɒ] (see Appendix VI)
also shows a higher peak in [kʰɛlɒ] for four of the five speakers.

b. Second phase   Smith did not analyse the airflow in the
                   second phase of the stød, which other pho-
neticians consider as containing the stød proper (with low in-
tensity and irregularities and/or Fo-decrease). Here a low
airflow should be expected. An analysis of the present mate-
rial confirms this expectation. The analysis consisted partly
in a comparison of individual words in the same reading, part-
ly in measurements of the difference in l/m for words with
long vowel on the basis of average curves. A survey of the re-
sults is given in Table XV, A and B, and measurements of l/m
values and differences for different word pairs and speakers
are given in Appendix VI, Table III.

A "+" was chosen if only a short stretch at the end of a long
vowel or in the consonant after a short vowel had lower air-
flow in the word with stød. The difference in l/m was measured
at the lowest point of the vowel with stød. In [pʰi:bɒ] with-
out stød the airflow increases clearly just before the [b];
thus if the end point of the vowel had been chosen, the differ-
ence would have been larger.

There was no difference between disyllables and monosyllables,
so that both are included in Table XV A. As for the measure-
ment of l/m only long vowels in disyllables were included be-
cause it was problematic to choose a relevant point for measure-
ment with any consistency in consonants and in monosyllables;
in the latter case there was generally a length difference be-
tween words with and without stød.

Table XV

A. *Number of pairs in which the word with stød has a lower (-),
higher (+) or the same (0) airflow in the second part of the
syllable compared to the corresponding word without stød in
the same reading.*

B. *Difference in l/m between words with long vowel with and
without stød.*

C. *Distance from vowel onset to the point where the airflow
gets lower in words with stød than in words without stød.*

	A.				B. diff. (1/m)	C. distance (cs)
	-	0	+	sf.		
BF	59	1	1	***	8.5	6.2
FJ	99	9	16	***	2.3	6.2
HU	120	0	0	***	3.9	4.3
JR	120	0	0	***	6.9	4.3
NR	112	6	2	***	1.5	5.0
sum	510	16	19		av. 4.6	5.2

The difference in airflow in the second phase of the stød is
obviously highly significant; and in contradistinction to the
differences in the first phase, which were only (partly) sig-
nificant for groups of words and not for separate word pairs
(with extremely few exceptions), the difference in the second
phase is generally highly significant for separate word pairs
as well, since generally all 8 (or 10) repetitions show the
same difference. This is true of 53 out of 65 word pairs.
According to the sign test the significance is 1% in these
cases. There are further 6 cases with 5% significance and 9
non-significant cases. - Average curves were made of 54 pairs,
and for these words the overlappings were analyzed. This gave
almost the same result, except that no overlapping of 8-10 ex-
amples, which was very common, gives 0.1% significance according
to the Mann-Whitney test.

4. SUBGLOTTAL AND ESOPHAGEAL PRESSURE

Subglottal pressure was recorded for BF reading list 1 in 1974
simultaneously with the other recordings. It was recorded by
the direct method inserting a needle into the trachea (see p.
87 above). There were 8 different word pairs with 5-6 repeti-
tions of each word (in one case only 4). The curves look very
reliable. The zero-line is almost stable, and there is very
little variation within the same word. According to a rough
estimate from the standard deviation curve of the computer
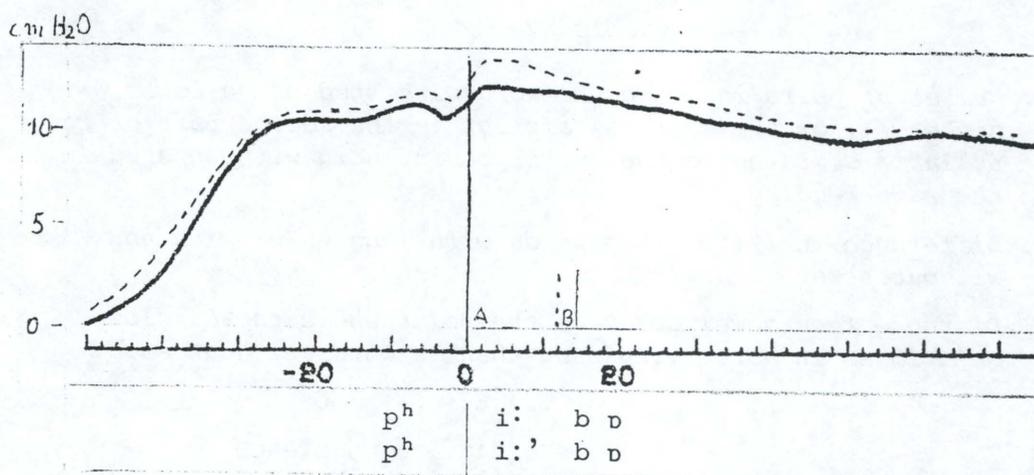
Figure 33

Subglottal pressure, average of 5 examples, speaker BF.

averages, the s.d. is less than 5% for words without stød, and
around 10% for words with stød. Expected differences due to
stress and aspiration are also visible. The material is given
in the form of curves averaged by computer in Appendix VII.
A typical example is shown in Fig. 33.

All 8 pairs show a higher maximum and a steeper rise in the
first part of the vowel (in [vɛn'] and [vɛn'n̩] in the [v]) in
words with stød compared to words without stød. The differ-
ences are small (generally less than 1 cm H_2O), but they are
consistent. Due to the small number of repetitions significance
for individual word pairs can only be proven for four of the
eight pairs ([kʰɛl'ɒ / kʰɛlɒ], [hu:'ən / hu:ən] 1%, and
[pʰi:'bɒ / pʰi:bɒ], [vɛn'n̩ / vɛnɒ] 5%); but eight pairs with
the same difference gives 1% significance for the total mate-
rial according to the sign test. Moreover, corresponding words
in the same reading with and without stød were compared, and
of 38 pairs 35 had a higher maximum in the word with stød, and
31 a higher start of the vowel. This is evidently highly sig-
nificant.

The distance from the start of the vowel to the pressure maxi-
mum in words with stød is on the average 5.0 cs, individual
averages varying between 2.6 and 6.4 cs except for [hu:'ən]
where the rise is much slower (11 cs). After the maximum the
pressure decreases again. Within the first 10 cs, i.e. until
the start of the acoustical stød, the decrease is, on the aver-
age, 0.5 cm H_2O (but [lɛ:'sɒ] does not show any fall at all),
and during the phase of the stød the pressure is still slight-
ly higher in words with stød except for [vɛn']. (The strong
decrease found in the words [kʰɛl'ɒ], [vɛn'] and [du:'] (see
Appendix VII) is much later and has nothing to do with the
stød, being due to cases where the speaker made a pause after
the test word.) In words without stød the distance to the peak

is very variable, and very often there is no decrease during the first 10 cs.

Quantitative measurements in cm H_2O were undertaken both on the computer-averaged and on the manually averaged curves as well as on the individual words in the mingographic recording. Averages for different word pairs from the latter measurement are given in Appendix VII, Table I, and the grand means of the three different types of measurement are shown in Table XVI.

Table XVI

Averages (in cm H_2O) at vowel start and maximum, and rise of subglottal pressure in words with and without stød (speaker BF, eight word pairs with 5-6 repetitions), (A) based on measurements of individual words, (B) based on manually produced average curves, and (C) based on computer-produced average curves).

	A (indiv. meas.)			B (man. av. c.)			C (computer av. c.)		
	vowel start	max.	rise	vowel start	max.	rise	vowel start	max.	rise
+stød	11.9	12.6	0.7	11.8	12.4	0.6	11.5	12.6	1.1
-stød	11.4	11.8	0.4	11.3	11.7	0.4	10.8	11.5	0.7
diff.	0.5	0.8	0.3	0.5	0.7	0.2	0.7	1.1	0.4

The reason for these extra control measurements was that the differences are small, but at the same time of great interest for the theories concerning the production of the stød. The accordance between A and B, i.e. averages of individual measurements and measurement on manually produced average curves is very high. As for C (computer averages) the maximum in stød words is exactly the same as in A, but the maximum of words without stød is 0.3 cm H_2O lower, which I cannot explain. At any rate it is not much, and the maximum is higher in words with stød in all eight pairs according to all three methods of measurement. As for the start of the vowel it is 0.4 and 0.6 cm H_2O lower in the computer averages, which gives a higher rise (1.1 compared to 0.7 cm H_2O in stød words). This is mainly due to the words [du:'], [kʰɛ:lə] and [kʰɛlɒ] and can partly be explained by the fact that there is sometimes a certain lag in the computer averages probably due to the sampling, so that the line-up point is slightly more to the left, and some of the rise at the end of the dip during the aspiration will thus be included. I am therefore inclined to think that the two other types of measurement give a more correct result. Anyhow, maximum and rise are only around 1 cm H_2O higher in words with stød. The question whether these small differences are sufficient to explain the acoustic differences will be taken up in the final section. But a slightly higher subglottal pressure during the stød phase combined with a considerably lower airflow (see above p. 149) points to increased glottal resistance.

Esophageal pressure was measured for speaker FJ reading list
7. The list contained the pairs [diːʃəð / diːˈsən, siːlə /
siːˈl, miːlə / miːˈl] and [vɛn / vɛnˈ]. There were 12 repeti-
tions of each word. This recording is less reliable. The zero
line is often missing, and when it is present it is very vari-
able in height. Moreover, the subject sometimes did not breathe
in between the sentences (this was apparent from a simultaneous
airflow recording), and in these cases the esophageal pressure
was often considerably higher in the second sentence, as should
be expected if esophageal pressure reflects thoracic pressure
and not the combined thoracic and recoil pressure (see Kunze
1964). No correction for lung volume was undertaken, and the
pressure was not calibrated. Therefore superposed tracings
were made with the start of the vowel [iː] in the frame [di
vi siː] as vertical starting point. There was a rather large
variation, so that the tracing of the average was difficult.
However, the peaks are exact, and there is a clear difference
in all four pairs, the word with stød having a higher maximum.
Average curves are shown in Appendix VII.

In 1974 Jørgen Rischel (JR) made a recording of his esophageal
(and pharyngeal) pressure, while reading list 1 and list 3.
List 1 was repeated twice, list 3 four times. The recording
of esophageal pressure is, however, problematic. The curve
is strongly smoothed (no vibrations are seen), and the excur-
sions are very small. Moreover, the zero-line is moving up and
down all the time both between and within the sentences. In
list 1 sentences with stød often seem to be on a generally
higher level, and sometimes there seems to be a peak in the
beginning of vowels with stød, but it is too uncertain. In
list 3 (the *bibibibi*-list), there also often seems to be some-
what more rise and fall in syllables with stød, starting in
the consonant, but it is all very problematic.

5. PHARYNGEAL PRESSURE

Pharyngeal pressure was measured for BF reading list 1 in 1974
together with the recording of other properties (see Appendix
VIII), for FJ reading list 1 (1981) and for JR reading lists 1
and 3, i.e. together with esophageal pressure (see above).
BF's recording was calibrated in cm H_2O, the other two record-
ings were not calibrated.

In BF's recording there is a tendency for the maximum pharynge-
al pressure in the initial consonant (i.e. just before the re-
lease of [pʰ] and [kʰ] and at the transition to the vowel for
[v] and [l]) to be higher in words with stød. The difference
is found in all eight word pairs and is thus significant for
the material as a whole, but the difference is small (0.3 cm
H_2O on the average), the variation is much larger than for the
subglottal pressure, and the difference within individual pairs
is not statistically significant except for [huːən / huːˈən]
(5% level). The zero line varies (about 1 cm H_2O) which gives
some uncertainty. Moreover, the pressure is smaller than ex-
pected. Shortly before the release of aspirated [pʰ] and [kʰ]

one should expect to find identity between subglottal and pharyngeal pressure (see, e.g., Löfqvist et al. 1982), but for the three relevant word pairs the pharyngeal pressure is 3.2 - 3.3 cm H_2O lower. About 1.5 cm H_2O would be gained by using the zero-line of the computer averages, but these zero-lines are arbitrary (except for Fo). The zero-line in the curves in the Appendix has been placed by comparison with manually averaged curves from the mingograms, which were calibrated, and the error in this procedure is at most 0.2 cm H_2O. The deviation is therefore difficult to explain. BF read the sentences in a rather loud voice so that the subglottal pressure of about 10 cm H_2O is not higher than should be expected (see, e.g., Daniloff et al. 1980, p. 202). But the scale and thus the differences are OK. Measurement and averaging of selected mingograms gave the same differences with a deviation of only 0.1 cm H_2O.

During the stød phase the pressure (measured at the minimum) is lower than the corresponding point in words without stød in all word pairs except [kʰɛ:lə / kʰɛ:'lɒ]. This difference is, however, also small (0.6 cm H_2O on the average). All word pairs taken as a whole give significance at 5%, but there is no significance within separate word pairs except for [hu:ən / hu:'ən]. Averages for individual word pairs as well as computer produced averages are given in Appendix VIII. The tendency to slightly higher subglottal pressure in the stød phase compared to slightly lower pharyngeal pressure points to stronger glottis constriction in the stød, but the differences are small.

Pharyngeal pressure was also recorded for FJ reading list 7, which contained four word pairs (see section (d) above). All four word pairs showed a higher pressure in the initial consonant in words with stød, and the difference is significant except for [di:səð / di:'sən]. On the other hand, [di:'sən] has a steeper rise during the [d] closure in 11 out of 12 cases, when words from the same reading are compared (see Appendix VIII).

JR read list 1 twice. In this list no difference between words with and without stød can be seen, although the base line is quite stable in this recording in contradistinction to the esophageal pressure. In list 3, which was read four times, the initial consonant ([b]) has a higher pressure at the end of the closure in most words with stød, but the difference is not significant. There is, however, a clear difference in the movement of the pressure during the closure. After the first steep rise the pressure remains stable in words without stød in 8 out of 12 examples, whereas in words with stød there is a rise in 10 out of 12 examples. This difference is significant according to Fischer's probability test.

In JR's and FJ's curves the DC amplitude was rather small and the vibrations very large in voiced sounds, which made measurements of pressure during the stød phase difficult. But measurement of selected examples did not reveal any difference. What

could be seen very clearly, however, was a pronounced decrease
in the amplitude of the vibrations during the stød phase.

The stød thus also shows up in the pharyngeal pressure, but the
differences are small and not always significant.

6. ARTICULATORY FORCE

Since both airflow, pharyngeal pressure, intensity and pitch
tended to be higher at the start of the vowels with stød, it
seemed worth while to look for signs of more articulatory force
as well. Very informal observations seemed to indicate more
protrusion of the lips in rounded vowels with stød. But this
has not been investigated thoroughly.

Muscle activity in orbicularis oris superior (OOS) in initial
labial consonants in words with and without stød could be com-

p^{h}i:bɒ   p^{h}i:'bɒ

Figure 34

Palatograms of the words [p^{h}i:bɒ] *and* [p^{h}i:'bɒ] *pronounced
by FJ.*

pared in two word pairs: [pʰi bɒ / pʰi:'bɒ] and [man / man']
(average of 16 examples) in the Haskins recording 1972 (see
Fischer-Jørgensen and Hirose 1974b), but the activity was not
consistently stronger in the word with stød. PM had the same
activity in initial [p] in both words, whereas TB had more
activity in the word with stød. In [man / man'] PM had more
activity in the [m] in the word with stød, whereas for TB the
opposite was true. In the Haskins recording 1976 of FJ it was
also possible to compare OOS in a word pair with and without
stød ([pʰɛ:nə / pʰɛ:'n]). This comparison did not show any
difference either.

A number of palatograms dating from 1949 were also inspected
more closely. There were five speakers: FJ, KS, NE, OR and OT.
In one of the series with FJ as a speaker an artificial palate
was used (FJb), in the other cases the method was direct pala-
tography. The tongue was painted with a mixture of yellow
ochre, medical coal and gum arabic, and immediately after the
pronunciation of the word a small mirror was inserted, and the
outline of the contact area was drawn on a photo of a plaster
cast of the palate. An example is shown in Fig. 34 (the curved
lines indicate 50% height of the palate counted from the highest
point to the surface of the molars). The subjects pronounced
partly isolated vowels with and without stød, partly words of
the type [pʰi:bɒ / pʰi:'bɒ], where only the stressed vowel would
show contact with the palate. The distance between the right
and left boundaries of the contact at the narrowest passage was
measured for each vowel. Since words and isolated vowels be-
haved alike, and the total number was small, they have been com-
bined in Table XVII, which shows the difference between the

Table XVII

*Average difference in mm between vowels without and with stød
in respect of the distance between right and left contact area
on palatograms, measured at the narrowest point of the passage.
N = number of individual examples; significance: * < 5%,
** < 1%, *** < 0.1%.*

	i: - i:'		e: - e:'		ɛ: - ɛ:'		y: - y:'		u: - u:'	
	N	diff.	N	diff.	N	diff.	N	diff.	N	diff.
FJa	8/11	3.4**								
FJb	9/9	2.9	9/9	7.5***	9/7	-1.3	2/2	4.5		
NEa	3/3	3.0	3/3	7.0	3/5	2.9	3/2	1.7	5/12	5.0
NEb	5/5	7.3*								
KS	6/10	1.6	3/3	-2.7			3/3	0.6		
OR	4/5	1.8	4/4	-1.0	4/4	0.4			4/5	1.4
OT	10/6	1.6								

measurements for vowels with and without stød. These measure-
ments in mm are not real, in the first place because the photos
of the casts were about 10% shorter in both dimensions than the
originals, and in the second place because the contact areas
are larger than seen on the drawings due to the steepness of
the sides of the palate. But they give a reliable picture of
the direction of the difference between words with and without
stød and an approximate impression of the size of the differ-
ence. Because of the restricted number of examples it is only
rarely possible to demonstrate significant differences in the
individual averages, but seen as a whole the difference is sig-
nificant, vowels with stød having a smaller distance and thus
a larger contact in 17 out of 20 averages. There is thus a
clear tendency to pronounce vowels with stød with more artic-
ulatory energy.

7. ELECTROMYOGRAPHIC INVESTIGATION

a. Interarytenoid (INT) and   It is well known that INT
   posterior cricoarytenoid (PCA)   is an important muscle (or
                                      muscle group) for closing
the glottis by bringing the arytenoids together and that PCA
has the function of opening the glottis by pulling the muscular
processes in an arc towards the back, thus separating the vocal
processes which move outwards (see, e.g., Hirose 1975).

Since it is a general opinion (see below p.182) that the ary-
tenoids are close together in creaky voice, INT might perhaps
be expected to be active at the start of the stød and PCA active
for opening the glottis again (although, according to the fiber-
optic pictures only JR and BF seemed to have more constriction
in the posterior part of the glottis in words with stød).

In the Haskins investigation 1972 HA read two words with stød:
[pʰeˈdæːˈl] and [beˈtʰæːˈlə]. The latter word could be com-
pared with [tʰanə] without stød. But there was no difference
in the activity in INT for the two words. FJ read six word
pairs and moreover two words with and without stød and with
the same initial consonant. There were 16 repetitions of each
word. In four of the pairs the word with stød had, on the
average, a slightly higher peak in INT, in the three others a
slightly lower peak. There was thus no difference, nor was
there any difference in the duration of the activity. In her
case PCA was also recorded. It did not show any consistent
difference for the stød. But it showed a somewhat higher ac-
tivity in the preceding voiceless consonant in words with stød
in four pairs starting with [pʰ, kʰ] and [h], the average dif-
ference being 27 mv. This is in good agreement with the gener-
al finding that voiceless initial consonants have stronger
airflow in words with stød (see p. 149) though this difference
was not significant for FJ.

In the 1974 investigation the material is very restricted.
Three subjects (MF, LG and PM), whose INT and PCA were recorded
in connection with an investigation of obstruents (see Hutters
1984), also read the three words [vɛn], [vɛnˈ] and [vɛːˈn]

twelve times in the frame [de ... di siŋ]. Moreover, the text contained a certain number of words with stød which did not have any counterparts without stød. PM's INT was not very reliable, whereas the other recordings were good. The twelve mingograms of each word were superposed and scrutinized for LG and MF.

LG read the sentences rather quickly, and his stød was not very strong. There was decrease of intensity, but hardly any irregularity. Two simultaneous recordings of his INT had been made with a slightly different placement of the wire. In one the peak before the start of the vowel was slightly higher in [vɛn'] than in [vɛn], in the other recording the relation was reversed, and in both there was complete overlapping. In all cases the INT decreased slowly down to the valley for the (voiceless) [d̥-] of the frame. No differences between the three words could be found.

MF read the sentences very slowly and with a very strong stød with a long irregular phase of around 9 cs, starting about 15 cs after the start of the vowel. In [vɛn'] there sometimes seems to be a real closure. Her tempo was rather irregular, which made averaging somewhat problematic, and therefore her recording was not utilized by Hutters, but on the other hand the slow reading often makes the interpretation of individual words easier, and both INT and PCA have peaks and valleys at the expected places for voiceless consonants and vowels. Her INT had a slightly higher peak before [vɛn'] than before [vɛn] and [vɛ:'n], but there was complete overlapping. There was, however, a small difference in the vowel, [vɛn'] and [vɛ:'n] showing a small valley, whereas there was hardly any dip in [vɛn] (see Fig. 35 showing average curves of INT for the three words). For LG a possible valley in the vowel could not be distinguished from the valley for [d̥], whereas for MF, who spoke more slowly, this dip came later.

The different sentences used for the investigation of obstruents also contained some examples of stød, but it was not possible to see any particular activity in INT for the stød. In most cases there was a pause or a voiceless consonant following the vowel with stød, so that a possible valley would not be visible, but the word [bʁø:'ðəd] had a small valley before the stød in almost all cases in MF's recording, whereas a corresponding valley is rare in, e.g., the words [bi:ðə] or [pʰi:nə].

Thus, if there is any difference it rather consists in a certain relaxation of INT for the stød. Hirose (see Hirose et al. 1974) also interprets the examples of Danish stød as having no particular activity in INT.

As for PCA, LG does not show any activity for the stød, but he has a peak for the following [d̥] of the frame. MF very often makes a pause after the test word. In these cases she has two peaks in PCA, one for the pause and one for the [d̥]. In [vɛn'] the peak is in the [n] and could theoretically indicate PCA activity for the opening of the glottis, but in [vɛ:'n] it comes after the stød, and there is also a peak in [vɛn], so it must be interpreted as activity for the opening of the glottis for the pause in all cases. She sometimes has a small peak in PCA
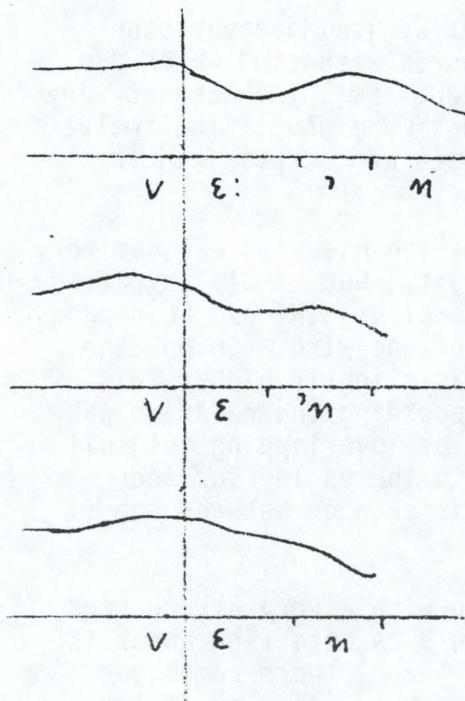
Figure 35

EMG (INT) average of 12 ex-
amples. Speaker MF.

for the [v] in [vɛn'] and [vɛ:'n]
but not in [vɛn]. This may have
to do with the degree of voicing
in these tokens ([v] sometimes
being voiceless).

Faaborg-Andersen (1957) included
some examples of words with and
without stød in his electromyo-
graphic investigation of the in-
trinsic laryngeal muscles. There
were only two examples with INT,
one had higher activity in the
word with stød and one the same
level of activity.

It may be of interest to compare
the activity of INT and PCA in
the stød with the activity in re-
lated phenomena, above all hard·
attack. Hirose and Gay (1973)
investigated the activity of
various laryngeal muscles in
vocal attack in the syllables
[ʔa], [ba] and [ha] said in iso-
lation by English speakers. INT
was recorded for three speakers.
One had no difference in INT be-
tween [ʔa] and [ba]. One had a
very small extra peak in INT
around 20 cs before the onset of
voicing, and one had a clear peak about 25 cs before the onset
of voicing in [ʔa]. PCA was recorded for two speakers only.
One speaker had a small peak at voice onset in [ʔa], not in
[ba], and the other also had some activity, but less clearly.

In the 1974 investigation a series of [ʔ ʔ ʔ] and [ʔa ʔa ʔa]
was used as identification test for INT and PCA at the start
and at the end of the recording. The distance between the
bursts was approximately 17 cs for PM, 20 cs for LG and 40 cs
for MF. After the first mentioned series [ʔ ʔ ʔ] there was
in all cases a short burst of sound, [ə]; PM and MF also pro-
nounced [ʔa ʔa ʔa] with varying length of the [a]. - INT and
PCA showed the expected alternating activity (see, e.g.,
Hirose and Gay 1972, and Hirose 1975; Hirano and Ohala 1967
also found alternating activity in PCA and LCA in a series of
[ʔ ʔ ʔ]). - The INT activity starts in or just after the pre-
ceding sound and has its peak 5-10 cs before the onset of
voicing, but it cannot be decided whether the peak would have
been lower for [ə] or [a] without hard attack.

As for PCA it starts at the peak of INT in the case of LG, and
also in the case of MF if [ʔ] is only followed by a short burst
of sound. Moreover, it occurs at a corresponding point in time
for PM, i.e. before the [ʔə] or [ʔa], and it <u>might</u> therefore

be seen as an activity for the opening of the glottis after
[ʔ]. However, in the case of MF's [ʔa ʔa ʔa] which sometimes
have a vowel duration of 10-14 cs, it very often starts after
voice onset, about 10-13 cs before the end of the vowel, and
thus its function is to open the glottis for the pause (which
often contains a rather strong airflow). Thus PCA activity is
not needed for the opening of the glottis from closed to
voicing position.

In the text there are various examples of hard attack, and in
two cases it comes after a vowel followed by two voiced seg-
ments, the vocalic contexts being [e:'ʔe:] (24 examples) and
[ɔ'ʔe:] (12 examples). Here the vocal folds are already in
voicing position, and an extra activity might not be needed
for the second vowel. However, MF, who always has a strong
hard attack with around 7 cs of glottal constriction, always
has a valley in INT with a new peak just before voicing onset
in ['e:]. But a valley with new onset of activity is also
often found for LG, who has hard attack only in a limited num-
ber of cases, and this valley and new peak have no connection
with the presence or absence of hard attack; the peak is evidently
a new onset of activity for the following (stressed) syllable.
Thus nothing speaks for a particular activity of INT for stød
or hard attack (except for one of Hirose's speakers).

Faaborg-Andersen (1957) found a very small increase of activity
(10 mv) in INT in two examples of [ʔɔb] compared to [bɔb]. He
concludes that there is no significant difference.

As for PCA, LG and PM have no activity in these cases, but MF
has a peak in PCA during the glottis constriction, i.e. simul-
taneously with the INT peak, in contradistinction to the normal
activity in these two muscles. The occurrences of a peak in
PCA are in agreement with two cases in Hirose and Gay 1973, but
in only one of the two cases does it coincide with a peak in
INT. These peaks in PCA seem in fact to have something to do
with the opening of the glottis after hard attack (probably in
the case of a strong constriction, stronger than in a stød).
Fig. 36 shows average curves of INT and PCA for MF's [ɔ'ʔe:].

b. Vocalis (VOC), crico-thyroideus (CT)
   and the lateral cricoarytenoideus (LCA)

(i) General function of CT, VOC and LCA.

The three muscles VOC, CT and LCA are treated together because
they have partly common functions, which gives some problems
for the interpretation. It is well known and generally accepted
that CT's main function is to lengthen the vocal folds, making
them thinner and more tense and thus raising the pitch. VOC is
also normally active in raising the pitch in the chest voice.
This has been documented in numerous papers, e.g. Faaborg-
Andersen 1957 (7 subjects), Shipp and McGlone 1971 (14 subjects),
and Dejonckere 1980 (15 subjects). It is therefore also often
active in pitch accent (cf., e.g., Sawashima et al. 1973,
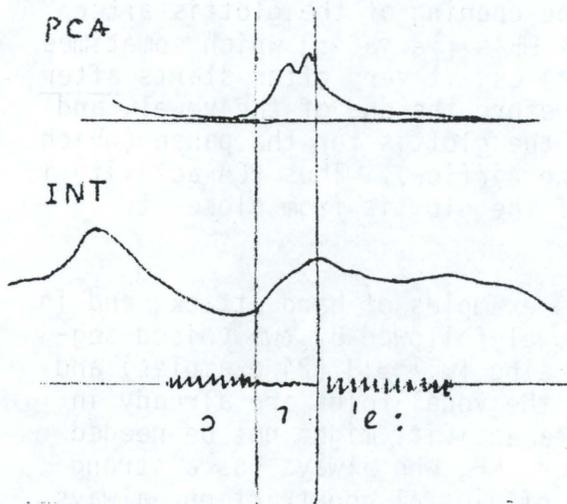
Figure 36

EMG (PCA and INT) of hard attack; average of 12 examples. Speaker MF.

Yoshioka and Hirose 1981, and Gårding 1970) and sentence intonation (Harris et al. 1969). Its pitch raising function is, however, less consistent than that of CT. Atkinson's subject (1978) showed a rather low correlation between VOC and Fo, and Shipp (1982) found much intra-subjective variation in this respect. This was also the case in the present investigation (see below). It is also somewhat uncertain what the mechanism is: whether the increased tension in VOC raises the pitch, or whether its task is to keep the vocal folds close together against their tendency to be slightly separated by the CT-tension (Hirano 1981), or whether VOC acts as an antagonist to CT in the sense that simultaneous activity for lengthening (CT) and shortening (VOC) of the vocal folds results in increased tension (Gårding 1971, Daniloff et al. 1980, Zemlin 1981), or whether, finally, a contraction of the body of the vocal folds makes the cover looser and better suited for vibrations when it is being drawn tight by the activity of CT. The last mentioned explanation has been proposed by Hirano in 1972 (see Hirano 1977 and 1981); he finds, however, that in the case of strong contraction the whole vocal fold may be stiffened (1977). The distinction between cover and body and the emphasis on the relatively free vibration of the cover was proposed already in 1957 by S. Smith (the "membrane-cushion theory") on the basis of a rubber model of the vocal folds, whereas Hirano has based his description on an anatomical analysis.

It can sometimes be seen in published curves that VOC starts around 5 cs later than CT and also has its peak correspondingly later (e.g. Gårding 1970), and it is a very general phenomenon in the present material. (In Yoshioka and Hirose 1981 the peak is earlier in VOC than in CT, but this is because VOC is active for the hard attack in the test word, which begins with a vowel.) The later rise of VOC cannot be due to a slower contraction time, on the contrary: VOC is quicker than CT (cf. Sawashima 1974, Atkinson 1978 and Mårtensson 1982). The later activity in VOC speaks for Hirano's theory, and the fact that VOC does not always participate in Fo-rise speaks against the assumption that both CT and VOC must be contracted to produce tension.

VOC has, however, a number of other functions. It is always
active in voiced sounds, and generally starts its activity
around 25 cs before the start of an utterance after a pause,
whereas CT remains inactive during the same period and does not
show activity until there is a pitch rise. This is mentioned
by Gårding (1970) and is seen very often in the present materi-
al. (The initial period of VOC activity may be preceded by a
short period of CT activity and VOC inactivity.) On the other
hand, VOC is relaxed for voiceless sounds (and more so for
aspirated than for unaspirated consonants) so that there is a
clear dip in the curve (see, for Danish, Hutters 1984), whereas
CT's behaviour is less clear and more dependent on the pitch
contour. Finally, VOC has been found to be active in cases of
strong glottal constrictions, e.g. in hard attack (Faaborg-
Andersen (1957), Hirose and Gay (1973), Gårding (1970)) and
Korean laryngealized (fortis) consonants (Hirose et al. 1973).
CT did not seem to have any function in the Korean stops, where-
as its role in hard attack is less clear. Hirose and Gay (1973)
found stronger activity in [ʔa] than in [ba] in CT, whereas
Faaborg-Andersen found this stronger activity only in VOC.
Lindquist (1972) says that glottal stops show peaks in VOC but
inhibition of CT, and Gårding (1970) has found this confirmed
for one subject producing a glottal constriction in emphatic
Swedish [jaʔa], but for another subject (Gårding et al. 1970)
this is not clear. On the whole, the activity of CT must always
be seen in connection with the pitch contour; and glottal attacks
after a pause (Hirose and Gay 1973, Faaborg-Andersen 1957) are
not easy to interpret because all adductor and tensing muscles
and in many cases the raising muscle CT as well, must be active
in this position.

As for LCA, it acts, of course, in a different way from VOC,
because its attachments are different (its contraction brings
the vocal processes together and raises the medial compression
of the vocal folds (see, e.g., Laver 1980), but in speech it
very often has the same functions as VOC: it has been found to
be active in glottal stops (Hirano and Ohala 1967), glottal
attack (Hirose and Gay 1973), Korean fortis stops (Hirose et
al. 1973); it also takes part in voicing and pitch raising, and
the curves of VOC and LCA are often practically indistinguishable,
but it seems to be particularly active in glottal constriction
(Hirose and Gay 1973) and its activity in pitch raising seems
to be somewhat less regular (see, e.g., MacNeilage 1972).

In order to judge the function of the muscles the time lag be-
tween muscle contraction and acoustic effect must be taken into
consideration. This aspect has not been studied very extensive-
ly, but some observations have been made. Buchthal and Faaborg-
Andersen (1964) studied the time interval between the onset of
electrical activity and the onset of phonation, using isolated
vowels and syllables. For CT they found an interval of 10-20
cs. But onset of phonation may require longer time than changes
during phonation. Simada and Hirose (1971) found that the ac-
tivity of CT begins to increase 12-18 cs before the onset of
the speech signal and that it reaches its peak 7-8 cs before
the corresponding peak in the pitch contour. Fujimura (1977)

mentions 10 cs as a typical lag time in speech gestures. Atkinson (1978) used the method of shifting the EMG-curve forward in time until the correlation with the Fo curve was at its maximum. In this way he found extremely short time lags (15 ms for VOC and LCA, and 40 ms for CT). He finds excellent agreement between these findings and the results of experiments with cats and dogs, cited by Sawashima (1974), but these latter experiments concerned twitch time of single motor units, which should be expected to be shorter. Niels Jørn Dyhr (personal communication) found 5-7 cs as the most common distance between the peaks of CT and Fo. In the present material I found 5-10 cs in the majority of the cases both for the start and the peaks, but the distance may be both shorter and longer, and there is much variation, the distance between the start of activity in CT and Fo being more uncertain than the distance between peaks. When the vocalis muscle participates in pitch, it may sometimes have its peak after the Fo peak, or stay at a high level after Fo has decreased.

(ii) Function of VOC, LCA and CT in the stød

The EMG activity of laryngeal muscles in the Danish stød was first investigated by Faaborg-Andersen (1957) and later by Fischer-Jørgensen and Hirose (1974) (see the summaries in section Id, p. 79-80 above). In both investigations the activity of VOC was found to be stronger in words with stød than in words without stød, but the material was restricted.

In the present investigation recordings of VOC and CT were made in 1974 for seven subjects reading list 1 in the frame: [de: ... di siɒ]. The subjects were BF, BH, BM, HU, JJ, NR and JR. NR read the list (which contained 8 word pairs) 6 times, JR 3 times, the others 10-12 times. BM and JR also read list 3 ([bibibi] nonsense words). A new recording of BF was made in 1977 and again in 1979. In both cases list 1 was read, both in the normal frame and in the frame [di siɒ 'alə ...] or [di siɒ 'ɔsə ...] (1977 and 1979, respectively), and list 1 was further supplemented with the short list 2 with stød on secondary stress (see Appendix I, p. 1).

According to the activity of VOC in stød the seven subjects form two groups. Five speakers (BF, BM, HU, JJ and NR) have a clear peak in VOC in words with stød, whereas two (JR and BH) do not show any difference between words with and without stød. The two groups will be treated separately.

Group 1

In the first group it is pretty certain that the recorded muscle is really VOC. Besides for the stød, it shows activity for swallowing and for [ʔa ʔa ʔa], and there are valleys for voiceless consonants (see Hutters 1984), except for NR, where the valleys appear irregularly and are very weak. Moreover, BF, BM and NR have clear activity for rising pitch in the tests, but for BM and NR there is only very moderate activity

for pitch rise in the sentences. The recording of CT was
successful for BM, HU, JJ and BF (1974 and 1977; in 1979 LCA
was chosen for BF instead of CT). For BH CT was allright in
the test, but then the wire must have moved, and during the
word list it looked rather like sternohyoid. For NR LCA was
hit instead of CT. Thus VOC and CT can only be compared for
BF, BM, HU and JJ.

The higher activity in VOC for stød is quite consistent for
the five subjects of group 1, the average activity being
higher in the word with stød in all 75 pairs. Moreover, 67
word pairs from list 1 were analyzed individually for sig-
nificance. In BF's recording 1974 the activity of VOC in-
creased in the middle of the recording, but within the same
reading the word with stød always had higher activity than
the corresponding word without stød. All other recordings
(i.e. 59 pairs) could be analyzed by means of the Mann-Whitney
test. One pair (NR [du / du:']) showed 1% significance, all
other pairs 0.1%, and only 9 pairs showed a slight overlapping,
whereas there was no overlapping at all in the other pairs.
The difference in VOC activity is thus very stable.

The extra activity in VOC in words with stød begins in most
cases 2-4 cs after the start of the vowel (for BF 1974 often
a few cs before vowel start). It has its peak 10-13 cs after
vowel start (see Table XVIII), i.e. shortly after the point
where the stød phase (with decrease in frequency or irregular
vibrations) starts (see Table XII, p. 111 above). The activity
decreases quickly again and crosses the curve for the corre-
sponding word without stød approximately at the end of the
vowel for long vowels with stød and at the end of the conso-
nant in the cases of short vowel with stød in the following
consonant (sometimes about 2 cs later) (see Appendix IX, p.261-
265). The activity is thus generally of rather brief duration
(10-20 cs in the average curves and often somewhat shorter in
individual examples), and the peak may be very sharp.

Table XVIII

*Distance (in cs) from vowel start to the peak in VOC in words
with stød (grand means of 7-8 averages).*

BF	BF	BF	BF	BF	BM	HU	JJ	NR	av.
74	77a	77b	79a	79b					
10.9	11.3	11.6	9.7	10.8	11.8	12.6	11.3	13.0	11.4

There is thus a clear connection between VOC and stød. CT has,
however, also a peak in the beginning of the vowel in words
with stød. In BF's curves it occurs about 8 cs earlier, just
after the start of the vowel, whereas for BM, HU and JJ it is
later, only 2-4 cs before the peak in VOC. This difference be-
tween the speakers can be explained by their Fo-curves. BF has
a jump up to the stressed syllable in stød words (with fall in

the following unstressed syllable), whereas the other speakers
have approximately the same pitch as in the preceding vowel of
the frame in words with [ɛ] (only slightly higher after voice-
less consonants) and a jump up only in words with [i] or [u]
(the following unstressed syllable normally being higher than
the stressed syllable). Therefore their CT-peak is later.
This explanation is corroborated by the fact that BM (and part-
ly HU) have an earlier CT-peak in words with [i] and [u] than
in words with [ɛ] (this, by the way, shows that CT-activity
may be involved in the intrinsic pitch difference, a question
which is being investigated by Niels Jørn Dyhr).

The presence of a peak both in VOC and in CT in the stressed
vowels of words with stød raises the problem whether the peak
in VOC might be partly (or completely) due to the pitch move-
ment, and (on the other hand) whether the peak in CT (or at
least its amplitude) may have anything to do with the stød.

In order to throw some light on this question some selected
examples (two for each speaker and recording) will be analyzed
in more detail (they are averages of 10-16 examples (6 for NR)).

Fig. 37 shows VOC, CT and Fo for the words [huːən / huːˀən]
and [kʰɛlɒ / kʰɛlˀɒ] in BF's 1974-recording. It is evident
that his VOC is very active in pitch rise in words without stød.
The peak is clearly later in VOC than in CT, and the activity
continues for a longer time (this is not an unusual phenomenon,
see p. 160 above). In words with stød the peak in VOC also
comes later than the CT-peak. It can therefore not be ex-
cluded that the VOC-peak in stød-words might be mainly due to
the pitch contour. This was the reason why BF was recorded
again in 1977 and 1979. A correct analysis of his recordings
was also particularly important because he is the only speaker
for whom subglottal pressure and airflow have been recorded
simultaneously with the electromyographic recordings.

In 1977 and 1979 BF was asked to say the words both in the
generally used frame [deː ... di siɒ] and in the frame [di siɒ
ˈalə ...] (1979: ˈɔsə), where the test word was found finally
after an emphatic word, and where it might thus be expected to
have low pitch. Fig. 38 contains the same words as Fig. 37.
In Fig. 38a the frame is [deː ... di siɒ]. Here again VOC is
active for pitch and has a later and longer peak than CT in
the words without stød. But whereas the CT-peaks are of ap-
proximately the same height in words with and without stød
(in accordance with the Fo-curves), the peaks in VOC are con-
siderably higher and sharper in words with stød than in words
without stød. A good deal of this activity must be for the
stød. In Fig. 38b, where the stød word is said finally after
an emphatic word, the pitch is definitely low, but BF still
makes the same difference in pitch contour between words with
and without stød, although with smaller amplitudes. However,
just as in Fig. 38a, the peak in VOC in stød words is con-
siderably higher and sharper than should be expected on the
basis of its activity in words without stød. If it were a
peak for higher pitch, it would also be expected to continue
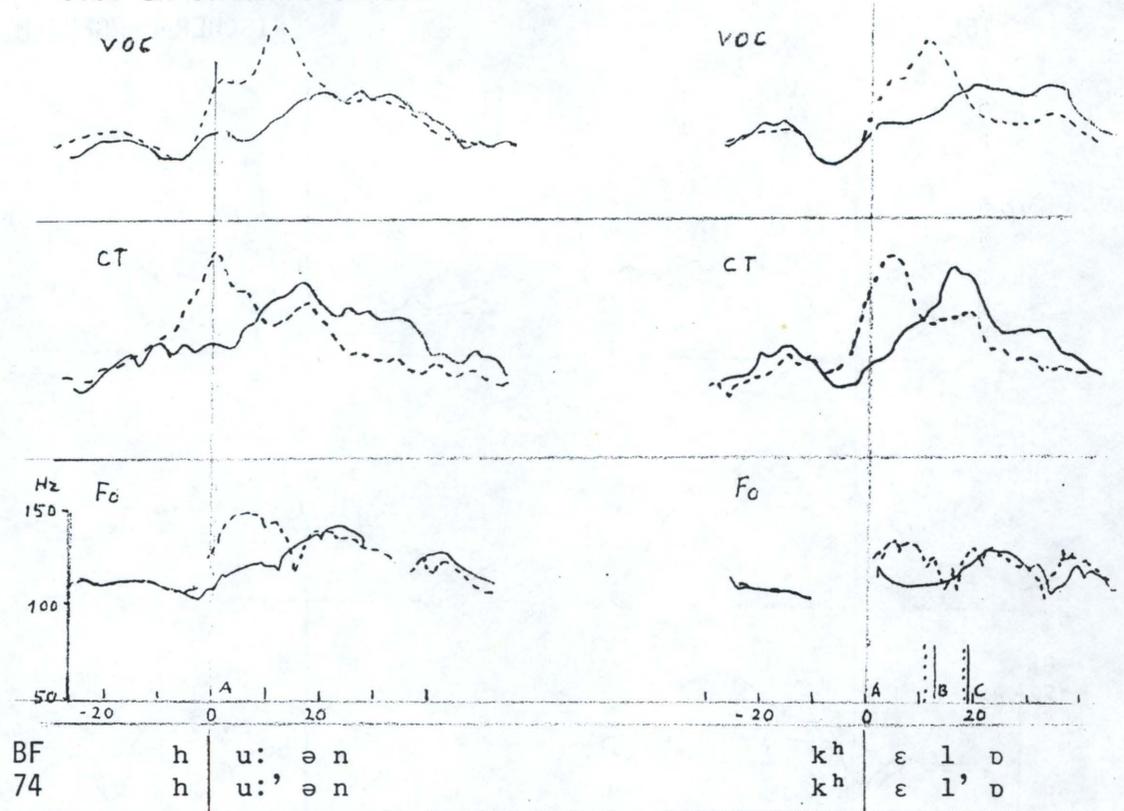
Figure 37

EMG of VOC and CT, and Fo for words with and without stød.
Speaker BF 1974. A: start of vowel (line-up point), B: end
of vowel. C: end of postvocalic consonant.— no stød,-- stød.
⸺ 10 cs.

for a longer time. In [kʰɛl'ɒ] (both in Fig. 38 a and b) there
is a small peak in VOC at the line-up point, which is also found
in the words without stød. This is evidently activity for voicing
after the valley for the initial aspirated [kʰ]. The same is
seen, though less clearly, in [hu:'ən] in Fig. 38 a.

Fig. 39 a and b show the words [lɛ:sɒ / lɛ:'sɒ] and [du / du:']
read by BF in 1979 in the same two frames. Here CT is replaced
by LCA, which looks almost exactly like VOC. The second peak in
[lɛ:sɒ / lɛ:'sɒ] must be activity for voicing after [s] (cf. that
there is no peak at the line-up point after [l]). Both VOC and
LCA show activity for pitch rise in Fig. 39 a, but the peaks in
words with stød are much higher than should be expected for pitch.
In Fig. 39 b the pitch is low in the test words (but they are
still different), and particularly in the word [du:'] the peaks
in VOC and LCA cannot be explained by the pitch contour (and a
peak after the voiceless [d̥] should occur earlier).

In 1977 and 1979 BF also read the word pairs ['hɔi̯ˌhu:sə /
'hɔi̯ˌhu:'səð] and ['au̯ˌtʰæ:lə / 'au̯ˌtʰæ:'lɒ] with stød in a syl-
lable with secondary stress (he has low pitch in secondary stress
in contradistinction to the normal contour in the Copenhagen
Standard). Fig. 40 a, b and c contain three examples. In Fig.
40 a the pitch contour of the second syllable is almost the same

VOC

CT

Hz
150 Fo

100

50
     -20   0   20   -20   0   20

BF   h   u: ə n   kʰ   ɛ   l   ɒ
77a   h   u:' ə n   kʰ   ɛ   l' ɒ

VOC

CT

Hz Fo
150

100

50
      -20   0   20   -20   0   20

BF   h   u: ə n   kʰ   ɛ   l   ɒ
77b   h   u:' ə n   kʰ   ɛ   l' ɒ
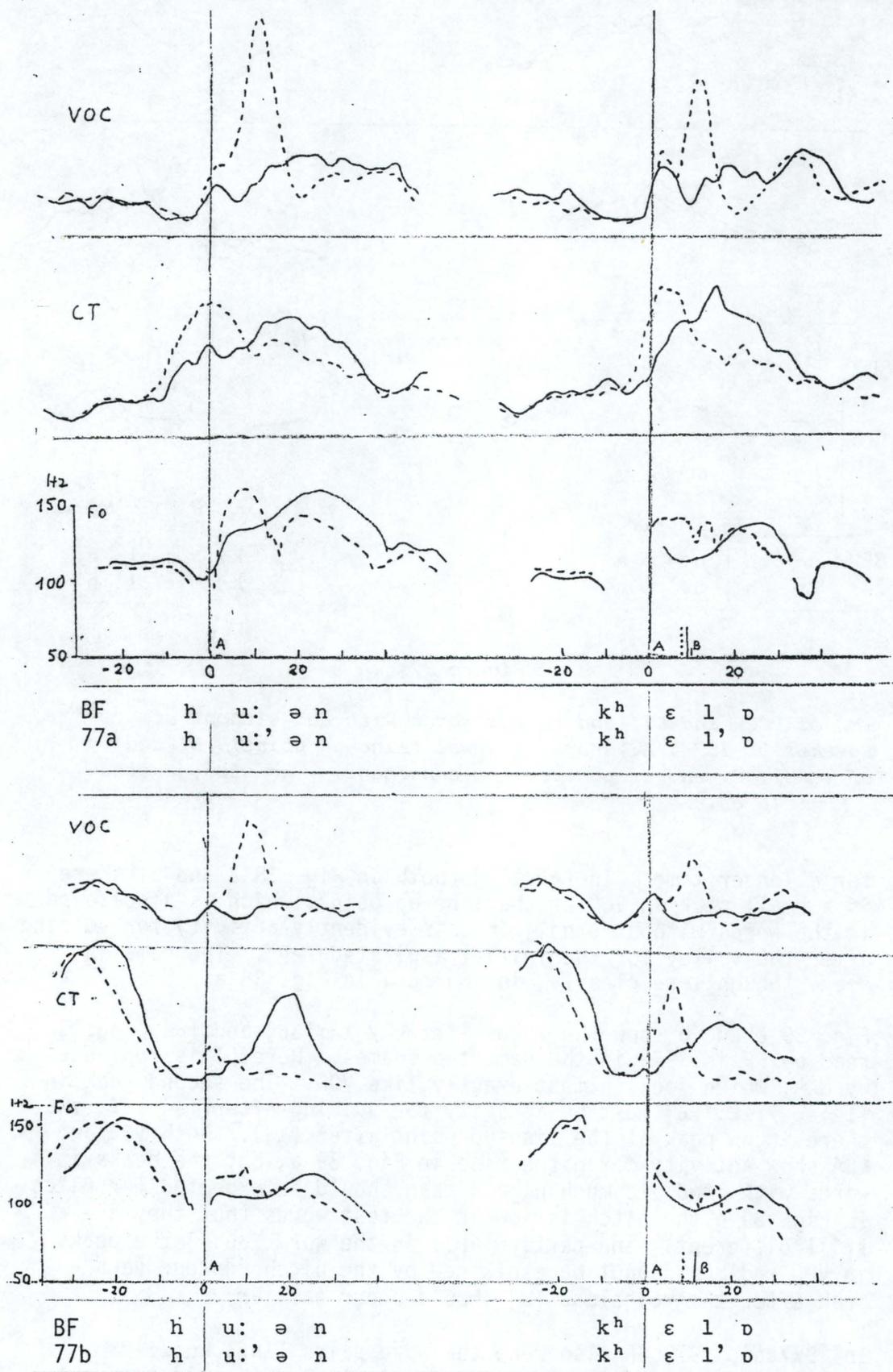
Figure 38

EMG of VOC and CT, and Fo for words with (---) and without (——) stød.
a: in the frame: [de: ... di sɪɒ], b: in the frame [di sɪɒ 'alə
...]. Speaker BF 1977. See legend to Fig. 37.
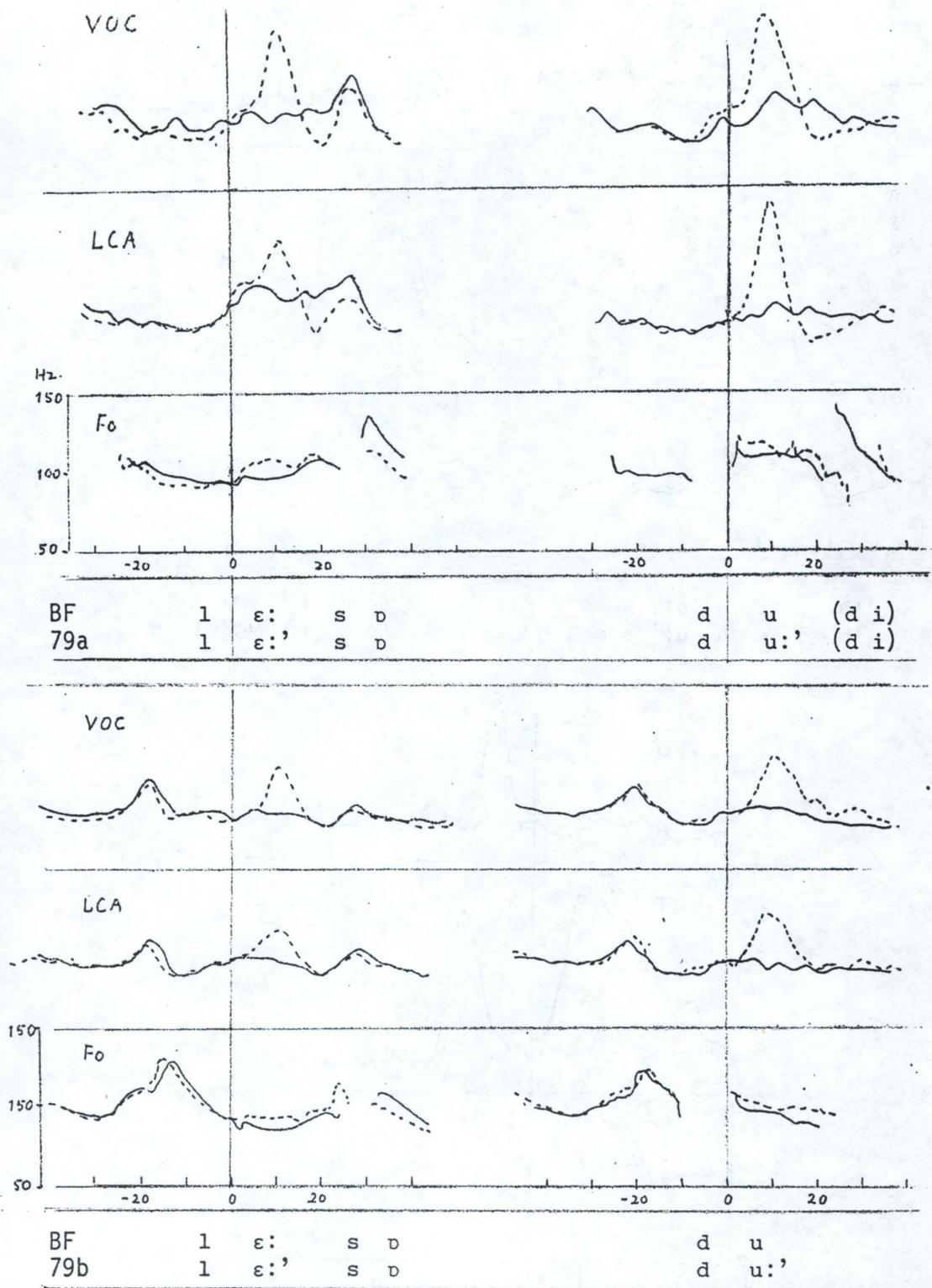
Figure 39

EMG of VOC and LCA, and Fo of words with (---) and without (——) stød. (a) in the frame [de: ... di siŋ], (b) in the frame [di siŋ 'ɔsə ...]. Speaker BF 1979. See legend to Fig. 37.
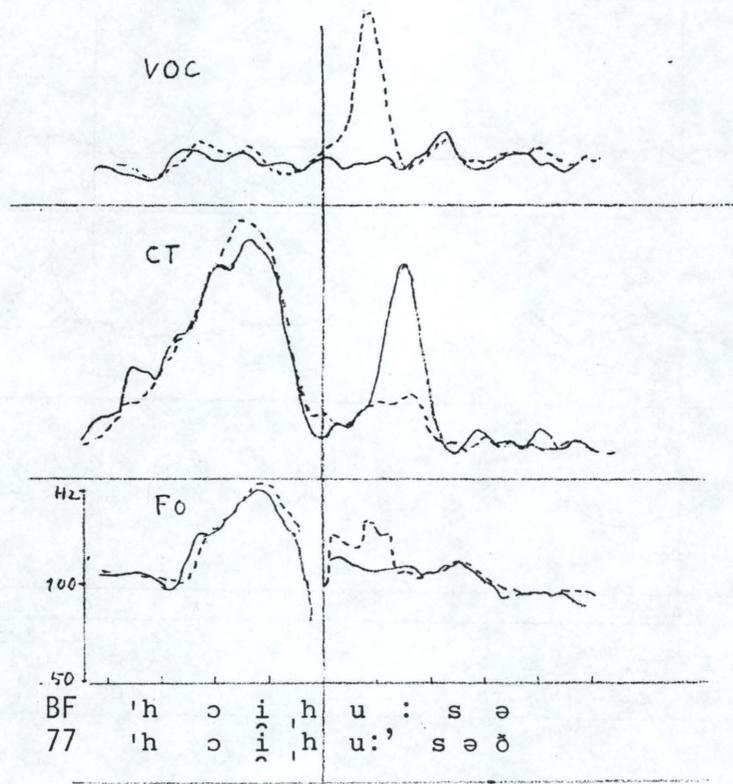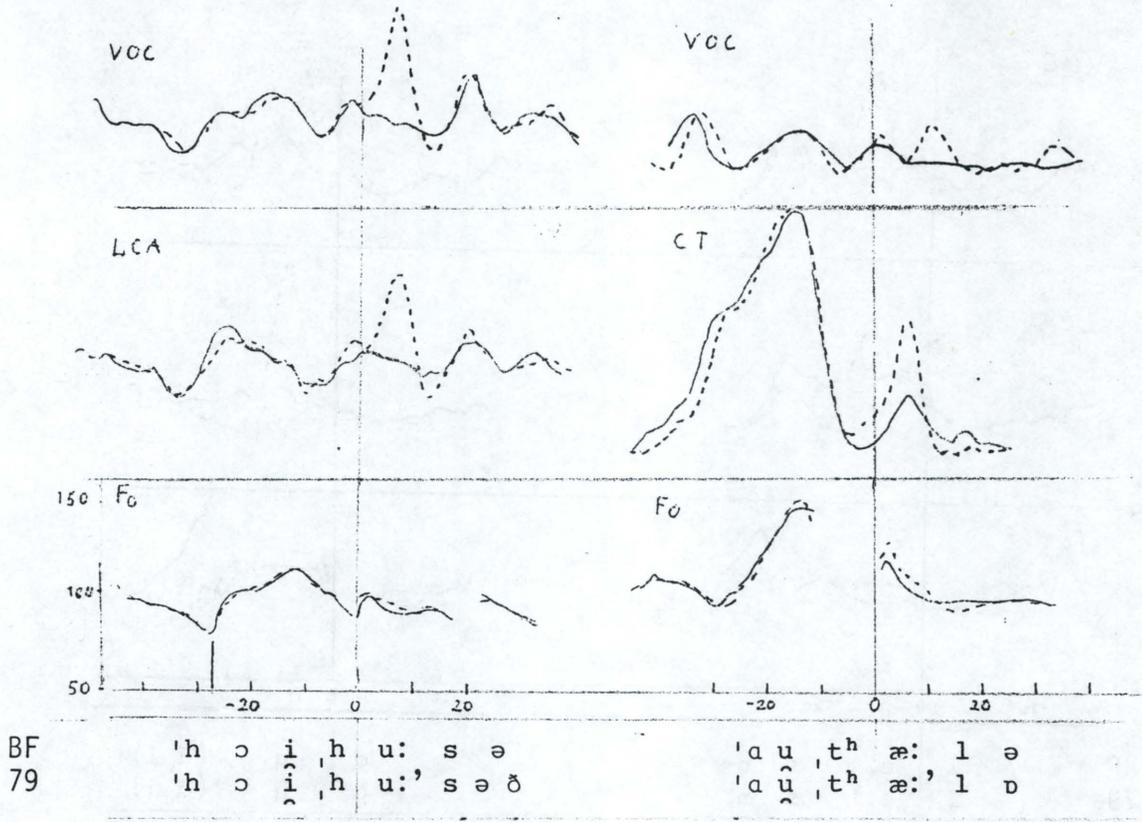
Figure 40
EMG of VOC and LCA, and Fo of words with (---) and without (——)
stød in secondary stressed syllables.   Speaker BF.   See legend
to Fig. 37.

in the words with and without stød, so that the peaks in VOC
and LCA must be for the stød. In Fig. 40 b the peak in VOC in
[æ:'] is rather low, but it should not be expected to be very
high for an [æ] (see below).

The conclusion is that the peaks found in VOC for stød-words
in BF's recordings may be somewhat influenced by the pitch con-
tour, but that the activity must be mainly for the stød. This
can be concluded from (1) the consistent temporal difference
between the peaks in VOC and CT (8 cs), which is smaller and
less clear when only pitch is involved, (2) the height of the
peak compared to the height for pitch rise alone, (3) the sharp
peak with quickly decreasing activity compared to the activity
for pitch, which remains high for a longer time.

As for CT, its behaviour can be almost completely understood
as activity for the pitch contour. In [hu:'ən] and [kʰɛl'ɒ]
1974 (Fig. 37) and in [hu:'ən] 1977 (Fig. 38 a) it has a dip
corresponding to the peak in VOC, which might be interpreted as
an inhibition (as assumed by Lindquist 1972) or as a prepara-
tion for the frequency dip during the stød, but in [kʰɛl'ɒ]
1977 (Fig. 38 a) it is too late for that. - On the other hand,
in [kʰɛl'ɒ] 1977 (Fig. 38 b) CT has a surprisingly high peak
for the rather low first syllable of the test word. This is
also the case for most other words in this series, i.e.
[kʰɛ:'lɒ, lɛ:'sɒ, pʰi:'bɒ, sɛn'], whereas [hu:'ən] has a re-
latively high peak in only 5 out of 16 examples, and there-
fore a low average peak (Fig. 38 b), and [du:'] has no peak.
In all these cases the test word comes after an emphatic word
with a strong and quick rise and fall of CT and Fo, and it may
therefore be necessary to make a new start (BF also often makes
a short pause before the test word). Words without stød have
a different pitch contour with rising pitch on the second syl-
lable, which may require a different CT-activity. The CT-peak
in ['ɑu̯ˌtʰæ:'lɒ] (Fig. 40 b) is more problematic. In this
case the pitch contour of the second part of the compound is
very similar in the words with and without stød. Nevertheless
the word with stød has a much higher CT-peak. Still more enig-
matic is the CT-peak in ['hɔi̯ˌhu:sə] in Fig. 40 c which, con-
trary to the preceding example, is found in the word without
stød (it is quite regular in all 12 tokens).

The other speakers give less problems. Fig. 41 shows the word
pairs [hu:ən / hu:'ən] and [vɛn / vɛn'] read by JJ with record-
ing of VOC, CT and Fo. He has very clear activity in CT for
pitch rise, but hardly any activity in VOC for pitch. (This
was also the case in the introductory identification test,
which contained strongly rising and falling tones.) Neverthe-
less he has high peaks in VOC in words with stød. They can
hardly have anything to do with pitch.

Fig. 42 shows the pairs [kʰɛ:lə / kʰɛ:'lɒ] and [vɛn / vɛn']
read by HU. Just like JJ, she has activity in CT for pitch
rise, but hardly any activity in VOC. The high peaks in VOC
in words with stød must therefore reflect activity for the stød.

JJ   h u: ə n   v   ε n   (di)
          h u: ʼ ə n   v   ε nʼ (di)

Figure 41

EMG of VOC and CT, and Fo of words with (---) and without (——)
stød. Speaker JJ 1974. See legend to Fig. 37.

HU   kʰ   ε: l ə   v   ε n   (di)
          kʰ   ε: ʼ l ɒ   v   ε nʼ (di)

Figure 42

EMG of VOC and CT, and Fo of words with (---) and without (——) stød.
Speaker HU 1974. See legend to Fig. 37.

Fig. 43 contains the word pairs [kʰɛːlə / kʰɛːʼlɒ] and [ɑu / ɑuːʼ] read by BM. In the identification test he has activity in VOC for pitch (except for falsetto), but it is very weak in the text. The peaks in words with stød are so much stronger than the small rise for pitch in words without stød that they clearly reflect activity for the stød.

Fig. 44 shows the word pairs [kʰɛlɒ / kʰɛlʼɒ] and [ɑu / ɑuːʼ] read by NR, with recording of VOC and LCA. The curves of these two muscles are very much alike. Both have activity for pitch rise, but the peaks in VOC and LCA in [kʰɛlʼɒ] cannot have anything to do with pitch, since in that case it would be much later (cp. the contour for the word without stød), and in [ɑu / ɑuːʼ] the pitch contours are almost identical and cannot in any way explain the peaks in VOC and LCA.

It is apparent from these examples that activity in VOC is closely connected with the stød. A final problem is whether it might be activity in order to obtain the right conditions for voicing after the glottal constriction. This was the interpretation which was suggested for INT activity prior to hard attack, and it has also been proposed for VOC by Fujimura (1977 a and b) for fortis consonants in Korean and for the [ʔ] in Swedish [jaʔa]. As far as the Swedish example is concerned, I think that the peak comes too early in the Skåne example to permit this interpretation. And as far as the activity in words with stød is concerned, this assumption can be refuted. In the first place there is very often voicing all through the stød, only with a dip in frequency, and in the second place clear peaks in VOC are also found in the cases where the stød occurs before a voiceless consonant (as in [lɛːʼsɒ]) or finally before a pause, e.g. [sɛnʼ] and [ɑuːʼ] in BF 1977 b and 1979 b (see Fig. 38 b and Appendix IX).

For all speakers the VOC activity tends to be stronger in words with high vowels and in monosyllables than in disyllables with [ɛ]. I cannot explain this tendency.

BF sometimes has a small dip in CT corresponding to the peak in VOC. But the other three speakers (BM, HU and JJ) do not have such a dip. Thus, in their speech at least, CT is only active for the higher start of the pitch in words with stød but does not seem to have anything to do with the stød phase or the dip in frequency concomitant with it. In the Swedish accent 2, on the other hand, which has a dip in pitch at the end of the first syllable in Standard Swedish, there is a corresponding dip both in VOC and in CT (Gårding 1970).

BM, HU and JJ have rising pitch in the unstressed syllable both after syllables with and without stød. Very often the activity in CT decreases in spite of a new peak in the following weak syllable, but that is also the case in words without stød, see, e.g., BM [kʰɛːlə / kʰɛːʼlɒ] (Fig. 43) and JJ [vɛn / vɛnʼ] (Fig. 41). Only HU maintains a high activity in CT. Otherwise it seems to be particularly active for the first rise.
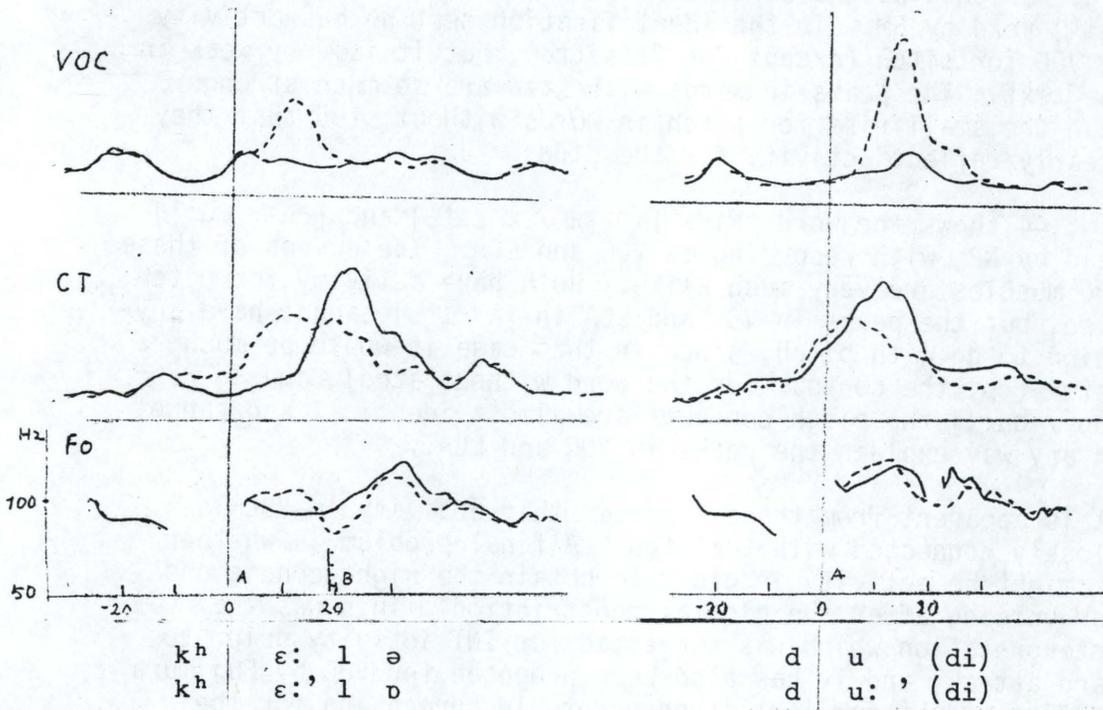
Figure 43

EMG of VOC and CT, and Fo of words with (---) and without (——) stød.
Speaker BM 1974. See legend to Fig. 37.
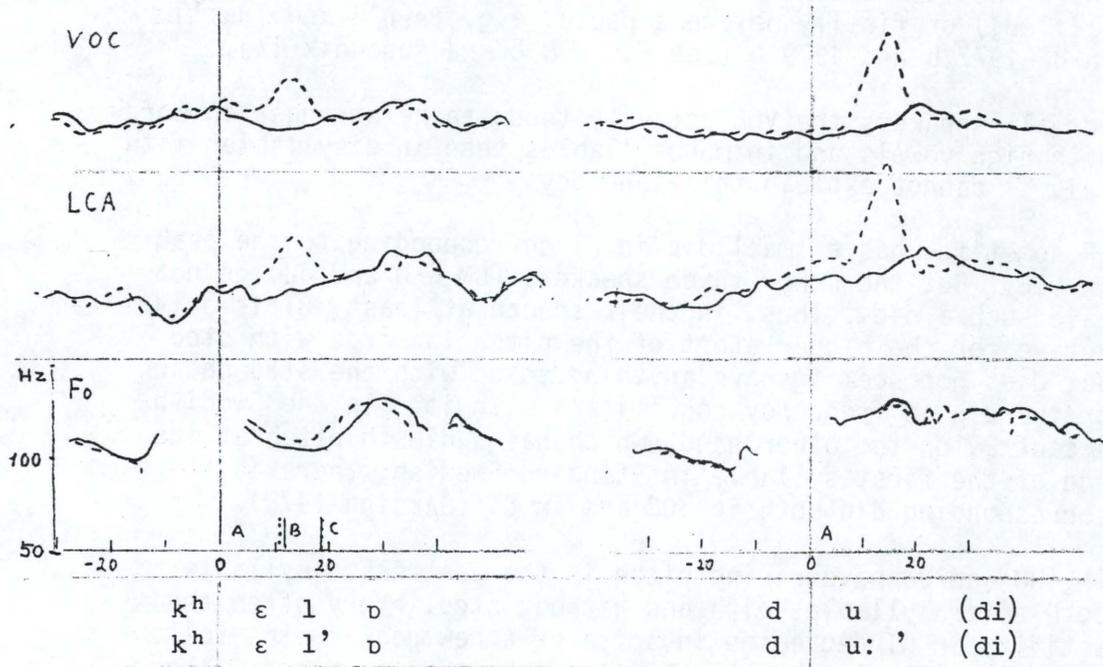
Figure 44

EMG of VOC and LCA, and Fo of words with (---) and without (——) stød.
Speaker NR 1974. See legend to Fig. 37.

For HU there is possibly a slight contamination with LCA since
her CT is active in swallowing. It is true that Faaborg-Ander-
sen (1957) found activity in CT for swallowing in a number of
cases, but he used needle electrodes which may move, particu-
larly during swallowing, and according to Hirose's clinical ex-
perience (based on thousands of cases) CT is always suppressed
in swallowing (personal communication, see also Hirose 1971).

VOC and LCA were also found to be active for hard attack for
BF, and in this case the activity is often still stronger than
for the stød. In 1977 and in 1979 he was asked to include the
word [alə] as a test word and to pronounce it partly with soft
attack and partly with hard attack. He did not always succeed
in pronouncing it with soft attack, but a comparison between
the cases with soft or moderately hard attack and the cases with
an evident hard attack shows a clear difference (see Fig. 45).
The 1979 recording showed the same activity in LCA. CT does
not show any inhibition. On the contrary, it has a small peak
(cf. that Lindquist 1972a found CT inhibition in glottal stop,
and Gårding (1971) found decrease in CT-activity in [ʔ] as a
boundary signal in Swedish). Activity in VOC was also found in
occasional hard attacks in the recordings of other speakers and
in a large number of cases in a recording of a German subject.
The peak coincides with the start of the hard attack, and it is
therefore highly probable that it is activity for glottal con-
striction, not for voicing after the glottal constriction.

Group 2

In JR's and BH's VOC recordings it was not possible to see any
difference between words with and without stød. JR read list 1
only twice in the first session and once in the second session,
because the tape-recorder broke down in the first session, and
the recording had to be interrupted in the second session.
This list has therefore not been averaged. But list 2 ([bibibi]
words) was read 10 times and has been averaged. Fig. 46 shows
"VOC", CT and Fo for two word pairs ['bi:bi‚bi:'bi/'bi:'bi‚bi:'bi]
and [bibi'bi:bi/bibi'bi:'bi]. "VOC" and CT look practically
alike, and the relatively small extra activity for the syllables
with stød can be explained completely by the Fo contour. For
comparison BM's VOC of the same pairs is given below.

BH's recording was not computer-averaged, but four pairs were
averaged manually. It is not possible to compare her VOC with
her "CT", because it was evidently not CT, but perhaps the ster-
nohyoid or a contamination. Fig. 47 shows her VOC for the
pairs [vɛn / vɛn'] and [kʰɛ:lə / kʰɛ:'lɒ]. In [vɛn'] there is
slightly more activity than in [vɛn], but there is extensive
overlapping; the same was the case for [pʰi:'bɒ / pʰi:bɒ],
whereas [lɛ:sɒ / lɛ:'sɒ] and [kʰɛ:lə / kʰɛ:'lɒ] are quite alike.

There are two possible explanations of the missing activity in
VOC: (1) The muscle aimed at was not reached, and (2) these
speakers do not use their vocalis muscle but some other muscles
for the stød. They both had an acoustically and perceptually
clear stød.
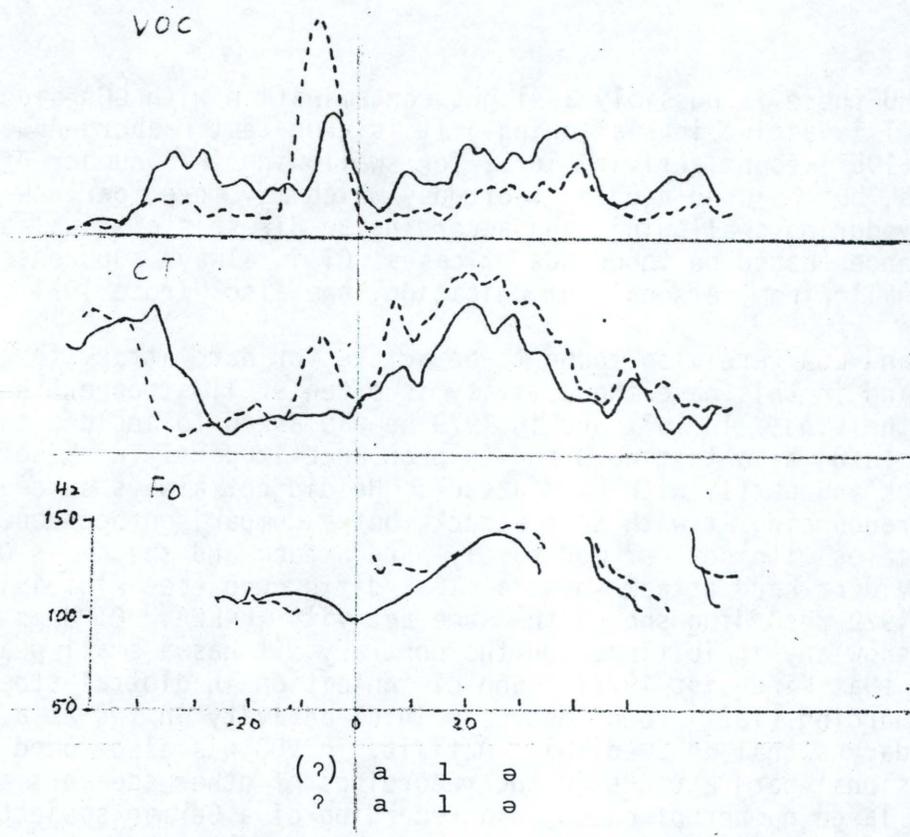
Figure 45

EMG of VOC and CT, and Fo in words with soft (or moderate)
glottal attack (——), and with hard attack (---).
Speaker BF 1977. See legend to Fig. 37.

(1) BH's VOC seems in many respects in accordance with expec-
tations. In the identification test it reacted to swallowing,
to voicing and very clearly to [ʔa ʔa ʔa], but not to pitch,
and it has clear valleys for voiceless consonants. Birgit
Hutters (1984) accepted it as a good VOC. According to its
reactions it might be INT, but it is hardly possible to hit
INT when aiming at VOC. A better guess is perhaps that the
wire has slid somewhat outwards, as it did in the case of CT,
and that it was rather the lateral part of the thyro-arytenoid
muscle, also called thyromuscularis, not the inner part, the
vocalis proper, which was recorded. These two parts seem to
be anatomically somewhat different (Bowden 1974, p. 297), and
may not have quite the same function. But not all scholars
think that it is possible to make this distinction (e.g. Zem-
lin 1981), and those who make the distinction do not ascribe
the same function to thyromuscularis. Some (e.g. Daniloff
et al. 1980) assume that its function is to shorten and relax
the vocal folds, others (e.g. Broad 1973, Sonesson 1968, and
Laver 1980) assume that it may help closing the glottis by
drawing the vocal processes together (like LCA). In the latter
case it should be supposed to be active in the stød.

STØD IN STANDARD DANISH
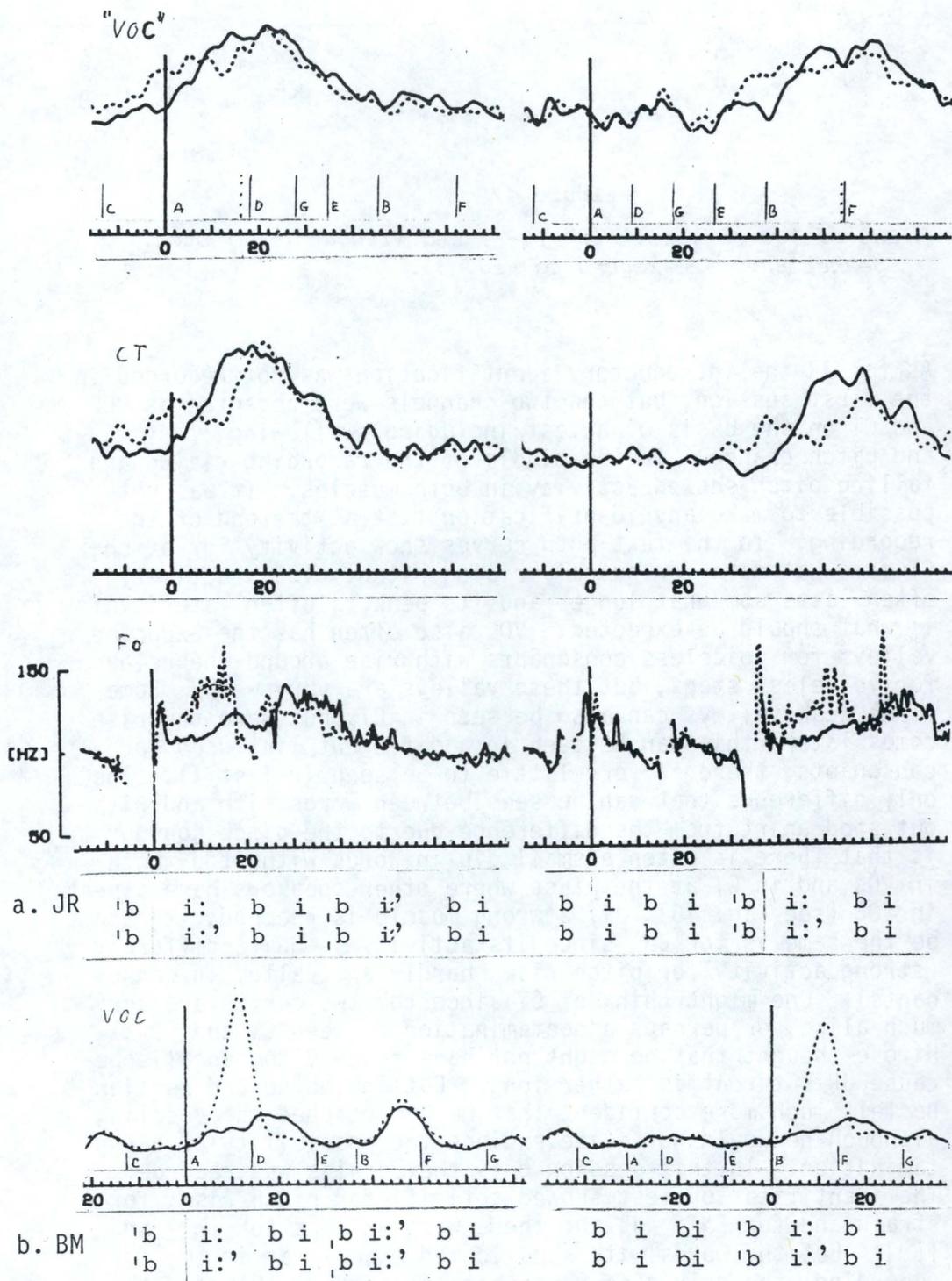
Figure 46

a. EMG of "VOC" and CT, and Fo of words with (---) and
without (——) stød in the first and the third syllable.
Speaker JR 1974.
b. VOC of the same words read by BM. See legend to Fig. 37.

v	ε	n			kʰ	ε :	l	ə
v	ε	n'			kʰ	ε :'	l	ɒ

Figure 47

EMG of VOC of words with (---) and without (——) stød.
Speaker BH. See legend to Fig. 37.

As for JR the introductory identification was not recorded in
the first session, but the two channels were accepted as VOC
and CT on the basis of a test including swallowing, [ʔ ʔ ʔ]
and pitch change. In the middle of the recording rising and
falling pitch showed activity in both muscles. It was not
possible to make any identification test at the end of the
recording. In the text both curves show activity for pitch,
CT somewhat more for quickly rising pitch. VOC's activity
often lasts somewhat longer and its peak is often later. This
is what should be expected. VOC also often has the expected
valleys for voiceless consonants with rise around the release
for voiceless stops, but these valleys are very weak. Some-
times weak valleys can also be seen in CT, but here the rise
comes later (this can be seen in a different list used for
consonants; there is very little to be seen in list 1). The
only difference that can be seen between words with and with-
out stød apart from the difference due to the pitch contour
is that there is often a small dip in words with stød, both
in VOC and in CT at the place where other speakers have a peak
in VOC (see Fig. 46). If a wrong muscle is reached, it cannot
be the same as for BH, since its activity is quite different
(strong activity for pitch rise, hardly any valley in conso-
nants). One might think of CT since the two curves are very
much alike, or perhaps a contamination between CT and VOC.
Hirose thought that he might not have reached the vocalis be-
cause JR's throat is rather long. But in the second session
he felt much more confident that he had reached the vocalis,
although he would not quite exclude the possibility of a con-
tamination. In this session only the vocalis was recorded.
The identification test showed activity for pitch rise, for
strain and for [ʔ ʔ ʔ], and there were valleys for [pʰ] and
[tʰ]. But the words with stød looked exactly as in the first
recording, the only difference between words with and without
stød consisting in an earlier rise in the first case because
the syllable was higher (as was also the case in the first
recording) (see Fig. 46).

(2) Particularly in JR's case much speaks in favour of the
second explanation, viz. that this subject does not use his
vocalis muscle in the stød. It should be remembered that
although his stød sounds exactly like that of other speakers,

it differed acoustically by often having a rising Fo with small
irregularities and no Fo dip. Moreover, the fiberoptic pic-
tures of his vocal folds showed a very strong constriction be-
tween the ventricular folds, so that his vocal folds could prac-
tically not be seen. BH also had a stronger contraction of her
ventricular folds than most of the other subjects, but not as
strong as in the case of JR. However, BF and BM, who have ac-
tivity in VOC, also have adduction of the ventricular folds.
A constriction of the larynx above the vocal folds in glottal
stops was found by Lindquist, e.g. in [ʔ ʔ] used in the case
of hesitation in Swedish (1969, 1972 a and b). He is of the
opinion that a contraction of the sphincter muscles including
the aryepiglottic sphincters is important in laryngealization
and that a glottal closure can be made without assistant activity
in VOC. An increase of activity in the aryepiglottic sphincters
results in a shortening and thickening of the vocal folds, and
it also serves as a pitch lowering mechanism. Simultaneous ac-
tivity in VOC serves to keep the pitch high. He also explains
the low pitch in the Danish stød by this contraction. It is
possible that JR and BH use this mechanism, but just JR did not
have regular pitch drop in the stød. Catford (1977) criticizes
Lindquist for generalizing one possible way of making a glottal
stop. Unfortunately JR's and BH's sphincter muscles were not
recorded, nor has any recording been made of their LCA.
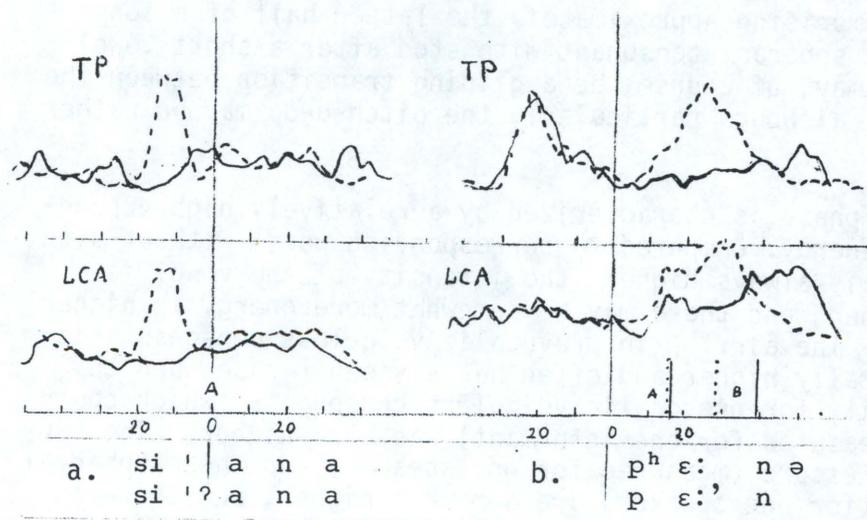
Figure 48

a. *EMG of LCA and TP in hard (---) and soft (———) attack.*
   Speaker FJ. Line-up point start of vowel.
b. *EMG of LCA and TP in words with (---) and without (———)*
   stød. Speaker FJ. Line-up point start of implosion in
   [p]. A.start of [ɛ(:)], B. end of [ɛ(:)]. See legend
   to Fig. 37.   ⊢⊣ 10 cs.

In 1977 a recording of FJ's LCA and thyropharyngeus (TP) was
undertaken at the Haskins Laboratories in cooperation with
Seiji Niimi. FJ read list 6 (with 20 repetitions) containing
examples of stød and of hard attack (see Appendix I). There
was a very clear peak in both muscles for hard attack (see Fig.
48a). There was also activity in both muscles for strong stød
like [pʰɛ:'n]and [pʰɛn'] said rather vigorously (see Fig. 48b).
In [li:'] there was a clear peak in LCA but not in TP. But in
disyllables like [kʰɛ:lə / kʰɛ:'lɒ] the difference was very
small in LCA, and there was hardly any difference in TP. It
must, however, be remembered that in FJ's fiberscope recordings
there was hardly any adduction of the ventricular folds. TP
showed strong activity for the pharyngealized Danish [ʁ], and
for the ending -er, pronounced as a pharyngealized [ɒ] by this
speaker. The peak at the start in Fig. 48b is probably due to
a certain pharyngealization of the [æ:] in [sæ:] as a sort of
boundary signal before the test word. There is no peak in
[si:], nor in [tʰæ:lə].

IV. SUMMARY AND DISCUSSION
A. SUMMARY

In the preceding sections the stød has been described from dif-
ferent angles. In accordance with Svend Smith (1944) a dis-
tinction was made between the first phase, i.e. approximately
the first half of a long vowel or a short vowel before a sono-
rant consonant, and the second phase, the phase of the stød
proper, comprising approximately the latter half of a long
vowel or a sonorant consonant with stød after a short vowel,
but there may, of course, be a gliding transition between the
two parts, although particularly the pitch-drop may be rather
abrupt.

The first phase is characterized by a relatively high expend-
iture of energy: Compared to corresponding words without stød
the pitch is always higher, the intensity of the vowel is
often higher, and there may be somewhat more energy in higher
formants. The airflow in prevocalic voiceless consonants is
also generally higher and often has a steeper rise, and the
PCA-activity for prevocalic voiceless consonants (which could
only be measured for one informant) was also higher. The sub-
glottal pressure (measured for one speaker) and the esophageal
pressure (for one speaker) are somewhat higher, and there is
a (relatively weak) tendency for the pharyngeal pressure to
be higher in the initial consonant. Whether the larger con-
tact area in palatograms of vowels with stød belong to this
first phase cannot be decided. The difference in airflow was
not found in monosyllables, and the pitch difference was also
smaller in monosyllables, but in most monosyllables a short
vowel without stød was compared to a long vowel with stød,
and the smaller difference might be due to a tendency for
words with short vowels to have relatively higher pitch and
airflow.

The second phase, the stød proper, is characterized by a
strong fall in intensity (which, however, starts already
during the first phase, except for HU), and very often by a
decrease in fundamental frequency followed by or combined with
irregular vibrations (but BRP and often JR have rising Fo).
Moreover, there is a tendency to a decrease in the level of
the lower harmonics; inverse filtering shows a decrease in
the negative spikes, and the integrated curve (the flow curve)
shows a decrease in glottal flow and a longer closure time.
There is also lower oral airflow and a tendency to lower phar-
yngeal pressure; and there is decrease in subglottal pressure,
but it is still slightly higher than in the words without stød.
Fiberscopic pictures of the larynx show constriction of the
vocal folds and adduction of the ventricular folds, but with
large interindividual variation. Relatively high subglottal
pressure combined with low airflow also points to glottal con-
striction. Finally, five out of seven (and if the Haskins in-
vestigation is included, seven out of nine) speakers show a
consistent strong activity of the vocalis muscle starting during
the first phase of the vowel, but with its peak shortly after
the start of pitch decrease or irregular vibrations, thus pre-
paring for the second phase. LCA showed a similar peak in the
cases where it was measured (three subjects plus one from the
Haskins investigation).

Finally, long vowels with stød were found to be significantly
shorter than long vowels without stød (but only in distinct
speech), whereas sonorant consonants with stød were significant-
ly longer than sonorant consonants without stød.

B. DISCUSSION

1. THE STØD AS A PHONATION TYPE

In some of the preceding sections the stød was compared to
creaky voice. It may be useful now at the end to take these
scattered observations up again and raise the problem of the
stød as a phonation type. This is not a simple question, since
phonation types are described differently by different scholars,
and the terminology is by no means unambiguous; and moreover,
the stød is not always implemented in the same way.

Catford (1977) defines phonation as any laryngeal activity of
speech that has neither initiatory nor articulatory function.
According to this definition the difference between chest voice
and falsetto should be included, but they are generally treated
as two registers within normal voicing, probably because this
difference does not seem to have any linguistic function.
Hollien (1974), however, sets up three registers, distinguished
by their fundamental frequency domain: loft (= falsetto),
modal (= normal voice) and pulse register. The latter is iden-
tified with creak (or vocal fry), which by other scholars is
placed in the system of phonation types as a step in a dimension
of glottal stricture.

Ladefoged (1971 and 1973) describes the different phonation
types in one dimension according to glottal stricture with in-
creasing stricture from voiceless sounds over breathy voice,
murmur, lax (slack) voice, normal voice, tense (stiff) voice,
creaky voice, creak, and ending with glottal stop. This is a
gliding scale, and he does not always distinguish between creak
and creaky voice or between murmur and breathy voice.

Catford (1964 and 1977) also uses the dimension of stricture,
comprising breath, whisper, voice and creak. Creaky voice and
murmur are not considered as steps in this scale, but as com-
binations (creaky voice as a combination of creak and voice,
and murmur as a combination of whisper and voice). Tense voice
is considered to belong to a different dimension called location
and comprising full glottal, anterior and ventricular location.
He considers tense voice to be produced with closed cartilagenous
glottis, so that only the membranous part vibrates (hence the
name "anterior"). These dimensions may be combined in different
ways. Both whisper and voice may be anterior, and creak
often, but not necessarily, is anterior. The cartilagenous part
of the glottis is narrow, but there need not be any active com-
pression.

Lindquist (1969, 1972a) also uses the stricture dimension, cal-
led "adduction", and comprising voice, lax voice, breathy voice
and voiceless, thus starting from Ladefoged's mid point: voice.
The other end of Ladefoged's stricture scale (voice, creak and
glottal stop) is considered to be a different dimension called
laryngealization. Creaky voice is lax creak, and whisper is a
laryngealized form of breathy voice or voiceless.

Finally Halle and Stevens (1971) sets up a rather different
system comprising four binary features: ± constricted, ± spread,
± stiff and ± slack (i.e. two dimensions with three steps in a
binary formulation). According to this system breathy vowels
are + spread, - constricted, - stiff and + slack, whereas creaky
voice is - spread, + constricted, - stiff and + slack. But
creaky vowels are distinguished from glottalized vowels, which
are also - spread and + constricted, but + stiff and - slack.

In a paper on articulatory parameters (1979) Ladefoged distin-
guishes between glottal aperture and glottal tension. Of course,
articulatory parameters, i.e. parameters that need to be con-
trolled in a model of speech production, are not the same as
linguistic features. Nevertheless, it is conspicuous that he
now states that glottal aperture is relevant for voiced-voice-
less, whereas glottal tension determines phonation types. He
thus seems to have modified his system.

Laver (1980) gives extensive summaries of the preceding litera-
ture (except for Halle-Stevens). He describes the following
main types: modal voice, falsetto, whisper, creak, harshness
and breathiness. Like Catford he sets up combined types, e.g.
creaky voice, harsh voice, etc., and like Catford he treats
tenseness separately, but in contradistinction to Catford he
includes supralaryngeal tension in this type.

In spite of all these different systems there is, fortunately,
a good deal of agreement on at least some of the characteristica
of the individual phonation types, e.g. breathy voice and creak.

The Danish stød is mentioned by various authors. Catford (1964)
says (cautiously) that creaky voice may be one form of the
Danish stød. Abercrombie (1967, p. 101) also mentions the
Danish stød as creaky voice, and both of them have had good
opportunity to listen to Danish. Ladefoged (1983) does not use
this label, but says that *"the Danish glottal catch .. may also
be considered an additonal phonation type"*. Thus he is not cer-
tain that it can be identified with any of the current types.
Finally, Halle and Stevens (1971) describe the Danish stød as
glottalized. As mentioned above, this feature differs from
creaky voice in their system by having stiff vocal folds. But
since in this system stiffness is correlated with high pitch,
and since vowels with stød often start on a high pitch followed
by a fall, they suggest that the first part of a vowel with stød
is + constricted + stiff and then changes into - constricted
- stiff. This is obviously in contradiction to the facts, since
it is always the second part of the vowel that shows constric-
tion in the glottis, not the first part (see particularly the
section above on the fiberscope investigation, but the same is
apparent from oscillograms, airflow curves, etc.). But it is,
of course, correct that the first and the second part of a vowel
with stød cannot be described as belonging to the same phonation
type.

The phonation types which may be relevant for a description of
the stød are tense phonation, creaky voice, creak and, perhaps,
harsh voice.

It is evident that the second phase of the stød, the stød proper,
belongs in the constricted end of Ladefoged's stricture dimen-
sion. Perhaps one might describe an exaggerated stød as a glot-
tal stop, a strong stød as a creak, and a milder stød as creaky
voice. The perceptual effect of a creak is described by Catford
as the sound of a stick being run along a railing, i.e. the
pitch is so low that the single pulses are perceived. The dis-
tance between them may be irregular. The wide band spectrogram
of a creak in Laver 1980, p. 115 looks very much like a strong
stød (see, e.g., the spectrogram of PD, p.121 above). Creaky
voice is also generally considered to have low pitch (Zemlin
1981, Ladefoged 1973, Catford 1964), but Ladefoged states that
this tendency, which he ascribes to a shortening of the vocal
folds, may be counteracted by activity in other muscles, e.g.
CT, and it is not unusual to find creaky voice combined with
higher tone levels in tone languages (see also Matisoff 1973).
Moreover, creak and creaky voice are characterized by a low
level of Fo (Löfqvist et al. 1983), particularly compared to
F1 (Ladefoged 1983, Kirk et al. 1984) and the glottal wave is
characterized by a long closure time (Zemlin 1981, Kitzing et
al. 1982, Javkin and Maddieson 1983) and low glottal flow
(Catford 1977, Hollien 1974). It is also characterized by
period to period variation in fundamental frequency (Monsen
and Engelbretson 1977) also called jitter (Kirk et al. 1984,

Javkin and Maddieson 1983). There is often constriction in
the larynx, the vocal folds are close together (Ladefoged 1973,
Catford 1977, Zemlin 1981), and there seems to be medial com-
pression (Laver 1980). There may also be adduction of the
ventricular folds (Hollien 1974).

All these features were also found in the preceding analysis
of the Danish stød. There is some disagreement concerning the
tension of the vocal folds in creaky voice. Some find that
they are close together but with relatively loose borders
(Zemlin 1981, Catford 1977), others consider them as stiff,
thus apparently Ladefoged (1973). The degree of stiffness in
the borders of the vocal folds in the stød cannot be decided
on the basis of the fiberoptic pictures.

There are, however, also some divergencies between the descrip-
tion of creak and creaky voice and the properties found for
the stød. In the first place all authors agree that in creak
and creaky voice the cartilagenous glottis is very narrow,
whereas there is an opening in the front, and most assume that
the cartilagenous part of the folds do not take part in the
vibrations (Ladefoged 1974, Catford 1977), whereas Abercrombie
(1967) assumes that they vibrate at a slower rate than the
membraneous part. (Ladefoged has given a similar description
earlier in his analysis of laryngealization in some West
African languages (1964), i.e. separate vibration of the two
parts.) In the fiberoptic pictures of the vocal folds only
BF and JR showed earlier narrowing of the posterior part, for
HU it was rather the opposite, for the others it was difficult
to decide, but nothing pointed to a particular narrowing of
the cartilagenous part. It is at any rate not a dominating
or conspicuous feature of the stød. In this case one should
also expect a particular activity in INT, and it should be re-
membered that INT, which as a pure adductor muscle is active
in voicing, is not active in the stød. Only those adductor
muscles which are at the same time tensor muscles (VOC and LCA)
are active in this case. This, by the way, speaks against
placing all phonation types in a single dimension. - To my
knowledge, nobody has made electromyographic recordings of the
activity of the muscles in creak and creaky voice; but strong
vocalis activity has been found for glottal stop, e.g. in hard
attack (Gårding 1970, Hirose and Gay 1973) and in Korean forced
stops (Hirose et al. 1973), which have closure in the posterior
part of the glottis and a small opening in the front (Kagaya
1974) .

In the second place, the most consistent acoustic feature of
the stød, i.e. the decrease of overall intensity, is never men-
tioned for creak or creaky voice. On the contrary, Javkin and
Maddieson find steeper slopes in the glottal wave in creaky
voice and mention that the consequence of steeper slope in the
closing phase of creaky voice is higher intensity and intensity
of higher overtones, adding that this is characteristic of
creaky voice. A steep closure phase in creaky voice was, as men-
tioned (p. 130), also found by Roach and Hardcastle (1979) and
by Esling (1984), and there were indications of this in BRP's
flow curves. However, this effect must be counteracted by

the low flow amplitude. - Finally Catford (1977) says that
there is very low subglottal pressure in creak. But BF's sub-
glottal pressure and FJ's esophageal pressure did not show
this. The pressure was decreasing but still higher than in
normal vowels.

Thus many features are identical for creak or creaky voice and
stød, but it is not quite the same. Stød is not _just_ creaky
voice.

The concept of harshness may also be relevant for the stød.
According to Laver (1980), who refers to a number of investi-
gations, the predominant characteristic of harshness is aperi-
odicity of the fundamental frequency, and there is strong
laryngeal and pharyngeal tension. In strong harshness the ven-
tricular folds are also involved. MacCurtain (1979) mentions
constriction in the laryngopharynx and emphasizes that the
pharynx should not be neglected in the description of voice
qualities. Harsh voice seems to be used paralinguistically as
a sign of anger. But the properties described also apply to
the stød. Some cases of strong stød may perhaps be described
as harsh creaky voice. But the irregularity in the stød is
not just a question of fundamental frequency; there is also
irregularity in intensity.

The first part of vowels with stød has some features in common
with what is often called tense, tight or pressed voice, i.e.
a relatively high subglottal pressure (Laver 1980), relatively
strong higher overtones and overall intensity (Laver 1980,
Sundberg and Gauffin 1979) and more articulatory energy (Laver
1980). But other features mentioned as characteristic of
tense voice are practically the same as those mentioned for
creaky voice, e.g. low Fo compared to F1 (Sundberg and Gauffin),
low flow pulses (Rothenberg 1972), closed cartilagenous glottis
(Catford 1977), constriction of the glottis, medial compression
(Laver 1980), and these features are not characteristic of the
start of the vowel with stød. For BRP low flow and shorter
negative spikes in the inverse filtered curve start rather
early in the vowel, but not quite at the start; for FJ the
shortening of the negative spikes starts later. And only BRP
and FJ had relatively low Fo compared to F1 in the beginning
of the vowel, whereas the others did not show any difference
in this respect between vowels with and without stød. At the
start of the vowel the fiberscope pictures also looked quite
alike for vowels with and without stød.

Thus a syllable with stød may be said to start with a relative-
ly strong expenditure of energy, but it is not what is called
tense or tight phonation in the literature.

2. CAUSAL RELATIONS BETWEEN THE PROPERTIES
    OF THE STØD

An important factor when one is looking for causal relations
is the temporal relation between the properties investigated.

In this connection the recordings of BF in 1974 are particu-
larly useful since a large number of different types of re-
cordings were made at the same time: electromyography of VOC
and CT, subglottal pressure, pharyngeal pressure and airflow
as well as the audio signal, which permitted measurement of
duration, fundamental frequency and intensity. The discussion
will therefore be based mainly on BF 1974. In Fig. 49 a-d
the different curves are placed in a vertical column with the
same line-up point.

As mentioned in the introductory chapter, Svend Smith proposed
the theory that the dominating factor in the production of
the stød was a quick contraction and relaxation of the ex-
piratory muscles, causing an abrupt rise and fall in subglottal
pressure. The vocal folds are supposed to react to the pres-
sure rise by a constriction of the glottis (there is thus no
primary contraction in the larynx). The following abrupt fall
in subglottal pressure causes a fall in intensity and sometimes
in frequency, and if the tension in the vocal folds is not
adjusted sufficiently to the quickly falling subglottal pres-
sure, irregular vibrations may result.

In the first place we must therefore ask: which of the stated
differences between words with and without stød can be caused
by the change in the subglottal pressure contour? It was found
(see p. 151 above) that BF's subglottal pressure was about
1 cm H_2O higher in words with stød, the difference starting at
vowel onset (in [lɛ:'sɒ] and [hu:'ən]) or 5-10 cs earlier.
In aspirated consonants there is a small difference in pressure
during the aspiration, which might perhaps explain the slight-
ly higher airflow (but a wider glottis opening cannot be ex-
cluded). The higher subglottal pressure may also be respon-
sible for the tendency to higher intensity at the start of
the vowel. The difference between vowels with and without
stød was on the average 1.7 dB. According to Flanagan (1958)
3 cm H_2O may cause a rise of 5 dB (= 1.7 dB per cm H_2O), and
MacNeilage (1972) mentions 0.5 - 3 dB per cm H_2O (largest
effect at low levels).

However, the fall in intensity in the stød cannot be due to
the fall in subglottal pressure, since the intensity often
starts falling earlier than the subglottal pressure. For BF
the intensity decrease starts on the average 5.8 cs after the
start of the vowel (in the 1974 recording 4.3 cs), whereas the
fall in subglottal pressure in, e.g., [lɛ:'sɒ] and [hu:'ən]
is much later (around 15 cs after vowel start). In [pʰi:'bɒ]
and [kʰɛ:'lɒ] it is earlier (3-5 cs after vowel start), but it
is slow, and a decrease of, on the average, 1.5 cm H_2O in
[pʰi:'bɒ] and around 1.0 cm H_2O in [kʰɛ:'lɒ] cannot explain
a decrease in intensity which for all speakers is from 10-13
dB. It was not measured for BF, but his intensity curves show
a drastic fall.

The recording of esophageal pressure for FJ was not calibrated, but the temporal relations can be observed: in two of the four words (each comprising 10-14 repetitions) the decrease in esophageal pressure and intensity is approximately simultaneous, in the other two the intensity decrease starts 3-4 cs earlier (and it starts earlier in 29 out of 44 individual cases in the four words). At the end of the vowels with stød the esophageal pressure is of the same height (two word pairs) or definitely higher (two pairs) than in the corresponding vowel without stød (see Appendix VII, Fig. 2).

The pitch decrease starts later than the intensity decrease, for BF on the average 9.2 cs after the vowel onset, but still too early to be caused by the decrease of subglottal pressure in e.g. [hu:'ən] and [lɛ:'sɒ], and it is often much too extensive to be explained by the slow and small decrease in subglottal pressure. In [kʰɛ:'lɒ], for instance, the drop in Fo for BF is on the average 15 Hz, and the drop in subglottal pressure during the same time is less than 1 cm H_2O.

As for the high pitch at the start of vowels with stød found in the present investigation and by Riber Petersen (1973) but not by Smith, it cannot possibly be explained by the higher subglottal pressure. For BF 1974 this difference was on the average 27 Hz for long vowels and 19 Hz for short vowels, measured at the maximum, and even Lieberman, who goes farther than anybody else in assuming frequency rise to be due to subglottal pressure, mentions 3-18 Hz per cm H_2O (the highest effect for low intensity, and BF used a rather loud voice (Lieberman et al. 1967)). The general assumption is 2-5 Hz / cm H_2O (e.g. Ohala and Ladefoged 1970, Ohala 1978, Shipp 1982, MacNeilage 1972, Marchal and Carton 1980 and Baer 1979).

The next question to be asked is whether the subglottal pressure change can be the cause of the vocalis contraction. The extra rise in subglottal pressure starts sometimes 3-4 cs before and sometimes 3-5 cs after the start of the extra rise in vocalis activity. The peak is in most cases earlier than the VOC peak (5-9 cs in [pʰi:'bɒ, kʰɛ:'lɒ, kʰɛl'ɒ, vɛn'] and [vɛn'n̩]). This means that it is at least excluded that it can be the glottis constriction which gives rise to the extra subglottal pressure (the fiberoptic pictures also showed that the strong constriction comes in the latter half of the syllable, about the time when the pitch starts falling). The timing difference in most cases permits the hypothesis that the vocalis activity might be a reaction to the rise in subglottal pressure. According to recent research the larynx contains various reflex organs which may react to raised pressure and to a consequent stretching of the tissue. Only a restricted number of spindles have been found (but Baker (1971) found some). There are, however, a number of spiral endings, both in the mucosa, in the muscles and in the joints (see Wyke 1967, 1974 and 1983), and there are afferent fibres in the recurrent nerve feeding the intrinsic muscles (with the exception of CT) (Bowden 1974), which can bring the information to a higher center. The problem is how fast this system works. In the discussions in the
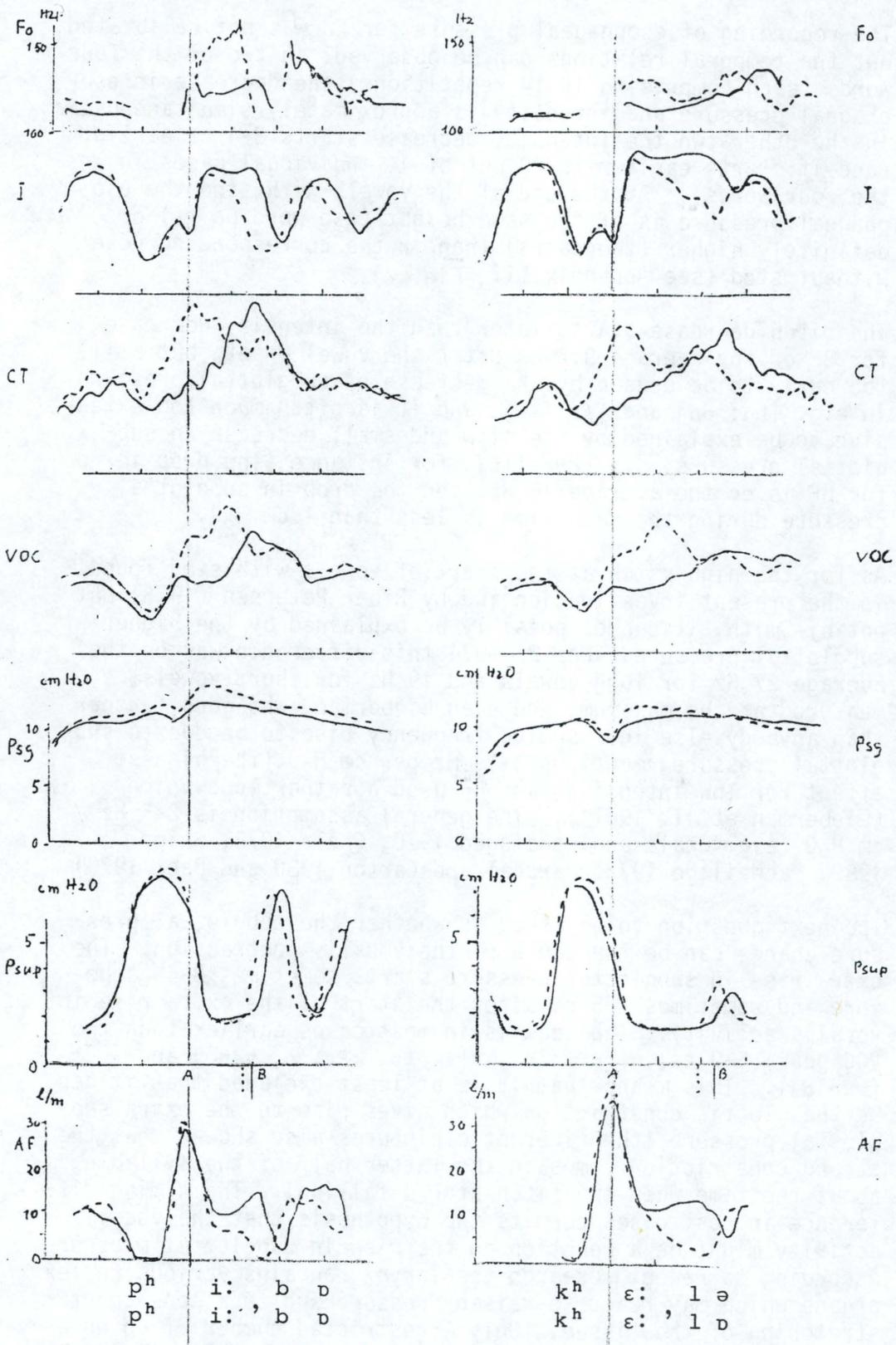
Figure 49 a.

Fo, Intensity (I), CT, VOC, Subglottal pressure (Psg), Phar-
yngeal pressure (Psup.) and airflow (AF). Speaker BF 1974.
——— : no stød, - - - : stød. A: vowel start (line-up point),
B: vowel end. ┆ no stød, ┊ stød. ⊢——⊣ 10 cs.
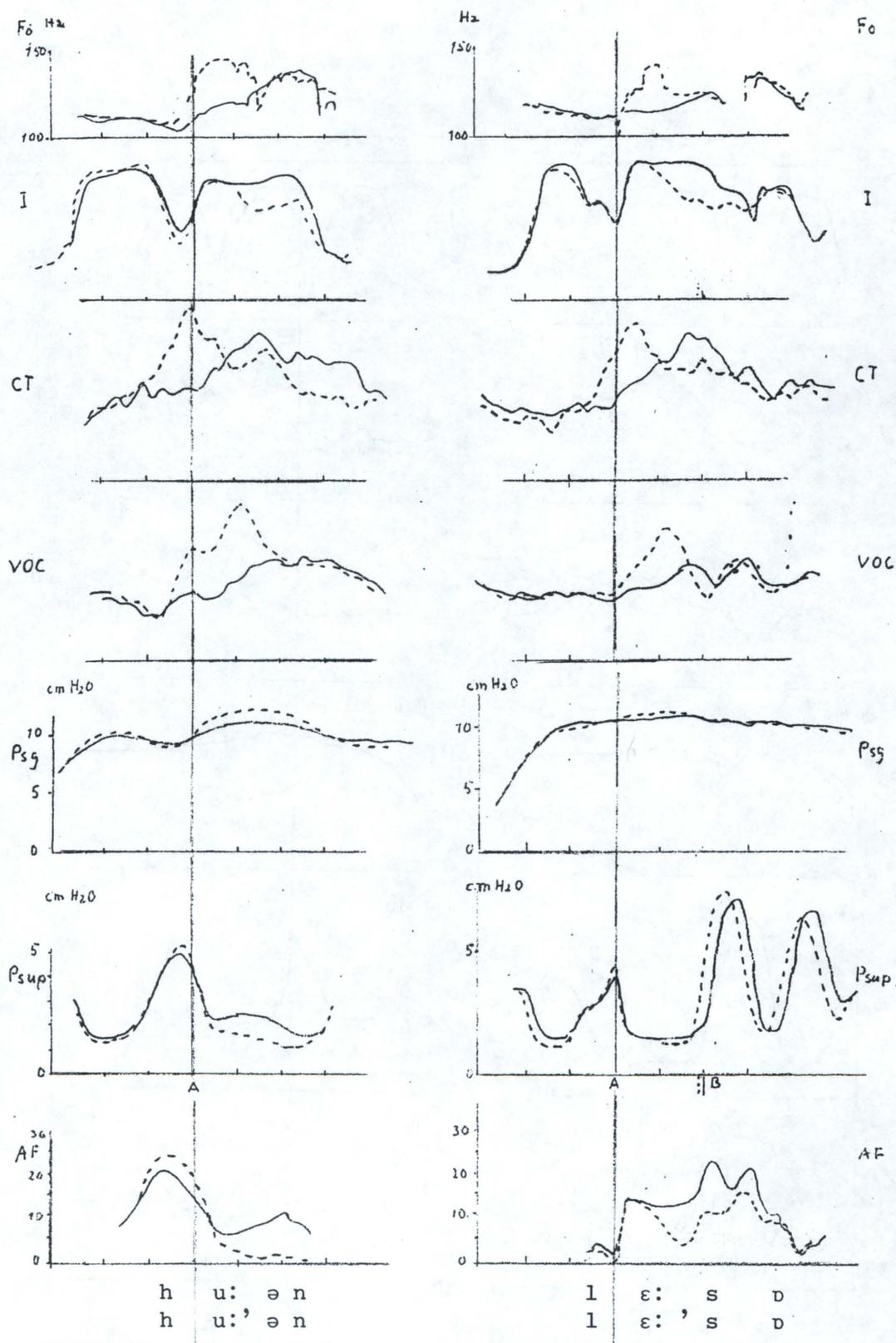
Figure 49 b.

—— : no stød, --- : stød. Speaker BF 1974. See legend to Fig. 49 a.
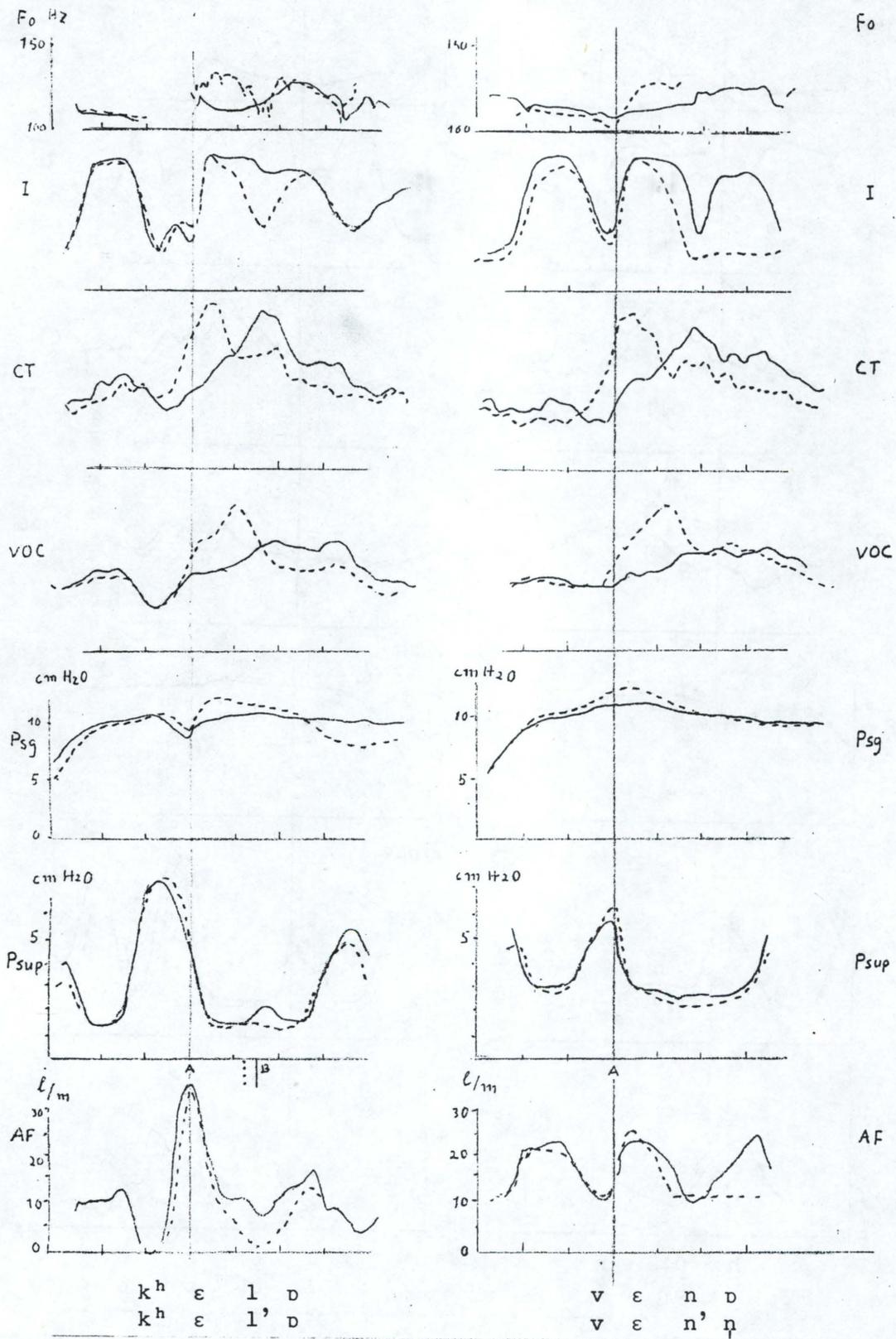
Figure 49 c.

———: *no stød,* ———: *stød. Speaker BF 1974. See legend to Fig. 49 a.*
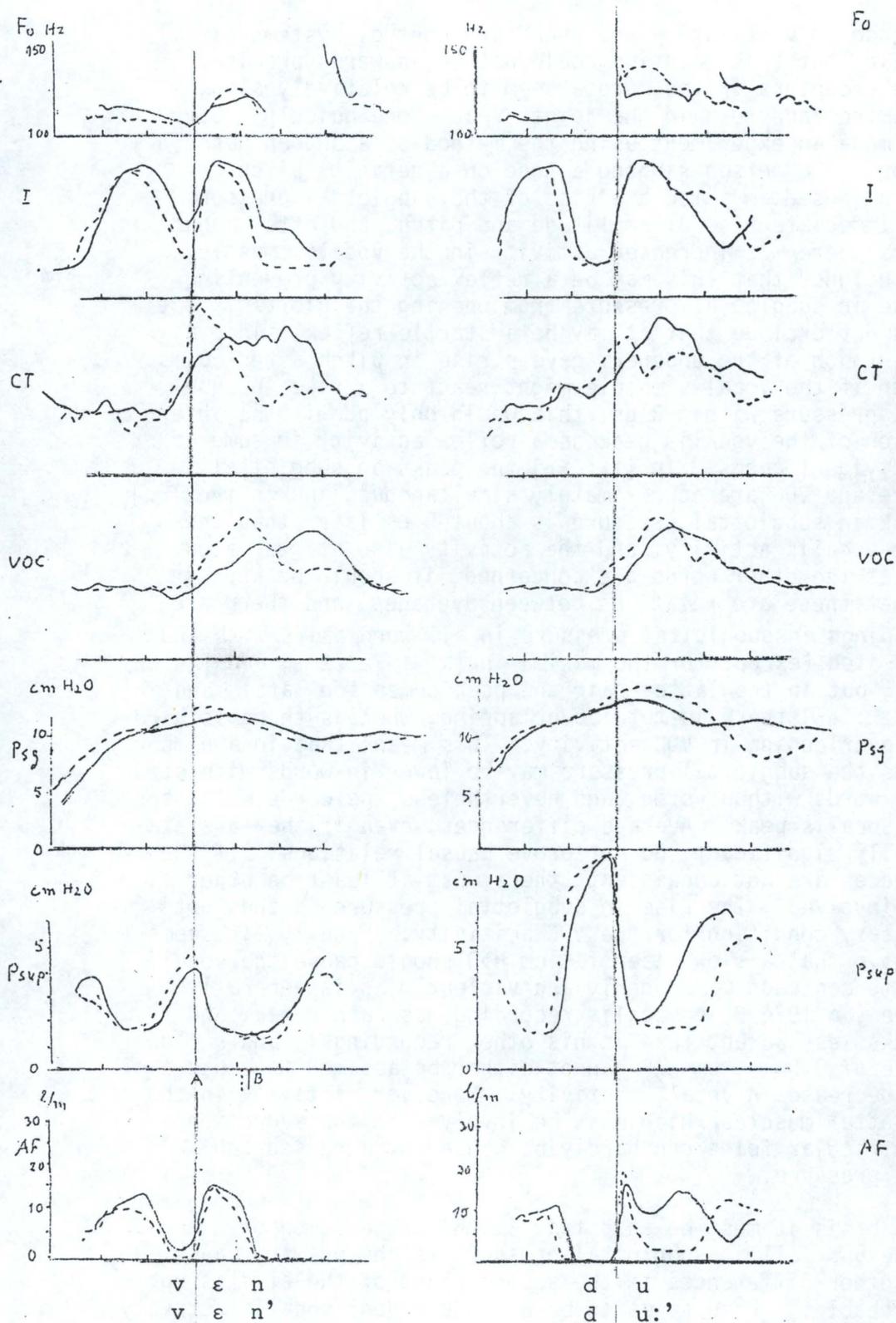
Figure 49 d.

———: no stød, ---: stød. Speaker BF 1974. See legend to Fig. 49 a.

conference on ventilatory and phonatory control systems (1974)
Wyke said that this question could not be answered precisely,
but the receptors in the mucosa seem to be relatively slow,
whereas the receptors in the joints react more quickly. Baer
(1979) made an experiment using the method of a sudden push in
the chest of a person singing a tone on a definite pitch.
The push caused an immediate rise of the subglottal pressure
and an immediate rise of amplitude and pitch, and after about
30-40 ms there was increased activity in the vocalis muscle.
Baer concluded that this may be a reflex activity preventing
the rise in subglottal pressure from opening the glottis. But
he does not exclude that it may be a startle reflex, since a
painful touch of the underarm gave a rise in pitch after 50 ms.
But even if the vocalis muscle might react to a rise in sub-
glottal pressure within 3 cs, this would only permit the inter-
pretation of the vocalis peak as a reflex activity in some of
the individual cases. In [lɛ:'sɒ] the peaks in subglottal
pressure and VOC are approximately simultaneous, and in [hu:'ən]
the peak in subglottal pressure is about 5 cs later than the
peak in vocalis activity, and the activity also starts later.
As far as the other words are concerned, it should be kept in
mind that these are relations between averages, and there are
overlappings in subglottal pressure in all word pairs with and
without stød (except for the maxima in [kʰɛlɒ/kʰɛl'ɒ] and [hu:ən/
hu:'ən], but in the latter pair the peak comes too late), and in
[lɛ:sɒ/lɛ:'sɒ] there is total overlapping, whereas there is hard-
ly any overlapping in VOC activity. This means that in a number
of cases the subglottal pressure may be lower in words with stød
than in words without stød, and nevertheless the words with stød
have a vocalis peak. Average differences, even if they are sta-
tistically significant, do not prove causal relations. If the
differences are not consistent, there must at least be other
causes involved. The rise in subglottal pressure is thus not
a necessary condition for the VOC acitivity. Finally, it seems
improbable that a slow rise of 1 cm H_2O should cause the vocalis
muscle to contract so suddenly and violently as is generally
the case (in 1974 BF's vocalis recording was rather weak and
the peaks less abrupt than in his other recordings), and a slow
decrease of 0.5 - 1 cm H_2O cannot either be assumed to cause a
sudden decrease in vocalis activity. Moreover, activity in the
supraglottal muscles, which must be involved in the adduction of
the ventricular folds, can hardly be caused by a raised sub-
glottal pressure.

On this basis it must be said that Smith's assumption of a sud-
den rise and fall in subglottal pressure as the primary cause
of the other differences in the second phase of the stød is not
very probable. There seems to be an independent vocalis activity,
and the changes in subglottal pressure cannot explain the higher
pitch in the start, nor the decrease of pitch and intensity in
the second phase.

What then are the causes of the specific pitch and intensity
contours in words with stød?

The high pitch in the beginning of words with stød can be suf-
ficiently explained by the early CT activity, which starts
around vowel onset and has its peak 5-10 cs before the Fo peak.
But the frequent pitch drop in the second phase of the stød
cannot be explained by CT relaxation. CT starts falling again
in the beginning of the vowel, sometimes even before the pitch
peak is reached, but this is normal, also in words without stød.
High activity in CT seems to be necessary for stretching the
vocal folds, but once the position is reached less activity is
necessary to maintain it. BF has a small dip in CT in stød
words, but this is not found for other speakers. There is a
gradual decrease but no dip and rise again corresponding to the
dip in pitch. One might think of a possible activity in sterno-
hyoid. This muscle was not recorded. But it did not show any
activity for the pitch valley in Standard Swedish accent II
(see Gårding 1970). It is, however, possible that a strong
contraction of VOC and LCA resulting in a strong compression
of the vocal folds often combined with adduction of the ventri-
cular folds, may hamper the vibrations and thus cause a de-
crease in pitch and also irregular vibrations. Both VOC and
LCA have their peaks just when the pitch decrease and the irre-
gularities start.

The point where Fo starts decreasing is not always quite un-
ambiguous, but its distance from vowel onset was measured in
a number of clear cases (see above p. 111) and found to be on
the average 9.7 cs for BF, BM, HU, JJ and NR. - The VOC peak
is generally quite clear. For the same speakers it was on the
average 11.6 cs after vowel onset with very little variation.
This means that Fo decrease (and irregularity) starts very
shortly before VOC activity has reached its peak.

The decrease in intensity is more difficult to explain. It
starts earlier (in BF's 1974 recording on the average 4.3 cs
after the start of the vowel) and gets lower than in vowels
without stød after, on the average, 5 cs (the airflow also
starts decreasing early, in BF's 1974 recording, on the aver-
age 6.2 cs after vowel start). In BRP's inverse filtering
curves there is a rather close correlation between decreasing
negative spikes, decreasing amplitude of the flow pulses, and
decreasing overall intensity. In [må:'lɒ]3 with weak stød
there is not much decrease in overall intensity corresponding
to the decrease in the glottal pulses, but otherwise it is
quite clear (in 7 out of 8 examples). If we assume that BRP,
like BF and FJ, does not have much decrease in subglottal pres-
sure, there must be a certain constriction of the larynx at a
rather early point. The decrease of oral airflow for the
other speakers also points to a larynx constriction. But
intensity and airflow start decreasing before the peaks in
vocalis and LCA are reached and before the strong constriction
of the larynx is seen in the fiberoptic pictures.

The steep rise in the VOC curve (after the small rise for
voicing) takes place, on the average, 5.1 cs after vowel onset
in the 1974 recordings, and LCA activity starts at the same
time; in the same recordings the decrease of intensity starts

6.4 cs after vowel onset, i.e. only a little more than 1 cs
later. Thus a possible larynx constriction at this point can
hardly be ascribed to the activity of VOC. In BF's strong
stød the adduction of the ventricular folds starts early in
the vowel, but this adduction takes place later for the other
speakers. However, HU, who has a later VOC peak than the
other speakers (13.6 cs), also has a later start of the in-
tensity decrease (9.1 cs), 4.1 cs after her VOC activity be-
gan to increase. But for the other speakers the early in-
tensity decrease has not been sufficiently explained. -
However, it often decreases more rapidly later, simultaneously
with the Fo decrease.

In conclusion of this discussion about causal relations I agree
with Svend Smith in considering the first phase of the stød as
characterized by a relatively high energy in expiration,
phonation and articulation, but I do not think that the rise
in subglottal pressure is the primary factor. It is rather
a general energetic accentuation, which also comprises the
intrinsic laryngeal muscles. As for the second phase, Smith
considers it to be a phase of relaxation, and he describes the
cases where the glottis remains constricted as a non-normative
stød due to lack of adjustment to the falling subglottal pres-
sure. But strong constriction in the second phase is quite
normal in Danish, as shown in this study. It is only from the
point of the speech therapist that, e.g., creaky or breathy
voice must be considered as due to malfunction. They are
linguistically relevant phonation types in a large number of
languages and certainly intended by the speaker.

Finally one may ask why long vowels with stød are shorter than
long vowels without stød, and why only in distinct speech?
This may probably be explained by the fact that although vowels
with stød are long in the sense that their duration is closer
to long vowels than to short vowels and that they have the
quality of long vowels and are subjected to the same modifica-
tions by following consonants as long vowels (and not as short
vowels), they are not susceptible to lengthening in slow speech
in the same way as normal long vowels because they are charac-
terized by a more or less continuous change in phonatory qual-
ity, and the creaky part cannot be lengthened indefinitely.
If one tries to say, e.g., [pʰiː'bɒ] or [kʰɛː'lɒ] very slowly,
the vowel will generally end in a glottal stop.

When, on the other hand, sonorant consonants with stød are
longer than consonants without stød, it is probably a question
of perceptibility. A sonorant consonant is generally only
5-6 cs, and if it were covered completely by the low intensity
second phase of the stød, it would hardly be identifiable.
Therefore it must be somewhat longer.

3. PHONETIC EXPLANATIONS OF THE
   ORIGIN OF THE STØD

Is it possible, on the basis of a phonetic description of the
stød, to throw some light on the theories of its origin? -
Not very much, but a few tentative observations may perhaps
be of some relevance. There are two main theories concerning
the origin of the stød (see p. 67ff above). Verner thought
that it had developed out of a quickly rising tone involving
a strong tension ending in a "snapping" of the vocal folds and
a short closure. Others (Kock and A. Pedersen) assume that
it is the result of a concentration of energy on the stressed
syllable due to syncope, and Skautrup and Smith connect the
origin of the stød with the later apocope.

Verner described the tonal movement in his own pronunciation
of words with stød as a low tone, which at the end of a long
vowel rises quickly ending in a glottal closure, with the
following unstressed syllable on a low tone. But this does
not correspond to any contour found in the present investiga-
tion. All speakers had a high start or a quick rise in the
first few centiseconds, often followed by a quick fall. In
modern Jutlandish dialects the contour also seems to be rising-
falling during the first syllable. But it is true that there
is a high tone, and that may be old (although in southern
Jutland, where there is a tonal opposition, accent 1 is slowly
rising-falling and not very high, see M. Bjerrum 1948). But
in present-day Danish, as in other languages, the main muscle
responsible for pitch rise is the cricothyroid, and a strong
activity of this muscle does not involve a constriction of the
glottis but rather a slight opening and more breathy voice.
The muscles used for the constriction of the glottis in the
stød are the vocalis and lateral cricothyroid and perhaps some
of the sphincter muscles. It is, of course, conceivable that
the vocalis has acted as an antagonist to the CT to keep the
vocal folds together, and that this reaction has been exagger-
ated, but that is pure speculation.

However, the problem is complicated, and the pitch hypothesis
is not so easily refuted. It is a striking fact that languages
with phonation type oppositions are very often tone languages
or related to tone languages. These connections are found in
some African and in many Southeast Asian languages, particular-
ly the Sino-Tibetan language group, but also in Austro-Thai
and Austro-Asiatic (see, e.g., Matisoff 1973, Egerod 1971,
Henderson 1977 and Ivanov 1983). Very often low or falling
pitch is combined with breathiness and high or rising pitch
with glottal stop or creakiness (Matisoff 1973). In some cases
a glottal stop has disappeared in the preceding vowel leaving
a rising tone (e.g. in Vietnamese according to Matisoff 1973);
and Ivanov (1983) and Hombert et al. (1979) mention quite a
number of languages in Asia, Africa and North America where
glottal stop and rising or high tone are connected. In Kachavi
(a Tibeto-Burmese language) rising tone and final glottal stop
are in complementary distribution (Ivanov 1983) and a Middle
Chinese rising tone comes from a final glottal stop (Hombert

et al. 1979 with references to some of the relevant literature,
e.g. Haudricourt). On the other hand, a final [h] seems to
lower the tone of the preceding vowel. Hombert has recorded
the time course of Fo for four Arabic speakers. He found that
an [h] produced a drop in Fo (varying from 25-50 Hz) on the
preceding vowel, while [ʔ] produced a rise (from 9-48 Hz).
There are, however, exceptions, where a glottal stop seems to
have lowered the tone of a preceding vowel. Hombert et al.
mention Mohawk and a number of Middle Chinese dialects, but
they suggest that it may not have been a glottal stop but
creaky voice. However, Javkin and Maddieson, who measured the
Fo contours of the tones of a Burmese speaker, distinguish
expressly tone 3 with creaky voice from tone 4 ending in a
glottal stop, both being falling tones.

In Thai various types of glottalization are found in combina-
tion with both high and low (level or contour) tones in dif-
ferent dialects, but in Thai (as well as in Chinese) there are
distinct historical layers of tonal development: an older layer
of tonogenesis due to final (probably partly glottal) conso-
nants and a later layer due to initial consonants, so that the
situation in modern dialects cannot be immediately used as a
basis for conclusions about the causal relation between glot-
talization and tone level or tone contour. (Rischel, personal
communication.)

It is not straightforward to apply these experiences to the
Danish stød and its origin. In the first place: in all the
examples mentioned it is a glottal stop which has raised the
pitch of a preceding vowel; it is not a rising pitch which has
produced a glottal stop. In the second place the connection
between glottal stop and preceding high tone does not seem to
be an absolute universal. In the third place the connection
between creaky voice and tone seems to be still more uncertain.
Matisoff says that creaky voice is connected with high tone
(1973), Henderson (1977) mentions that this is often the case,
and the Danish stød may be combined with both falling and
rising Fo depending on the speaker (see above p.112).
Finally we do not know whether the stød started as a type of
creaky voice or as a glottal stop. The fact that all phoneti-
cians in the 19th century mention it as a glottal stop might
indicate that it may have been stronger than it is now in
the standard language.

On the other hand, it is a fact that the stød is found in
word forms which had become monosyllabic through the old
Scandinavian syncope (around 8-900), and this may have con-
ditioned the strong concentration of energy which is still
characteristic of the stød, and - perhaps at a later time -
has caused the glottal constriction.

A parallel development is found in the Finno-Ugrian language
Livonian, which is spoken in areas very close to Latvian.
Professor Kalevi Wiik has drawn my attention to some descrip-
tions of Livonian (Posti 1942 and Kettunen 1947). Posti de-
scribes the "Stossintonation" in the following way: *"Bei der*

*Stossintonation steigt der Ton zuerst stark an, dann tritt der
Stoss auf, und nach diesem fällt der Ton schnell, der fallende
Teil ist länger als der steigende."* Kettunen quotes Endzelin's
description of the "Stosston" in Latvian: *"Beim Stosston, der
zum Beispiel auch im Livischen und im Dänischen vorkommt, zer-
fällt die Länge in zwei Teile, indem nach dem stärker schallen-
den Anfang inmitten der Silbe ein momentaner Glottisverschluss
eintritt (der aber oft durch Stimmschwächung ersetzt wird),
worauf der zweite Teil hervorgestossen wird."* Kettunen de-
scribes the "Stossintonation" in Livonian as very variable. A
complete closure is not rare, but sometimes it is only a falling
tone, which is characterized by a shorter syllabic quantity
than the so-called lengthened ("gedehnt") tone, which is rising.
Latvian also has a rising tone, and both languages also have a
purely falling tone, which, however, is rare in Livonian.

These descriptions remind very much of the Danish stød, except
that the rebound after the laryngealization seems to be more
common than it is now in Standard Danish.

As to the origin of the stød in Livonian and in the Baltic lan-
guages there are different opinions. Ivanov (1983) mentions
Latvian and Lithuanian as examples of a stød which developed
from a rising tone. As for Livonian it is generally assumed
that the stød was taken over from Latvian. However, Kettunen
(1947) argues that since it can be explained by historical sound
changes within Livonian, it is more probable that the Latvian
stød is due to Livonian substratum (Livonian was spoken in a
much larger area earlier). According to both Posti (1942) and
to Kettunen it is a fact that very often Livonian stød appears
in cases where there has been syncope or apocope of a weak syl-
lable after a short stressed syllable. Further it is found
before a disappearing [h], in which case there is also apocope,
or before a final [h] followed by a consonant initiating the
following syllable; in the latter case Kettunen assumes that a
schwa had developed between the [h] and the following consonant
and then disappeared, so that all cases might be seen as due to
syncope or apocope. Through this development the first syllable
was reinforced and (perhaps at a somewhat later date) developed
a stød. (Both in Latvian and Livonian there is also a stød in
some syllables with secondary stress, which must be explained
in a different way.)

Posti thinks that the reinforcement involved a strong pitch
rise, and that this is what gave rise to the stød (he thus ac-
cepts Verner's explanation). Wiik has a somewhat different ex-
planation (personal communication). He assumes that the stød
is a remnant of the old syllable boundary between the contracted
syllables and refers to the stød which may appear in hiatus
(like Danish *sofa - sofaen* ['soːfa - 'soːfæːˀən]). A similar
phenomenon is found in Finnish.

This is, of course, all very hypothetical, but it seems that
the development in Livonian supports the hypothesis of a re-
inforced accent due to syncope as being the origin of the Danish
stød as well. The reinforcement may have involved a pitch rise

and consequently a tonal difference between reinforced syl-
lables and other syllables, so that developments in various
directions were possible.

4. VARIABILITY AND INVARIANCE

The phonetic description of the Danish stød given in this
paper, revealed a high degree of variability both in the pro-
duction and in the acoustic nature of the stød. Not all seem
to use their vocalis muscle in the stød, and those who do use
it use it in different ways for other purposes. Some subjects
have strong activity for pitch rise, some very little, some
have deep valleys in voiceless consonants, some hardly any
valleys, and all combinations seem to occur. It can, of course,
not be excluded that some of these observed differences may be
due to slightly different placements of the electrodes (there
are differences in vocalis activity for pitch and consonant
dips in different recordings by BF), but there is no doubt that
there is genuine individual variation. Moreover, some have
strong adduction of the ventricular folds, some hardly any ad-
duction. Some have a strong pitch decrease, some have rising
pitch, and in both cases there is decrease of intensity and
there may be irregular vibrations. Nevertheless there is no
problem in the perceptual identification. A similar inter-
individual variation has been found in other phonetic studies,
e.g. in the function of the strap muscles and the hyoid bone.

I agree completely with Lindblom (1982) when he states that
what is aimed at is not invariance, but perceptual equivalence.
Sufficient, but not necessarily identical acoustic cues are
supplemented by top-down predictability.

5. PROSPECTS FOR FUTURE RESEARCH

In spite of the relatively large material and different methods
of analysis used in this study, there are still many gaps in
the description, and much remains to be done. It would cer-
tainly have been preferable to record a larger number of muscles
and to measure subglottal pressure on more subjects. It is
also a serious drawback that the respiratory function has not
been investigated (a short experiment with surface electrodes
was negative). But with this type of physiological investiga-
tion what is scientifically desirable is not always humanly
possible. Most subjects having tried laryngeal electromyo-
graphy once do not want to repeat the experience. And a
planned recording of the internal intercostals was given up
because Hirose declared that there was a 20% risk of piercing
the pulmonary pleura.

Finally, it must be emphasized that the perceptual aspect has
not even been touched upon in this investigation. A thorough
study of the relative importance of the acoustical differences
as cues for the perceptual identification is a great desidera-
tum. I hope that the present description of the acoustic fea-
tures of the stød may be useful as a basis for such studies.

V. NOTE

1. The phonetic transcription used in this paper is in principle IPA.

The stød is, however, transcribed ['] in accordance with a common Danish tradition, in order to emphasize that it is not a glottal stop [ʔ].

IPA is ill suited for the transcription of Danish lower rounded back vowels. For the long vowel in e.g. *måle* (IPA [ɔ:+⁻]) the Danish letter *å* has therefore been used ([å:]). The short vowel in, e.g., *komme* (IPA [ɔ(+)⁻]) is transcribed [ɔ], and the r-coloured vowel in e.g. *hår* (IPA [ɒ⁻]) is transcribed [ɒ]. Many Danish phoneticians (wanting to avoid non-IPA symbols) use [ɔ:] for the long vowel in *måle* and [ʌ] for the short vowel in *komme*, but this symbol is somewhat misleading, since the unrounded pronunciation is very rare nowadays, and the fronting is being reduced.

The unstressed endings *-en, -el, -et* are transcribed [ən, əl, əð] as a generalization of slow pronunciation. The actual pronunciations in the text are variable. After a consonant [ə] is very often elided, and the final consonant becomes syllabic. After [n] the ending [ən] is practically always [n̩], and therefore this transcription is used in *vennen* ['vɛn'n̩]. After a vowel [ə] may also be assimilated to this vowel, and the stressed vowel may be shortened, thus [hu:ən, huən, hu:un, huun, hu:n̩, hun̩]. Here [hu:ən] has been generalized.

Danish /bdg/ are voiceless in syllable-initial stressed position and finally, but may be (partly or fully) voiced initially in unstressed syllables. The symbol for voicelessness (̥) has been omitted here, except in a few cases where it was relevant for the argument.

Danish /ptk/ in syllable-initial position are aspirated, and *t* (sometimes also *k*) is affricated, particularly before high vowels. The affrication is not indicated in the transcription here, /ptk/ being transcribed [pʰ, tʰ, kʰ] in syllable-initial position.

REFERENCES

Abercrombie, D. 1967: *Elements of General Phonetics* (Edinburgh University Press)

Abrahams, H. 1943: "Nogle fonetiske Iagttagelser vedrørende Stødet i moderne Dansk", *In Memoriam Kr. Sandfeld* (Gyldendal, Copenhagen), p. 23-30

Abrahams, H. 1960: "Kvantitet ved vestjysk stød", *Sprog og Kultur 22*, p. 105-111

Adzaku, F.K. and Wyke, B. 1982: "Laryngeal subglottal mucosal reflexogenic influences on laryngeal muscle activity", *Folia Phoniatrica 34*, p. 57-64

Andersen, P. 1949: Review of E. Kroman *Musikalsk Akcent i Dansk, Danske Folkemål 15*, p. 5, p. 102-113

Andersen, P. 1958: *Fonemsystemet i Østfynsk* (Schultz, Copenhagen)

Andersen, P. 1965: "Dialektforskningen", *Det danske sprogs udforskning i det 20. århundrede*, p. 85-126 (Gyldendal, Copenhagen)

Atkinson, J.E. 1978: "Correlation analysis of the physiological factors controlling fundamental voice frequency", *J. Acoust. Soc. Am. 63*, p. 211-222

Baer, Th. 1979: "Reflex activation of laryngeal muscles by sudden induced subglottal pressure changes", *J. Acoust. Soc. Am. 65*, p. 1271-1275

Baken, R.J. 1971: "Neuromuscular spindles in the intrinsic muscles of the human larynx", *Folia Phoniatrica 23*, p. 204-210

Basbøll, H. 1971-73: "A commentary on Hjelmslev's analysis of the Danish expression system", *Acta Linguistica Hafniensia XIII*, p. 173-211 and *XIV*, p. 1-24

Basbøll, H. 1972: "Some remarks concerning the stød in a generative grammar of Danish", *Proceedings of the KVAL Seminar: Derivational Processes* (Stockholm), p. 5-30

Basbøll, H. 1985: "Stød in Modern Danish", *Folia Linguistica XIX*, p. 1-50

Basmajian, J.V. 1974: *Muscles alive*, 3rd edition (Baltimore)

Berg, J. van den 1968: "Mechanism of the larynx and the laryngeal vibrations", *Manual of Phonetics* (ed. Malmberg, B.) (North-Holland, Amsterdam)

Bjerrum, M.   1948: *Feldstedmaalets tonale Accenter* (Universi-
    tetsforlaget, Aarhus), *Humanistiske Studier III*

Bjerrum, M.   1959: *Rasmus Rasks afhandlinger om det danske
    sprog* (Dansk Videnskabs Forlag, Copenhagen)

Bowden, R.   1974: Contribution to the discussion of communica-
    tion, *Ventilatory and Phonatory Control Systems* (ed.:
    Wyke, B.) (Oxford University Press, London), p. 297

Bowden, R.   1974: "Innervation of intrinsic laryngeal muscles",
    Ventilatory and Phonatory Control Systems (ed.: Wyke, B.)
    (Oxford University Press, London), p. 370-391

Brink, L. and Lund, J.   1975: *Dansk Rigsmål* (Gyldendal, Copen-
    hagen)

Broad, W.J.   1973: "Phonation", *Normal Aspects of Speech,
    Hearing and Language* (eds.: Minifie, F.D., Hixon, T.J.
    and Williams, F.) (Prentice-Hall, New Jersey)

Bruun, C.F.   1883: *Om Bogstavlydenes Længde i danske Ord*
    (Horsens)

Buchthal, F. and Faaborg-Andersen, K.   1964: "Electromyography
    of laryngeal and respiratory muscles", *Annals of Otology,
    Rhinology and Laryngology, vol. 73*, p. 118-123

Catford, I.C.   1964: "Phonation types: the classification of
    some laryngeal components of speech production", *In Honor
    of Daniel Jones* (eds.: Abercrombie, D., Fry, D.B.,
    MacCarthy, P.A.D., Scott, N.C. and Trim, J.L.M.)
    (Longmans, Green & Co., London), p. 26-37

Catford, I.C.   1977: *Fundamentals of Phonetics* (Edinburgh
    University Press)

Daniloff, R., Schuckers, G. and Feth, L.   1980: *The Physiology
    of Speech and Hearing* (Prentice-Hall, New Jersey)

Dejonckere, P.   1980: "Les mécanismes musculaires élémentaires
    de la corde vocale au cours de la phonation", *Folia
    Phoniatrica 32*, p. 1-13

Egerod, S.   1971: "Phonation types in Chinese and South East
    Asian Languages", *Acta Linguistica Hafniensia XIII*,
    p. 159-171

Ejskjær, I.   1967: *Kortvokalstødet i sjællandsk* (Akademisk For-
    lag, Copenhagen)

Ekblom, R. 1933: "Om de danska accentarterna", *Språkvetenskap-liga Sällskapets i Uppsala Förhandlingar, Uppsala Univ. årsskrift 5*, p. 1-12

Ekblom, R. 1939: "Till frågan om de nordiska accentarternas uppkomst", *Arkiv för nordisk Filologi 54*, p. 161-180

Elert, C.-C. 1970: *Ljud och ord i Svenskan* (Almquist & Wiksell, Stockholm)

Esling, J.H. 1984: "Laryngographic study of phonation type and laryngeal configuration", *J. Intern. Phon. Assoc. 14*, p. 56-73

Faaborg-Andersen, K. 1957: *Electromyographic Investigation of Intrinsic Laryngeal Muscles in Humans* (Møllers Bog-trykkeri, Copenhagen)

Fant, G. 1983: "The voice source - acoustic modelling" *Abstracts, 10 Int. Congr. Phon. Sc.*, p. 151-177. Also: *Speech Transm. Lab., Quart. Prog. and Status Rep. 4/1982 Royal Inst. Techn., Stockholm*, p. 28-48

Fischer-Jørgensen, E. 1955: "Om vokallængde i dansk rigsmål", *Nordisk Tidsskrift for Tale og Stemme 15*, p. 33-56

Fischer-Jørgensen, E. and Hirose, H. 1974a: "A preliminary electromyographic study of labial and laryngeal muscles in Danish stop consonant production", *Status Rep. Speech Res., Haskins Labs. 39/40*, p. 231-254

Fischer-Jørgensen, E. and Hirose, H. 1974b: "A note on laryngeal activity in the Danish "stød"", *Status Rep. Speech Res., Haskins Labs. 39/40*, p. 255-259

Fischer-Jørgensen, E. 1983: "Supplementary notes on vowel length in Danish", *Ann. Rep. Inst. Phon., Univ. Copenhagen 17*, p. 21-54

Flanagan, J. 1958: "Some properties of the glottal sound source", *J. Speech and Hearing Research 1*, p. 99-116

Forchhammer, J. 1942: "Der dänische "Stoss"", *Archiv für die gesamte Phonetik 6*, p. 180-184

Forchhammer, V. 1954: "Stemmedannelse", *Nordisk Lærebog for Talepædagoger*, p. 174-199

Fourcin, A.J. 1974: "Laryngographic examination of vocal fold vibration", *Ventilatory and Phonatory Control Systems* (ed.: Wyke, B.) (Oxford University Press, London), p. 314-333

Fujimura, O. 1977a: "Control of the larynx in speech", *The Larynx and Language, Phonetica 34*, p. 80-88

Fujimura, O. 1977b: Contribution to discussion, *Dynamic Aspects of Speech Production*, p. 69-70

Fujimura, O. and Sawashima, M. 1971: "Consonant sequences and laryngeal control", *Ann. Bull. Res. Inst. Logopedics and Phoniatrics, Tokyo, 5*, p. 1-6

Gårding, E. 1970: "Word tones and larynx muscles", *Working Papers 3, Phonetic Laboratory Lund University*, p. 20-46

Gårding, E. 1971: "Laryngeal boundary signals", *Working Papers 4, Phonetic Laboratory Lund University*, p. 23-47

Gårding, E., Fujimura, O. and Hirose, H. 1970: "Laryngeal control of Swedish word tones. A preliminary report on an EMG study", *Ann. Bull. Res. Inst. Logopedics and Phoniatrics 4, Tokyo*, p. 45-54

Gårding, E. 1977: *The Scandinavian Word Accents, Travaux de l'Institut de Linguistique de Lund XI*

Halle, M. and Stevens, K.N. 1971: "Review of acoustical and mechanical aspects of vocal cord operation", *MIT Quart. Prog. Rep. 101*, p. 198-213

Hansen, Aa. 1943: *Stødet i dansk. Det kgl. Videnskabernes Selskab, Historisk-filologiske Meddelelser XXIX,5* (Munksgaard, Copenhagen)

Harris, K.S., Gay, T., Lieberman, P. and Sholes, G. 1969: "The function of muscles in control of stress and intonation", *Status Rep. Speech Res., Haskins Labs. 19/20*, p. 127-138

Haugen, E. 1970: "The language history of Scandinavia, a profile of problems", *The Nordic Languages and Modern Linguistics* (ed.: Benediktsson, H.), p. 41-79

Haugen, E. 1976: *The Scandinavian Languages. An Introduction to their History* (Faber & Faber, London)

Heger, S. 1980: "Stødregler for dansk", *Danske Studier*, p. 78-99

Heger, L. 1931: "Zum dänischen Stød", *Casopis pro moderni filologii 17*, p. 40-45

Henderson, E. 1977: "The larynx and language: a missing dimension", *The Larynx and Language, Phonetica 34*, p. 256-363

Hesselman, B. 1948-53: "Huvudlinier i Nordisk Språkhistoria", *Nordisk Kultur III-IV*

Hirano, M.   1977: "Structure and vibratory pattern of the vocal
    folds", *Dynamic Aspects of Speech Production* (eds.: Sawa-
    shima, M. and Cooper, F.S.) (University of Tokyo Press),
    p. 13-30

Hirano, M.   1981: "The function of the intrinsic laryngeal
    muscles in singing", *Vocal Fold Physiology* (eds.: Stevens,
    K. and Hirano, M.) (University of Tokyo Press), p. 155-170

Hirano, M. and Ohala, J.   1967: "Use of hooked wire electrodes
    for electromyography", *Working Papers in Phonetics, UCLA*
    7, p. 33-45

Hirose, H.   1971: "Electromyography of the articulatory muscles:
    Current instrumentation and technique", *Status Rep. Speech*
    Res., Haskins Labs. 25/26, p. 73-86

Hirose, H.   1975: "The posterior cricothyroid as a speech
    muscle", *Ann. Bull. Res. Inst. Logopedics & Phoniatrics,*
    Tokyo 9, p. 47-66

Hirose, H. and Gay, T.   1972: "The activity of the intrinsic
    laryngeal muscles in voicing control: An electromyographic
    study", *Phonetica 25*, p. 140-164

Hirose, H. and Gay, T.   1973: "Laryngeal control in vocal
    attack", *Folia Phoniatrica 25*, p. 203-213

Hirose, H., Gay, T., Strome, M. and Sawashima, M.   1971:
    "Electrode insertion technique for laryngeal electromyo-
    graphy", *J. Acoust. Soc. Am. 50*, p. 1449-1450

Hirose, H., Lee, Ch. Y. and Ushijima, T.   1973: "Laryngeal con-
    trol in Korean stop production", *Status Rep. Speech Res.*
    Haskins Labs. 34, p. 191-201

Hjelmslev, L.   1951: "Grundtræk af det danske udtrykssystem",
    Selskab for Nordisk Filologi, årsberetning for 1948-50,
    p. 12-24

Hollien, H.   1974: "On vocal registers", *J. Phonetics 2*,
    p. 125-143

Holtse, P. and Stellinger, J.   1976: "A system for computer
    aided processing of phonetic measurements", *Ann. Rep.*
    Inst. Phon., Univ. Copenhagen 10, p. 201-219

Hombert, J.-M.   1976: "Phonetic motivations for the develop-
    ment of tones from postvocalic [h] and [ʔ]: Evidence from
    contour tone perception", *Rep. of Phonology Lab., Berkeley*
    1, p. 39-47

Hombert, J.-M., Ohala, J.J. and Ewan, W.G.   1979: "Phonetic ex-
    planations for the development of tones", *Language 55*,
    p. 37-58

Hommel, L. 1868-69: "Det danske Sprogs Tonelag", *Tidsskrift
    for Filologi og Pædagogik 8*, p. 1-31

Hutters, B. 1984: "Vocal fold adjustment in Danish voiceless
    obstruent production", *Ann. Rep. Inst. Phon., Univ. Copen-
    hagen 18*, 293-385

Høysgaard, J. Pedersen 1743: *Concordia res parvæ crescunt,
    eller Anden Prøve af dansk Orthographie* (København),
    reprinted in: *Danske Grammatikere* (ed. Bertelsen, H.) *IV*,
    1920, p. 221-247

Høysgaard, J. Pedersen 1747: *Accentuered og Raisonnered Gram-
    matica* (København), reprinted in: *Danske Grammatikere IV*
    ed. Bertelsen, H.) 1920, p. 249-488

Høysgaard, J. Pedersen 1769: *Første Anhang til den accentuerede
    Grammatika*, reprinted in: *Danske Grammatikere V* (ed.
    Bertelsen, H.) p. 507-550

Ivanov, V.V. 1983: "Synchronic and diachronic typology of pro-
    sodic systems with laryngealized and pharyngealized
    tonemes", *Academy of Sciences USSR, Institute of Slavic
    and Baltic Studies*, p. 1-3

Iwata, R., Sawashima, M., Hirose, H. and Niimi, S. 1979:
    "Laryngeal adjustments of Fukienese stops", *Ann. Bull.
    Res. Inst. Logopedics and Phoniatrics, Tokyo, 13*, p. 61-81

Izdebski, K. and Shipp, T. 1983: "Vocal reaction time stages:
    a physiological model", *Abstracts 10 Int. Congr. Phon.
    Sc.*, p. 446

Javkin, H.R. and Maddieson, I. 1983: "An inverse filtering
    study of Burmese creaky voice", *Working Papers in Phonetics
    UCLA 57*, p. 115-125

Javkin, H.R., Antonanzas-Barroso, N. and Maddieson, I. 1985:
    "Digital inverse filtering for linguistic research",
    Working Papers in Phonetics, UCLA 60, p. 87-100

Jensen, E. 1961: ""Vestjysk" Stød i Forbindelse med musikalsk
    Accent", *Danske Folkemål 1-8*, p. 14-37

Jespersen, O. 1897: "Stød og musikalsk Akcent", *Dania IV*,
    p. 215-239

Jespersen, O. 1897-99: *Fonetik* (Det Schubotheske Forlag,
    Copenhagen)

Jespersen, O. 1913: "Det danske stød og urnordisk synkope",
    Arkiv för nordisk filologi 29, p. 1-32

Jespersen, O. 1922: *Modersmålets Fonetik*, 2. udg. (Gyldendal,
    Copenhagen)

Kagaya, R.A. 1974: "A fiberscopic and acoustic study of Korean stops, affricates and fricatives", *J. Phonetics 2*, p. 161-180

Kettunnen, L. 1947: *Hauptzüge der livischen Laut- und Formenlehre* (Helsinki, Suomalais-Ugrilainen Seura)

Kirk, P.L., Ladefoged, P. and Ladefoged, J. 1984: "Using a spectrograph for measures of phonation types in a natural language", *Working Papers in Phonetics, UCLA 59*, p. 102-113

Kitzing, P. 1986: "LTAS criteria pertinent to the measurement of voice quality", *J. Phonetics 14*, p. 483-488

Kitzing, P., Carlborg, B. and Löfqvist, A. 1982: "Aerodynamic and glottographic studies on the laryngeal vibratory cycle", *Folia Phoniatrica 34*, p. 216-224

Kock, A. 1901: *Die alt- und neuschwedische Akzentuierung. Quellen und Forschungen 87* (Strassburg)

Kristensen, M. 1899: "Stødet i Dansk", *Arkiv för nordisk filologi 15*, p. 41-67

Kroman, E. 1947: *Musikalsk Akcent i Dansk* (Munksgaard, Copenhagen)

Kunze, L.H. 1964: "Evaluation of methods of estimating subglottal pressure", *J. Speech and Hearing Research 7*, p. 151-164

Ladefoged, P. 1964: *A Phonetic Study of West African Languages*, (Cambridge University Press)

Ladefoged, P. 1971: *Preliminaries to Linguistic Phonetics* (The University of Chicago Press)

Ladefoged, P. 1973: "The features of the larynx", *J. Phonetics 1*, p. 73-83

Ladefoged, P. 1979: "Articulatory parameters", *Proc. 9 Int. Congr. Phon. Sc.*, p. 41-47

Ladefoged, P. 1983: "The linguistic use of different phonation types", *Vocal Fold Physiology* (eds. Bless, D.M. and Abbs, J.H.), p. 351-360

Lauritsen, M. 1968: "A phonetic study of the Danish stød", *Project on Linguistic Analysis, Phonol. Lab., Dept. Ling. Univ. California Berkeley, Reports Second Series 7*, p. D1-D12

Laver, J. 1980: *The Phonetic Description of Voice Quality, Cambridge Studies in Linguistics 31*, (Cambridge University Press)

Levin, I. 1844: *Dansk Lydlære og Dansk Kjønslære* (Kjøbenhavn),
    (Samfundet til den danske Literaturs Fremme)

Liberman, A.S. 1976: "The origin of Scandinavian accentuation",
    Arkiv för nordisk filologi 91, p. 1-32

Liberman, A.S. 1982: *Germanic Accentology, Vol. I: The Scandi-
    navian Languages* (University of Minnesota Press, Minneapo-
    lis)

Lieberman, Ph., Knudson, R. and Mead, J. 1967: "Determination
    of the rate of change of fundamental frequency with respect
    to the subglottal air pressure during sustained phonation",
    J. Acoust. Soc. Am. 45, p. 1537-1543

Lindblom, B. 1982: "The interdisciplinary challenge on speech
    motor control", *Speech Motor Control* (eds.: Grillner, S.,
    Lindblom, B., Lubker, J. and Persson, A.) *Wenner-Gren Sym-
    posium Series, Vol. 36*, p. 3-18

Lindquist, J. 1969: "Laryngeal mechanisms in speech", *Speech
    Transm. Lab., Quart. Prog. and Status Rep., Royal Inst.
    Techn. Stockholm 2-3 /1969*, p. 26-32

Lindquist, J. 1972a: "A descriptive model of laryngeal articu-
    lations in speech", *Speech Transm. Lab., Quart. Prog. and
    Status Rep., Royal Inst. Techn. Stockholm 2-3 /1972*, p. 1-10

Lindquist, J. 1972b: "Laryngeal articulation studied on Swedish
    subjects", *Speech Transm. Lab., Quart. Prog. and Status
    Rep., Royal Inst. Techn. Stockholm 2-3 /1972*, p. 10-27

Löfqvist, A., McGarr, N.S. and Honda, K. 1983: "Physiological
    and acoustic studies of phonatory patterns", *Abstracts
    10 Int. Congr. Phon. Sc.*, p. 447

Löfqvist, A., Carlborg, P. and Kitzing, P. 1982: "Initial
    validation of an indirect measure of subglottal pressure
    during vowels", *J. Acoust. Soc. Am. 72*, p. 633-635

MacCurtain, F. 1983: "Pharyngeal gestures in contrastive
    voice quality", *Abstracts, 10 Int. Congr. Phon. Sc.*,
    p. 199-213

Marchal, A. and Carton, N. 1980: "La pression sous-glottique:
    mesure et relation avec intensité et la fréquence fonda-
    mentale", *Larynx et Parole* (eds.: Boë, L.-J., Descout, R.
    and Guérin, B.), *Institut de Phonétique de Grenoble*,
    p. 313-327

MacNeilage, P. 1972: "Speech physiology", *Speech and Cortical
    Function* (ed.: Gilbert, J.H.) (Academic Press, New York),
    p. 1-72

E R R A T U M
================

p. 207, add:

Petersen, Niels Reinholt 1985: "Fundamental frequency and larynx height in sentence and stress groups", *Ann. Rep. Inst. Phon., Univ. of Copenhagen 19,* p. 95-141.

Martinet, A. 1934: "Nature phonologique du stød danois",
    Bull. de la Société de Linguistique de Paris 35,
    p. 52-57

Martinet, A. 1937: *La phonologie du mot en danois* (Klincksieck,
    Paris)

Matisoff, J.A. 1973: "Tonogenesis in South East Asia",
    Consonant Types and Tone (ed. Hyman, L.M.), *Southern
    California Occasional Papers in Linguistics, No. 1*,
    p. 71-95

Møller, H. 1922: "Hochton nach Auftakt", *Indogermanische
    Forschungen XL*, p. 169-185

Monsen, R.B. and Engebretson, A.M. 1977: "Study of variations
    in the male and female glottal wave", *J. Acoust. Soc. Am.
    62*, p. 981-993

Mårtensson, A. 1982: "Some functional and histochemical proper-
    ties of the intrinsic laryngeal muscles", *Speech Motor
    Control* (eds. Grillner, S., Lindblom, B., Lubker, J. and
    Persson, A.) *Wenner-Gren Symposium Series, Vol. 36*,
    p. 119-127

Nielsen, N. Å. 1959: *De jyske dialekter* (Gyldendal, Copenhagen)

Oftedal, M. 1952: "On the origin of the Scandinavian tone
    distinction", *Norsk tidsskrift for sprogvidenskap 16*,
    p. 201-225

Ohala, J. and Ladefoged, P. 1970: "Further investigation of
    pitch regulation in speech", *Working Papers in Phonetics,
    UCLA, 14*, p. 12-24

Ohala, J. 1978: "The production of tone", *Tone, a Linguistic
    Survey* (ed. Fromkin, V.), p. 5-39

Öhman, S. and Lindquist, J. 1966: "Analysis by synthesis of
    prosodic pitch", *Speech Transm. Lab., Quart. Prog. and
    Status Rep., Royal Inst. Techn., Stockholm 4/1965*, p.1-6

Öhman, S. 1967: "Word and sentence intonation: A quantitative
    model", *Speech Transm. Lab., Quart. Prog. and Status Rep.,
    Royal Inst. Techn., Stockholm 2-3/1967*, p. 20-54

Öhman, S., Mårtensson, A., Leanderson, R. and Persson, A. 1967:
    "Cricothyroid and vocalis muscle activity in the production
    of Swedish tonal accents, a pilot study", *Speech Transm.
    Lab., Quart. Prog. and Status Rep., Royal Inst. Techn.,
    Stockholm 2-3/1967*, p. 55-57

Pedersen, A. 1912: "Dansk og urnordisk akcentuering", *Arkiv
    för nordisk filologi 28*, p. 1-53

Petersen, P. Riber 1973: "An instrumental investigation of the
    Danish stød", *Ann. Rep. Inst. Phon., Univ. Copenhagen 7*,
    p. 195-234

Posti, L.   1942: *Grundzüge der livischen Lautgeschichte*,
    (Helsinki) (Suomalais-Ugrilainen Seura)

Ringgaard, K.   1959: "Når tostavelsesord bliver enstavelses",
    Sprog og Kultur 21, p. 39-51

Ringgaard, K.   1960: *Vestjysk Stød* (Universitetsforlaget,
    Aarhus)

Ringgaard, K.   1962: "The pronunciation of a glottal stop",
    Phonetica 8, p. 203-208

Ringgaard, K.   1971: *Danske Dialekter* (Akademisk Boghandel,
    Aarhus)

Ringgaard, K.   1980: "The stød and the Scandinavian tonal
    accents", *The Nordic Languages and Modern Linguistics*,
    *Proc. 4 Int. Conf. on Nordic and General Linguistics in
    Oslo 1980* (ed. Hovdhaugen, E.), p. 323-333

Ringgaard, K.   1983: Review of An. Liberman: *Germanic Accent-
    ology, The Scandinavian Languages, Phonetica 40*, p. 342-344

Rischel, J.   1970: "Morpheme stress in Danish", *Ann. Rep. Inst.
    Phon., Univ. Copenhagen 4*, p. 111-144

Rischel, J. and Hutters, B.   1980: "Filtering of EMG signals",
    Ann. Rep. Inst. Phon., Univ. Copenhagen 14, p. 285-316

Roach, P.J. and Hardcastle, W.J.   1979: "Instrumental measure-
    ment of phonation types: A laryngographic contribution",
    *Current Issues in the Phonetic Sciences, Current Issues
    in Linguistic Theory, vol. 9, part I* (eds. Hollien, H. &
    P.) (John Benjamins B.V., Amsterdam), p. 201-207

Rothenberg, M.   1972: "The glottal volume velocity wave form
    during loose and tight voice glottal adjustments", *Proc.
    7 Int. Congr. Phon. Sc.*, p. 380-388

Rousselot, P.-J.   1897-1908: *Principes de phonétique expéri-
    mentale*, Nouvelle éd. 1924 (Didier, Paris)

Sawashima, M.   1974: "Laryngeal research in experimental
    phonetics", *Current Trends in Linguistics 12* (eds. Sebeok, *T.A.*
    et al.), (Mouton, The Hague), p. 2303-2348 (also: *Status
    Rep. Speech Res., Haskins Labs. 23*, p. 69-115)

Sawashima, M., Kakita, Y. and Hiki, S.   1973: "Activity of the
    intrinsic laryngeal muscles in relation to Japanese word
    accent", *Ann. Bull. Res. Inst. Logopedics and Phoniatrics
    Tokyo, 7*, p. 19-25

Selmer, E.   1925: "Noen bemerkninger om 'stød' og tonelag",
    Heidersskrift til Marius Hægstad, p. 90-99

Shipp, T. 1982: "Aspects of voice production and motor control", *Speech Motor Control* (eds.: Grillner, S., Lindblom, B., Lubker, J. and Persson, A.), *Wenner-Gren Symposium Series*, *vol. 36*, p. 105-112

Shipp, Th. and McGlone, R.E. 1971: "Laryngeal dynamics associated with voice frequency change", *J. Speech and Hearing Research 14*, p. 761-768

Siegel, S. 1956: *Nonparametric Statistics for the Behavioral Sciences* (McGraw-Hill International Book Company)

Simada, Z. and Hirose, H. 1970: "The function of the laryngeal muscles in respect to word accent distinction", *Ann. Bull. Res. Inst. Logopedics and Phoniatrics, Tokyo 4*, p. 27-40

Skautrup, P. 1944: *Det danske sprogs historie I* (Gyldendal, Copenhagen)

Smith, S. 1938: "Zur Physiologie des Stosses", *Acta Philologica Scandinavica 12*, p. 33-39

Smith, S. 1944: *Bidrag til Løsning af Problemer vedrørende Stødet i Dansk Rigssprog* (Kaifer, Copenhagen)

Smith, S. 1957: "Chest register versus head-register in the membrane-cushion model of the vocal cords", *Folia Phoniatrica 9*, p. 32-37

Sonesson, B. 1968: "The functional anatomy of the speech organs", *Manual of Phonetics* (ed.: Malmberg, B.) (North-Holland, Amsterdam), p. 45-75

Stevens, K.N. 1977: "Physics of laryngeal behavior and larynx modes", *The Larynx and Language, Phonetica 34*, p. 264-279

Storm, J. 1875: "Om tonefaldet (tonelaget) i de skandinaviske sprog", *Forhandlinger i Videnskabsselskabet i Christiania 1874*, p. 286-297

Sundberg, J. and Gauffin, J. 1979: "Waveform and spectrum of the glottal voice source", *Frontiers of Speech Communication Research* (eds.: Lindblom, B. and Öhman, S.) (Academic Press, London), p. 301-320 (also: *Speech Transm. Lab., Quart. Prog. and Status Rep., Royal Inst. Techn. Stockholm 2-3/ 1978*, p. 35-50)

Sweet, H. 1877: *A Handbook of Phonetics* (Clarendon, Oxford)

Thomsen, V. 1896-97: Obituary on Karl Verner, *Nordisk Tidsskrift for Filologi 3. Række, 5*, p. 187-201

Thorsen, N. 1974: "Acoustical and perceptual properties of the Danish stød", *Ann. Rep. Inst. Phon., Univ. Copenhagen 8*, p. 207-213

Thorsen, N. 1978: "An acoustical investigation of Danish in-
     tonation", *J. Phonetics 6*, p. 151-175

Thorsen, N. 1982: "On the variability in Fo patterning and
     function of Fo timing in languages where pitch cues
     stress", *Phonetica 39*, p. 302-316

Thorsen, N. 1983: "Standard Danish sentence intonation -
     phonetic data and their representation", *Folia Linguistica
     17*, p. 187-220

Uldall, H.J. 1933: *A Danish Phonetic Reader* (University of
     London Press, London)

Uldall, H.J. 1936: "The phonematics of Danish", *Proc. 2 Int.
     Congr. Phon. Sc. 1935*, p. 54-57

Verner, K. 1878: Review of Kock: *Språkhistoriska undersökningar
     om svensk akcent, Anzeiger für deutsches Altertum VII*,
     p. 1-13, reprinted in: *Afhandlinger og Breve 1903*, p. 84-
     104

Verner, K. 1903: *Afhandlinger og Breve*, (ed. by *Selskab for
     germansk Filologi)* (Frimodt, Copenhagen)

Wyke, B. 1967: "Recent advances in the neurology of phonation:
     Phonatory reflex mechanisms in the larynx", *British J.
     Disorders of Communication 2*, p. 2-14

Wyke, B. 1974: Contributions to the discussion of paper 25,
     Ventilatory and Phonatory Control Systems (ed.: Wyke, B.),
     (Oxford University Press), p. 451-456

Wyke, B. 1983: "Neuromuscular control systems in voice produc-
     tion", *Vocal Fold Physiology* (eds.: Bless, D.M. and
     Abbs, J.H.), p. 71-76

Yoshioka, H. and Hirose, H. 1981: "Laryngeal adjustments in
     Japanese word accent", *Ann. Bull. Res. Inst. Logopedics
     and Phoniatrics, Tokyo, 15*, p. 17-30

Zemlin, W.R. 1981: *Speech and Hearing Science*, 2nd ed.,
     (Prentice-Hall, New Jersey).

APPENDIX I

Material and subjects

A. The material

List 1 1974-79 (the main list) (frame: det er ... de siger)

piber	[pʰiːbɒ]	pl. of *pibe* 'pipe', or nomen agentis derived from the verb *pibe* 'to squeak'.
piber	[pʰiːʼbɒ]	pres. of the verb *pibe*
huen	[hu(ː)ən]	definite form of *hue* 'cap'
huen	[huːʼən]	definite form of *hu* 'mind' (obso- lete)
læser	[lɛːsɒ]	nomen agentis of the verb *læse* 'to read'
læser	[lɛːʼsɒ]	pres. of the verb *læse*
kæle	[kʰɛːlə]	infinitive, 'to fondle'
kæler	[kʰɛːʼlɒ]	pres. of the verb *kæle*
kælder	[kʰɛlɒ]	'basement'
Keller	[kʰɛlʼɒ]	a family name
venner	[vɛnɒ]	pl. of *ven* 'friend'
vennen	[vɛnʼn̩]	definite form of *ven*
ven	[vɛn]	'friend'
vend	[vɛnʼ]	imperative of *vende* 'to turn'
du	[du]	'you'
dug	[duːʼ]	'table-cloth'
væn	[vɛːʼn]	'beautiful' (poetic)
Vænern	[vɛːʼnɒn]	name of a lake in Sweden
læsser	[lɛsɒ]	pres. of the verb *læsse* 'to load'
pipper	[pʰibɒ]	pres. of the verb *pippe* 'to chirp'

List 2 1977-79   (frame: det er ... de siger)

aftalen	[ˈau̯ˌtʰæːlən]	'the agreement' def. form of *aftale*
aftaler	[ˈau̯ˌtʰæːʼlɒ]	'makes an agreement'
højhuse	[ˈhɔi̯ˌhuːsə]	'skyscrapers', pl. of *højhus*
højhuset	[ˈhɔi̯ˌhuːʼsəð]	'the skyscraper', def. form of *højhus*

List 3 1974   (frame: det er ... de siger)

5/25	[ˈbiːbiˌbibi / ˈbiːʼbiˌbibi]
15/17	[ˈbiːbiˌbiːbi / ˈbiːʼbiˌbiːbi]

```
16/18    ['bi:bi,bi:'bi / 'bi:'bi,bi:'bi] ·
6/10     [bi'bi:,bibi / bi'bi:',bibi].
7/11     [bibi'bi:bi / bibi'bi:'bi]
```

List 4   ven   vend   væn (frame: det er ...
                                                    de siger)
                        [vɛn]   [vɛn']   [vɛ:'n]
                        (see list 1)

List 5a 1972 (frame: de sagde ... .)

                        læser   læser   piber   piber
                [lɛ:sɒ   lɛ:'sɒ   pʰi:bɒ   pʰi:'bɒ]
                        (see list 1)   plus:

man   [man]   'one' (indef. pron.)
mand   [man']   'man'
pedal   [pʰe'dæ:'l]   'pedal'
betale   [be'tʰæ:'lə]   'to pay'
pagaj   [pʰa'gai̯']   'paddle'
bakkant   [ba'kʰan't]   'bacchant'
purist   [pʰu'ʁist]   'purist'
buddhist   [bu'dist]   'buddhist'

List 5b = 5a plus:

man   [mæ:'n]   'urge!' imper. of mane
manden   [man'n̩]   'the man', def. form of mand.

 kæle   kæler   kælder   Keller   huen   huen
[kʰɛ:lə   kʰɛ:'lɒ   kʰɛlɒ   kʰɛl'ɒ   hu(:)ən   hu:'ən
                (see list 1)

List 6 1977

taler   [tʰæ:lɒ]   nomen agentis of the verb tale 'to
taler   [tʰæ:'lɒ]   pres. of the verb tale   speak'
pæn   [pʰɛ:'n]   'pretty'
pæne   [pʰɛ:nə]   'pretty' (pl.)
pen   [pʰɛn']   'pen'   plus:

læser   læser   kæle   kæler   kælder   Keller
[lɛ:sɒ   lɛ:'sɒ   kʰɛ:lə   kʰɛ:'lɒ   kʰɛlɒ   kʰɛl'ɒ]
                (see list 1)

Kan du sige Anna?   [kʰa du si: 'ana] 'can you say Anna?'
  "   "   "   "   [kʰa du si: 'ʔana] "   "   "   "
Kan du sige Hanna?   [kʰa du si: 'hana] 'can you say Hanna?'
Kan du lide Nana?   [kʰa du 'li:' 'nana] 'do you like Nana?'
Han gik lige i seng   [han gig 'li: i 'sɛŋ'] 'he went straight
                                                        to bed'
  "   "   "   " "   [han gig 'li: ʔi 'sɛŋ'] "   "   "   "
Der er et lig i sengen [dɑ:·d 'li:' i 'sɛŋ'n̩] 'there is a
                                                corpse in the bed'
```

List 7 1981    (frame: de vil sige ... igén)

| | | |
|---|---|---|
| *mile* | [mi:lə] | 'mile' (pl.) |
| *mil* | [mi:'l] | 'mile' (sg.) . |
| *mild* | [mil'] | 'soft' |

| | | |
|---|---|---|
| *sile* | [si:lə] | 'to pour' |
| *sil* | [si:'l] | imperative of *sile* |
| *sild* | [sil'] | 'herring' |

| | | |
|---|---|---|
| *diset* | [di:səð] | 'hazy' |
| *disen* | [di:'sən] | 'the haze', def. form of *dis* |

| | | |
|---|---|---|
| *Sanddalen* | ['san͵dæ:'lən] | a place name |
| *sandalen* | [san'dæ:'lən] | 'the sandal' |

List 8a 1985   (frame: jeg kan gódt sige ... til Pálle)

All words from list 1, except *væn* and *Vænern*, plus:

| | | |
|---|---|---|
| *buse* | [bu:sə] | 'to rush' |
| *buser* | [bu:'sɒ] | present of *buse* |

| | | |
|---|---|---|
| *duen* | [du:ən] | 'the dove', def. form of *due* |
| *dugen* | [du:'ən] | 'the table-cloth', def. form of *dug* |

| | | |
|---|---|---|
| *taget* | [tʰæ:əð] | 'taken', part.perf. of *tage* |
| *taget* | [tʰæ:'əð] | 'the roof', def. form of *tag* |

| | | |
|---|---|---|
| *sejlet* | [sailəð] | part.perf. of *sejle* 'to sail' |
| *sejlet* | [sai̯'ləð] | 'the sail', def. form of *sejl* |

| | | |
|---|---|---|
| *fældes* | [fɛləs] | 'is felled', passiv of *fælde* |
| *fælles* | [fɛl'əs] | 'common' |

| | | |
|---|---|---|
| *gæller* | [gɛlɒ] | 'gills', pl. of *gælle* |
| *gælder* | [gɛl'ɒ] | 'is valid', pres. of *gælde* |

| | | |
|---|---|---|
| *føl* | [føl] | 'foal' |
| *føl* | [fø:'l] | 'feel!', imper. of *føle* |

| | | |
|---|---|---|
| *pib* | [pʰib] | 'chirp' |
| *pib* | [pʰi:'b] | 'squeak!', imper. of *pibe* |

| | | |
|---|---|---|
| *tag* | [tʰa] | 'take!', imper. of *tage* } variants |
| *tag* | [tʰæ:'] | 'take!',    "      "    " |

(both also short forms of the infinitive)

List 8b 1985  (frame: jeg kan gódt sige ... til Pálle)

All words from list 1, except *væn* and *Vænern* plus:

| | | |
|---|---|---|
| *buse* | [bu:sə] | 'to rush' |
| *buser* | [bu:'sɒ] | present of *buse* |

| | | |
|---|---|---|
| *file* | [fi:lə] | 'to file' |
| *filer* | [fi:'lɒ] | pres. of *file* |

bene      [beːnə]          'to leg it'
benet     [beːˈnəð]        'the leg', def. form of *ben*

tabe      [tʰæːbə]         'to lose'
tabet     [tʰæːˈbəð]       'the loss', def. form of *tab*

gabe      [gæːbə]          'to yawn'
gabet     [gæːˈbəð]        'the yawning', def. form of *gab*

sale      [sæːlə]          'halls', pl. of *sal*
salen     [sæːˈlən]        'the hall', def. form of *sal*

tag       [tʰa]            'take!'
tag       [tʰæːˈ]           "     (see 8a).


## List 9  1986  (frame: Jeg kan lét sige .... fém gánge)

maler     [mæːlɒ]          'painter', nomen agentis of the verb
maler     [mæːˈlɒ]         'paints', pres. of *male*          *male*

spiser    [sbiːsɒ]         'dishes', pl. of *spise*
spiser    [sbiːʔsɒ]        'eats', pres. of the verb *spise*

musen     [muːsən]         'the Muse', def. form of *muse*
musen     [muːˈsən]        'the mouse', def. form of *mus*

posen     [pʰoːsən]        'the bag', def. form of *pose*
Posen     [pʰoːˈsən]       Place name.


## List 10  1986

'far renser 'piber i 'aften   [pʰiːbɒ]
'musene 'piber på 'loftet     [pʰiːˈbɒ]

'børnene elsker at 'kæle med 'hunden  [kʰɛːlə]
'børnene 'sidder og 'kæler med 'hunden  [kʰɛːˈlɒ]

'bogens 'læser vil 'undre sig   [lɛːsɒ]
'drengen 'læser om 'aftenen     [lɛːˈsɒ]


## List 11  1986

Der 'står en 'maler på 'stigen   [mæːlɒ]
Han 'står og 'maler på 'stigen   [mæːˈlɒ]

'Digteren 'påkaldte 'Musen for'gæves  [muːsən]
'Bageren 'fangede 'musen i 'fælden    [muːˈsən]

Der var 'mange 'lækre 'spiser på 'bordet  [sbiːsɒ]
Hun har 'spurgt om 'Peter 'spiser på 'skolen  [sbiːˈsɒ]


## List 12  1986

Der 'står en 'maler på 'stigen   [mæːlɒ]
Han 'står og 'maler på 'stigen   [mæːˈlɒ]

Han 'viste en 'valen 'holdning   [væːlən]
Han 'fjernede 'hvalens 'finner   [væːˈləns]

*Der 'sidder en 'måler på 'væggen*     [må:lɒ]
*Han 'sidder og 'måler på 'kurven*      [må:'lɒ]

*'Bogens 'læser vil 'undre sig*         [lɛ:sɒ]
*'Drengen 'læser om 'aftenen*           [lɛ:'sɒ]

List 13    1986

| | | |
|---|---|---|
| *mile*  | [mi:lə]   | 'miles' |
| *milen* | [mi:'lən] | 'the mile' |
| *pile*  | [pʰi:lə]  | 'arrows, willows' |
| *pilen* | [pʰi:'lən] | 'the arrow, the willow' |
| *bile*  | [bi:lə]   | 'to go by motor car' |
| *bilen* | [bi:'lən] | 'the motor car' |
| *lime*  | [li:mə]   | 'to glue' |
| *limen* | [li:'mən] | 'the glue' |

## B. The subjects

BF        born 1935 in Ribe, West Jutland, since 1953 in
          Copenhagen. He speaks Standard Danish on a Jutlandic
          basis but also with some influence from Modern Copen-
          hagen speech.

BH        born 1946 in Copenhagen; has spent all her life in
          Copenhagen, speaks "Advanced Standard Copenhagen"
          (ASC).

BM        born 1947 in Grenaa, Eastern Jutland, but moved to
          Copenhagen at the age of seven; has still some remi-
          niscences of non-Copenhagen pronunciation.

BRP       (= Pia Riber Petersen's subject No. 22) born 1933 in
          Copenhagen and has spent all his life here; speaks ASC.

FJ        born 1911 in Nakskov, Lolland; grew up in South Funen
          but has never spoken dialect. Since 1929 in Copen-
          hagen, speaks a slightly conservative Standard Danish,
          but influenced by Copenhagen intonation.

HU        born 1945 in Copenhagen; has spent all her life in
          Copenhagen and speaks ASC.

JJ        born 1949 in Hornbæk, North Zealand; spoke regional
          Zealandish Standard as a child, now ASC. Has lived
          in Copenhagen since 1969.

JR        born 1934 in West Funen; spoke Standard Danish with
          his parents, speaks a slightly conservative Standard
          Danish but with influence from Copenhagen intonation.

LG        born 1946 in Copenhagen; has lived in North Zealand
          (Snekkersten) since his early childhood. Speaks ASC.

MF      born 1939 in North Zealand, from 1946-57 in South Zealand,
        from 1957 in Copenhagen; speaks Standard Danish

ND      born 1950 in Hellerup, Northern Copenhagen; has spent
        all his life here.

NR      born 1943 in Gammel Holte, North Zealand, since 1964 in
        Copenhagen; speaks ASC.

OB      born 1946 in East Jutland; lived until 1965 in various
        East Jutlandish towns, the last seven years in Århus,
        from 1965 in Copenhagen; speaks ASC on a Jutlandish
        basis.

PD      born 1950 in Southern Zealand; lived in various Zealandish
        towns until 1969, from then on in Copenhagen; speaks
        ASC.

PM      born 1946 in Himmerland, East Jutland; spoke dialect
        until the age of ten, then also regional standard.
        Lives in Copenhagen since 1967.  He has adopted the
        Copenhagen intonation, but he has a perceptible Jut-
        landish rhythm.

        Two subjects from the Haskins investigation have been
        included in some cases:

PMi     born 1942 in Copenhagen, has lived in Roskilde and
        Copenhagen; speaks ASC.

TB      born 1937, spent his childhood in southern Jutland,
        since 1955 in Copenhagen; speaks Standard Danish.

# APPENDIX II

## Duration

### 1. Survey of material used for measurements of duration.

#### a. Long vowel with and without stød

| List | Year | Number of word pairs | Subjects and (average) number of repetitions | | | | |
|------|------|------|------|------|------|------|------|
| 1 | 1974 | 3 | BF 10 | HU 12 | NR 6 | | |
|   |      |   | BH 8 | JJ 12 | | | |
|   |      |   | BM 10 | JR 3 | | | |
|   | 1977a-b | 3  3 | BF 12 11 | | | | |
|   | 1979a-b | 3  3 | BF 12 17 | | | | |
| 3 | 1974 | 4 | JR 10 | | | | |
|   |      | 3 | BM 9 | JJ 9 | | | |
| 5a | 1972 | 2 | TB 16 | PMI 16 | | | |
| 6 | 1977 | 3 | FJ 18 | | | | |
| 7 | 1981 | 1 | FJ 12 | | | | |
| 8a | 1985 | 4 | FJ 8 | | | | |
| 8b | 1985 | 9 | HU 8 | JR 8 | NR 8 | | |
| 9 | 1986 | 4 | ND 10 | NR 10 | PM 10 | PD 10 | OB 10 |
| 10 | 1986 | 3 | HU 8 | NR 8 | | | |
| 11 | 1986 | 3 | OB 8 | | | | |
| 12 | 1986 | 3 | BRP 8 | | | | |

#### b. Short vowel with and without following stød

| List | Year | Number of word pairs | Subjects and (average) number of repetitions | | |
|------|------|------|------|------|------|
| 1 | 1974 | 3 | same as a,1 | | |
|   | 1977 a-b | 3 | BF 12 | 11 | |
|   | 1979 a-b | 3 | BF 12 | 18 | |
| 8a | 1985 | 5 | FJ 7 | | |
| 8b |      | 3 | HU 8 | JR 8 | NR 8 |

c.  Consonant after long vowel with and without stød

| List | Year | Number of word pairs | Subjects and (average) number of repetitions | | | | |
|------|------|----------------------|----------------------------------------------|---|---|---|---|
| 1 | 1974 | 1 | BM 10 | HU 12 | | | |
|   |      | 3 | BF 10 | | | | |
| 1 | 1977 | 2 | BF 12 | 11 | | | |
| 8a | 1985 | 5 | FJ 8 | | | | |
| 8b | 1985 | 3 | HU 8 | JR 8 | NR 8 | | |

d.  Consonant after short vowel with and without stød

| List | Year | Number of word pairs | Subjects and (average) number of repetitions | | | | |
|------|------|----------------------|----------------------------------------------|---|---|---|---|
| 1 | 1974 | 1 | BF 12 | BM 10 | HU 12 | | |
|   |      |   |       | JR 3  | NR 6  | | |
|   |      | 2 | JJ 12 | | | | |
| 8a | 1985 | 5 | FJ 7 | | | | |
| 8b | 1985 | 3 | HU 8 | JR 8 | NR 8 | | |

2a. Duration (in cs) of V: and V:', and V:' in percentage of V:

List 1 (significance: * < 5%, ** < 1%, *** < 0.1%)

|        | BF 1974 | | 1977a | | 1977b | | 1979a | | 1979b | |
|--------|------|------|------|------|------|------|------|------|------|------|
| N      | 11 | | 12 | | 11 | | 12 | | 17 | |
|        | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. |
| pʰi:bɒ | 14.4 | 1.5 | 15.6 | 2.8 | 16.8 | 1.1 | 14.8 | 1.5 | 16.3 | 1.2 |
| pʰi:'bɒ | 11.9 | 2.0 | 12.0 | 1.1 | 13.5 | 1.4 | 13.6 | 1.8 | 14.1 | 2.0 |
| diff.  | 2.5** | | 3.6*** | | 3.3*** | | 1.2 | | 2.2*** | |
|        | 83% | | 77% | | 80% | | 92% | | 87% | |
| kʰɛ:lə | 22.8 | 1.8 | 21.6 | 1.6 | 23.0 | 1.5 | 21.4 | 8.0 | 23.0 | 2.3 |
| kʰɛ:'lɒ | 18.7 | 1.6 | 17.7 | 1.4 | 17.9 | 1.5 | 16.6 | 1.1 | 18.2 | 1.6 |
| diff.  | 4.1*** | | 3.9*** | | 5.1*** | | 4.8*** | | 4.8*** | |
|        | 82% | | 82% | | 78% | | 78% | | 79% | |
| lɛ:sɒ  | 19,7 | 1.2 | 19.5 | 0.9 | 19.6 | 1.2 | 19.3 | 1.1 | 18.8 | 1.3 |
| lɛ:'sɒ | 18.7 | 1.6 | 17.5 | 1.1 | 16.7 | 1.7 | 17.9 | 1.1 | 18.1 | 1.5 |
| diff.  | 1.0 | | 2.0*** | | 2.9*** | | 1.4 | | 0.7 | |
|        | 95% | | 90% | | 85% | | 93% | | 96% | |

|        | BH | | BM | | HU | | JJ | | JR | | NR | |
|--------|------|------|------|------|------|------|------|------|------|------|------|------|
| N      | 10 | | 10 | | 12 | | 12 | | 3 | | 6 | |
|        | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. |
| pʰi:bɒ | 10.5 | 1.1 | 13.9 | 0.7 | 17.2 | 0.9 | 14.7 | 1.4 | 14.5 | | 17.2 | 0.8 |
| pʰi:'bɒ | 11.4 | 1.3 | 13.6 | 0.7 | 14.7 | 1.2 | 12.9 | 1.4 | 12.5 | | 13.2 | 1.5 |
| diff.  | -0.9 | | 0.3 | | 2.5*** | | 1.8*** | | 2.0 | | 4.0*** | |
|        | 109% | | 98% | | 85% | | 88% | | 86% | | 77% | |
| kʰɛ:lə | 19.8 | 1.6 | 19.2 | 1.6 | 24.3 | 1.5 | 22.3 | 1.5 | 23.0 | | 25.5 | 1.4 |
| kʰɛ:'lɒ | 19.4 | 1.7 | 19.5 | 1.6 | 20.3 | 1.2 | 18.4 | 0.8 | 20.0 | | 19.0 | 1.1 |
| diff.  | 0.4 | | -0.4 | | 4.0*** | | 3.9*** | | 3.0 | | 6.5*** | |
|        | 98% | | 102% | | 84% | | 83% | | 87% | | 75% | |
| lɛ:sɒ  | 20.3 | 1.7 | 15.9 | 0.7 | 23.2 | 1.6 | 20.4 | 1.3 | 18.0 | | 20.0 | 1.1 |
| lɛ:'sɒ | 20.0 | 1.8 | 16.3 | 0.8 | 21.7 | 1.7 | 19.5 | 0.9 | 17.3 | | 19.0 | 0.6 |
| diff.  | 0.3 | | -0.4 | | 1.5* | | 0.9 | | 0.7 | | 1.0 | |
|        | 99% | | 103% | | 94% | | 96% | | 96% | | 95% | |

2b.  Duration (in cs) of V: and V:', and V:' in percentage of V:

List 3 (significance: * < 5%, ** < 1%, *** < 0.1%)

| Word No. | | JR | | BM | | JJ | |
|---|---|---|---|---|---|---|---|
| | N | 9 | | 9 | | 9 | |
| | | av. | s.d. | av. | s.d. | av. | s.d. |
| 15 | 'bi:bi‚bi:bi | 18.2 | 1.5 | 15.4 | 0.9 | 18.1 | 2.0 |
| 17 | 'bi:'bi‚bi:bi | 17.0 | 1.7 | 14.5 | 1.2 | 14.4 | 1.2 |
| | diff. | 1.2 | | 0.9 | | 3.7*** | |
| | | 93% | | 94% | | 80% | |
| 16 | 'bi:bi‚bi:'bi | 18.1 | 1.9 | 14.3 | 1.1 | 19.3 | 2.0 |
| 18 | 'bi:'bi‚bi:'bi | 16.1 | 2.1 | 14.6 | 1.2 | 13.2 | 1.7 |
| | diff. | 2.0* | | -0.3 | | 6.1*** | |
| | | 89% | | 102% | | 68% | |
| 7 | 'bibi'hi:bi | 16.6 | | | | 20.2 | 3.0 |
| 11 | 'bibi'bi:'bi | 15.9 | | | | 13.4 | 1.0 |
| | diff. | 0.7 | | | | 6.8*** | |
| | | 96% | | | | 66% | |
| 5 | 'bi:bi‚bibi | 18.0 | 2.0 | 14.8 | 0.8 | | |
| 25 | 'bi:'bi‚bibi | 16.6 | 1.4 | 14.0 | 1.5 | | |
| | diff. | 1.4 | | 0.8 | | | |
| | | 92% | | 95% | | | |

2c.  Duration (in cs) of V: and V:', and V:' in percentage of V:

Lists 5a, 6 and 7 (significance: * < 5%, ** < 1%, *** < 0.1%)

| List 5a. | TB | PMi | List 6 | FJ | List 7 | FJ |
|---|---|---|---|---|---|---|
| N | 16 | 16 | N | 19 | N | 12 |
| | av. | av. | | av. | | av. |
| pʰi:bɒ | 17.6 | 17.8 | tʰæ:lɒ | 25.9 | di:səð | 15.6 |
| pʰi:'bɒ | 13.0 | 13.5 | tʰæ:'lɒ | 21.8 | di:'sən | 14.1 |
| diff. | 4.6*** | 4.3*** | diff. | 4.1*** | diff. | 1.5*** |
| | 74% | 76% | | 84% | | 90% |
| lɛ:sɒ | 22.0 | 22.8 | kʰɛ:lə | 26.3 | | |
| lɛ:'sɒ | 18.1 | 21.6 | kʰɛ:'lɒ | 20.7 | | |
| diff. | 3.9*** | 1.2 | diff. | 5.6*** | | |
| | 82% | 95% | | 79% | | |
| | | | lɛ:sɒ | 21.8 | | |
| | | | lɛ:'sɒ | 19.3 | | |
| | | | diff. | 2.5*** | | |
| | | | | 89% | | |

## 2d. Duration (in cs) of V: and V:', and V:' in percentage of V:

Lists 8a and 8b (significance: * < 5%, ** < 1%, *** < 0.1%)

|  | 8a | | 8b | | | | | |
|---|---|---|---|---|---|---|---|---|
|  | FJ | | HU | | JR | | NR | |
| N | 8 | | 8 | | 8 | | 8 | |
|  | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. |
| pʰi:bɒ | 14.6 | 1.0 | 15.8 | 1.5 | 13.0 | 0.9 | 14.1 | 0.7 |
| pʰi:'bɒ | 11.4 | 1.1 | 13.4 | 0.8 | 11.5 | '0.8 | 11.2 | 1.1 |
| diff. | 3.2*** | | 2.4** | | 1.5** | | 2.9*** | |
|  | 78% | | 85% | | 88% | | 79% | |
| kʰɛ:lə | 20.7 | 1.1 | 24.1 | 1.5 | 16.8 | 1.2 | 20.9 | 1.0 |
| kʰɛ:'lɒ | 15.6 | 0.6 | 18.7 | 1.3 | 15.6 | 1.0 | 15.2 | 1.1 |
| diff. | 5.1*** | | 5.4*** | | 1.2** | | 5.7*** | |
|  | 75% | | 78% | | 93% | | 73% | |
| lɛ:sɒ | 19.6 | 1.0 | 22.1 | 1.3 | 16.9 | 0.5 | 19.8 | 1.8 |
| lɛ:'sɒ | 17.2 | 0.7 | 20.5 | 0.9 | 13.9 | 0.8 | 18.4 | 1.1 |
| diff. | 2.4*** | | 1.6** | | 3.0*** | | 1.4** | |
|  | 88% | | 93% | | 82% | | 93% | |
| bu:sə | 20.3 | 1.0 | 22.4 | 1.0 | 17.6 | 0.7 | 21.4 | 0.7 |
| bu:'sɒ | 16.1 | 0.7 | 18.6 | 0.4 | 15.6 | 0.4 | 17.0 | 1.1 |
| diff. | 4.2*** | | 3.8*** | | 2.0*** | | 4.4*** | |
|  | 79% | | 83% | | 89% | | 79% | |
| gæ:bə | | | 23.9 | 1.2 | 19.3 | 1.0 | 21.4 | 0.9 |
| gæ:'bəð | | | 20.8 | 1.0 | 18.3 | 0.9 | 19.3 | 1.0 |
| diff. | | | 3.1*** | | 1.0* | | 2.1** | |
|  | | | 87% | | 95% | | 90% | |
| tʰæ:bə | | | 21.6 | 0.7 | 17.0 | 0.5 | 20.1 | 0.9 |
| tʰæ:'bəð | | | 18.3 | 0.7 | 15.8 | 1.1 | 16.3 | 0.9 |
| diff. | | | 3.3*** | | 1.2* | | 3.8*** | |
|  | | | 85% | | 93% | | 81% | |
| be:nɒ | | | 22.5 | 1.6 | 18.2 | 0.9 | 18.6 | 0.9 |
| be:'nəð | | | 18.2 | 0.9 | 15.9 | 1.0 | 14.8 | 1.0 |
| diff. | | | 4.3*** | | 2.3** | | 3.8*** | |
|  | | | 81% | | 87% | | 80% | |
| sæ:lə | | | 26.4 | 1.2 | 20.3 | 0.8 | 21.7 | 0.8 |
| sæ:'lən | | | 23.5 | 1.1 | 17.7 | 1.4 | 18.4 | 0.9 |
| diff. | | | 2.9*** | | 2.6*** | | 3.3*** | |
|  | | | 89% | | 87% | | 85% | |
| fi:lə | | | 20.9 | 1.1 | 15.8 | 0.6 | 17.3 | 0.8 |
| fi:'lɒ | | | 15.7 | 1.7 | 14.7 | 1.2 | 12.8 | 1.0 |
| diff. | | | 5.2*** | | 1.1* | | 4.5*** | |
|  | | | 75% | | 93% | | 74% | |

2e. Duration (in cs) of V: and V:', and V:' in percentage of V:

List 9 (significance: * < 5%, ** < 1%, *** < 0.1%)

|        | ND | | PD | | PM | | OB | | NR |
|--------|------|------|------|------|------|------|------|------|------|
| N      | 10 | | 10 | | 10 | | 10 | | 10 |
|        | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. | av. |
| mæ:lɒ  | 29.3 | 1.8 | 18.7 | 1.5 | 15.6 | 0.8 | 17.9 | | 20.1 |
| mæ:'lɒ | 23.3 | 1.6 | 16.6 | 1.2 | 14.0 | 0.9 | 16.1 | | 18.0 |
| diff.  | 6.0*** | | 2.1** | | 1.6*** | | 1.8** | | 2.1*** |
|        | 80% | | 89% | | 90% | | 90% | | 90% |
| sbi:sɒ  | 20.9 | 0.9 | 14.4 | 1.2 | 13.7 | 0.8 | 16.3 | | 15.0 |
| sbi:'sɒ | 16.0 | 1.0 | 11.8 | 0.7 | 10.8 | 0.5 | 14.1 | | 15.1 |
| diff.  | 4.9*** | | 2.6*** | | 2.9*** | | 2.2** | | -0.1 |
|        | 77% | | 82% | | 79% | | 87% | | 101% |
| mu:sən  | 25.4 | 1.1 | 17.9 | 1.3 | 16.9 | 0.9 | 19.1 | | 17.2 |
| mu:'sən | 21.6 | 1.7 | 14.7 | 1.0 | 15.1 | 0.6 | 16.9 | | 15.3 |
| diff.  | 3.8*** | | 3.2*** | | 1.8*** | | 2.2** | | 1.9*** |
|        | 85% | | 82% | | 89% | | 88% | | 89% |
| pʰo:sən  | 26.2 | 1.9 | 19.1 | 1.2 | 16.6 | 0.7 | 18.2 | | 18.3 |
| pʰo:'sən | 20.7 | 1.6 | 14.6 | 1.1 | 14.8 | 1.1 | 15.9 | | 16.2 |
| diff.  | 5.5*** | | 4.5*** | | 1.8*** | | 2.3** | | 2.1*** |
|        | 79% | | 76% | | 89% | | 87% | | 89% |


2f. Duration (in cs) of V: and V:', and V:' in percentage of V:

|        | HU | NR |        | OB |        | BRP |
|--------|------|------|--------|------|--------|------|
| N      | 8 | 8 |        | 8 |        | 8 |
|        | av. | av. |        | av. |        | av. |
| kʰɛ:lə  | 12.8 | 15.6 | mæ:lɒ  | 12.9 | mæ:lɒ  | 19.9 |
| kʰɛ:'lɒ | 13.7 | 13.6 | mæ:'lɒ | 12.4 | mæ:'lɒ | 15.8 |
| diff.  | -0.9 | 2.0** |        | 0.5 |        | 4.1*** |
|        | 107% | 87% |        | 96% |        | 79% |
| pʰi:bɒ  | 11.4 | 12.2 | sbi:sɒ  | 11.6 | må:lɒ  | 21.0 |
| pʰi:'bɒ | 9.8 | 9.8 | sbi:'sɒ | 10.3 | må:'lɒ | 16.4 |
| diff.  | 1.6** | 2.4*** |        | 1.3** |        | 4.6*** |
|        | 86% | 80% |        | 89% |        | 78% |
| lɛ:sɒ  | 15.9 | 15.2 | mu:sən  | 14.0 | lɛ:sɒ  | 18.6 |
| lɛ:'sɒ | 15.6 | 16.1 | mu:'sən | 13.2 | lɛ:'sɒ | 19.1 |
| diff.  | 0.3 | -0.9 |        | 0.8* |        | -0.5 |
|        | 98% | 106% |        | 94% |        | 103% |

3a. Duration (in cs) of short vowels with and without following stød.

List 1 (significance: * < 5%, ** < 1%, *** < 0.1%)

| BF | 1974 | | 1977a | | 1977b | | 1979a | | 1979b | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | 12 | | 11 | | 11 | | 17 | | 12 | |
| | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. |
| kʰɛlɒ | 12.8 | 0.7 | 12.0 | 0.9 | 11.4 | 1.7 | 10.2 | 1.3 | 10.7 | 0.6 |
| kʰɛl'ɒ | 10.5 | 1.7 | 8.8 | 0.4 | 8.4 | 1.2 | 7.8 | 1.0 | 7.9 | 1.0 |
| diff. | 2.3*** | | 3.2*** | | 3.0*** | | 2.4*** | | 2.8*** | |
| sɛn | 12.5 | 1.4 | 9.1 | 0.2 | 10.0 | 1.4 | 8.7 | 1.2 | 8.2 | 1.7 |
| sɛn' | 11.0 | 0.9 | 7.8 | 1.3 | 8.7 | 1.5 | 8.3 | 1.3 | 8.8 | 1.0 |
| diff. | 1.5* | | 1.3** | | 1.3* | | 0.4 | | -0.6 | |

| | BH | | BM | | HU | | JJ | | JR | | NR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 10 | | 10 | | 12 | | 12 | | 3 | | 6 | |
| | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. | av. | s.d. |
| kʰɛlɒ | 11.6 | | 12.4 | 1.0 | 12.5 | 0.9 | 10.5 | 1.1 | 10.7 | | 12.1 | 1.2 |
| kʰɛl'ɒ | 11.6 | | 10.5 | 0.8 | 11.4 | 1.3 | 8.3 | 0.7 | 10.0 | | 11.1 | 0.5 |
| diff. | 0 | | 1.9** | | 1.1 | | 2.2*** | | 0.7 | | 1.0* | |
| vɛnɒ | 12.6 | 1.1 | 12.4 | 1.0 | 12.3 | | 12.0 | 1.0 | 10.3 | | 14.0 | 1.0 |
| vɛn'ṇ | 14.1 | 1.3 | 10.5 | 1.1 | 13.1 | | 10.1 | 1.3 | 10.3 | | 12.0 | 0.8 |
| diff. | -1.5* | | 1.9** | | -0.8 | | 1.9** | | 0 | | 2.0** | |
| vɛn | 11.1 | 0.6 | 10.0 | 0.8 | 10.9 | 0.7 | 9.1 | | 9.3 | | 9.5 | 1.0 |
| vɛn' | 14.1 | 1.2 | 9.9 | 0.7 | 12.6 | 1.2 | 9.9 | | 10.0 | | 11.2 | 1.8 |
| diff. | -3.0*** | | 0.1 | | -1.7** | | -0.8 | | -0.7 | | -1.7 | |

3b. Duration (in cs) of short vowels with and without following stød.

List 8 (significance: * < 5%, ** < 1%, *** < 0.1%)

| | 8a | | | 8b | | | | |
|---|---|---|---|---|---|---|---|---|
| | FJ | | | HU | | JR | | NR | |
| N | 7 | | | 8 | | 8 | | 8 | |
| | av. | s.d. | | av. | s.d. | av. | s.d. | av. | s.d. |
| kʰɛlɒ | 10.8 | 1.3 | | 10.8 | 1.1 | 8.5 | 0.4 | 10.9 | 0.7 |
| kʰɛl'ɒ | 8.2 | 0.8 | | 9.9 | 0.8 | 8.7 | 0.8 | 9.2 | 1.1 |
| diff. | 2.6*** | | | 0.9 | | -0.2 | | 1.7** | |
| vɛnɒ | 12.3 | 0.6 | | 11.3 | 0.8 | 10.0 | 0.7 | 11.2 | 0.5 |
| vɛn'n | 10.8 | 0.9 | | 10.4 | 0.5 | 9.6 | 1.0 | 9.9 | 0.5 |
| diff. | 1.5** | | | 0.9* | | 0.4 | | 1.3*** | |
| vɛn | 9.8 | 0.6 | | 9.4 | 0.9 | 8.6 | 0.7 | 9.2 | 0.9 |
| vɛn' | 9.7 | 0.9 | | 9.8 | 0.7 | 9.9 | 0.8 | 8.8 | 0.6 |
| diff. | 0.1 | | | -0.4 | | -1.3** | | 0.4 | |
| gɛlɒ | 12.8 | 1.2 | | | | | | | |
| gɛl'ɒ | 10.4 | 0.7 | | | | | | | |
| diff. | 2.4*** | | | | | | | | |
| fɛləs | 12.1 | 0.3 | | | | | | | |
| fɛl'əs | 9.5 | 0.8 | | | | | | | |
| diff. | 2.6*** | | | | | | | | |

## 4a. Duration (in cs) of consonants with and without stød.

List 1 (significance: * < 5%, ** < 1%, *** < 0.1%)

|          | BF 1974 |      | BM  |      | HU  |      | JJ  |      | JR  | NR  |      |
|----------|---------|------|-----|------|-----|------|-----|------|-----|-----|------|
| N        | 12      |      | 10  |      | 12  |      | 12  |      | 4   | 6   |      |
|          | av.     | s.d. | av. | s.d. | av. | s.d. | av. | s.d. | av. | av. | s.d. |
| kʰɛlɒ    | 6.1     | 1.1  | 5.6 | 1.0  | 5.9 | 0.9  | 6.8 | 0.9  | 5.3 | 6.7 | 0.8  |
| kʰɛl'ɒ   | 7.4     | 1.4  | 7.2 | 1.0  | 7.5 | 1.1  | 9.0 | 1.1  | 6.0 | 8.0 | 0.9  |
| diff.    | -1.3*   |      | -1.6** |   | -1.6** |  | -2.2*** | | -0.7 | -1.3* |  |

## 4b. Duration (in cs) of consonants with and without stød.

List 8 (significance: * < 5%, ** < 1%, *** < 0.1%)

|          | 8a  |      |      | 8b  |      |      |      |      |      |
|----------|-----|------|------|-----|------|------|------|------|------|
|          | FJ  |      |      | HU  |      | JR   |      | NR   |      |
| N        | 7   |      |      | 8   |      | 8    |      | 8    |      |
|          | av. | s.d. |      | av. | s.d. | av.  | s.d. | av.  | s.d. |
| kʰɛlɒ    | 5.8 | 0.7  |      | 6.4 | 0.6  | 4.7  | 0.4  | 5.3  | 0.6  |
| kʰɛl'ɒ   | 8.3 | 0.9  |      | 9.9 | 1.1  | 7.3  | 0.8  | 6.9  | 0.6  |
| diff.    | -2.5*** |  |      | -3.5** |  | -2.6*** |  | -1.6*** |   |
| vɛnɒ     | 5.3 | 0.8  |      | 9.6 | 1.0  | 5.8  | 1.0  | 5.4  | 0.8  |
| vɛn'n̩    | 10.3 | 1.1 |      | 12.1 | 0.9 | 8.3  | 1.0  | 8.9  | 0.6  |
| diff.    | -5.0*** |  |      | -2.5*** | | -2.5*** |  | -3.5*** |   |
| vɛn·     | 7.8 | 1.0  |      | 10.5 | 0.9 | 5.2  | 0.4  | 8.1  | 0.6  |
| vɛn'     | 11.7 | 1.9 |      | 13.3 | 0.8 | 6.8  | 0.5  | 9.4  | 1.0  |
| diff.    | -3.9*** |  |      | -2.8*** | | -1.6*** |  | -1.3*** |   |
| gɛlɒ     | 5.9 | 0.5  |      |     |      |      |      |      |      |
| gɛl'ɒ    | 7.5 | 1.1  |      |     |      |      |      |      |      |
| diff.    | -1.6* |    |      |     |      |      |      |      |      |
| fɛləs    | 6.4 | 0.5  |      |     |      |      |      |      |      |
| fɛl'əs   | 8.6 | 0.7  |      |     |      |      |      |      |      |
| diff.    | -2.2*** |  |      |     |      |      |      |      |      |

# APPENDIX III

## Intensity

### Survey of material used for analysis of intensity

| List | Year | Number of pairs | Subjects and number of repetitions | | | |
|------|------|-----------------|------------|---|---|---|
| 1 | 1974 | 7-10 | BF 11 | HU 12 | | |
| | | | BH 8 | JJ 12 | | |
| | | | BM 10 | NR 6 | | |
| | 1977a-b } | 6-7 | BF 12 11 | | | |
| | 1979 a-b } | | BF 12 17 | | | |
| 3 | 1974 | 3-5 | JR 10 | BM 10 | | |
| 9 | 1986 | 4 | ND 10 | NR 10 | OB 10 | |
| | | | PD 10 | PM 10 | | |
| 10 | 1986 | 3 | HU 8 | NR 8 | | |
| 11 | 1986 | 3 | OB 8 | | | |
| 13 | 1986 | 3 | BRP 8 | | | |

Average intensity curves of individual word pairs are shown on the following pages (Figures 1 a-d, and 2 a-b). For reasons of space some pairs which were quite similar to pairs included, were left out: In list 1 three of BF's five recordings, for all subjects the unpaired words and the pairs [ɑu / ɑu:'] (with different vowel length) and [vɛnɒ / vɛn'ɳ] (which is quite similar to [kʰɛlɒ/kʰɛl'ɒ]), in list 3: 16/18 and 5/25 which are almost identical to 15/17, in list 9: [pʰo:sən/pʰo:'sən].

Lists 1 and 3 were averaged by computer, Lists 9, 10, 11 and 12 manually. In list 1 [pʰi:bɒ] was left out by mistake in the sampling. Therefore averages of [pʰi:bɒ / pʰi:'bɒ] were made manually on the basis of a new mingographic recording (except for BF).

*Figure 1a*

*Intensity average curves 1974 (list 1). Subject BF (N = 11) and BF 1979b (N = 17).*
―― *: no stød.* ---- *: stød. A: vowel start (line-up point), B: vowel end, C: end*
*of following consonant.* | *: no stød,* ⁝ *: stød.* ┌┬┬┬┐ *10 cs.*

*Figure 1b*

*Intensity average curves 1974 (list 1). BM (N = 10), BH (N = 8).* ——— : *no stød,*
---- : *stød.  See legend to Fig. 1a.*

*Figure 1c*

*Intensity average curves 1974 (list 1). HU (N = 12), JJ (N = 12). ——— : no stød,
--- : stød.  See legend to Figure 1a.*

*Figure 1d*

*Intensity average curves 1974 (list 1). NR (N = 6), list 3 JR and BM (N = 10).*
—— *: no stød, --- : stød. See legend to Figure 1a.*

Figure 2a

Intensity average curves 1986 (list 9). NR, OB, PD, PM, ND (N = 10).
——— : no stød, --- : stød. I: 5 dB.  See legend to Figure 1a.

*Figure 2b*

*Intensity average curves 1986 (lists 10 and 11 and 13). HU, NR, OB, BRP
(N = 8). —— : no stød, --- : stød. I: 5 dB.  See legend to Figure 1a.*

# APPENDIX IV

## Fundamental Frequency

Survey of material used for analysis of fundamental frequency
----------------------------------------------------------------

| List | Year | Number of pairs | Subjects and number of repetitions |
|------|------|------|------|
| 1 | 1974 | 7-8 | BF 11, BH 10, BM 10, HU 11, JJ 11, NR 6 |
|   | 1977 a-b | 7 | BF 12, 11 |
|   | 1979 a-b | 7 | BF 12, 17 |
| 3 | 1974 | 3-5 | BM 9, JR 9 |
| 8 | 1985 | 15-17 | FJ 8, HU 8, JR 8, NR 8 |
| 9 | 1986 | 4 | ND 10, NR 10, OB 10, PD 10, PM 10 |
| 10 | 1986 | 3 | HU 8, NR 8 |
| 11 | 1986 | 3 | OB 8 |
| 12 | 1986 | 3 | BRP 8 |

Tables I and II give a survey of word contours for the individual speakers.

Figures 1a-b, 2a-c and 3 contain average curves of individual word pairs. List 1 was averaged by computer, lists 8-12 manually. The word pairs from lists 1 and 9, which were left out in the intensity averages (see Appendix III), are also left out here. Moreover, list 3 was left out altogether, and only some of the readings of list 1 are shown, because the average of the stød phase was problematic (see the section on averaging above). The average curves included here are two of BF's five readings, and the two subjects BM and JJ, who had less irregularity than the others, so that it was possible to leave out the tokens with strong irregularity from the averages.

For reasons of space a few word pairs were also left out in list 8.

In the curves averaged manually strong irregularities were skipped. There is thus sometimes only a gap (in list 9, the sensitivity of the pitchmeter was relatively low, and here the individual tokens also generally show a gap). When the average is based on only 2-3 tokens, dots are used instead of broken lines.

## Table I

*Number of examples with the vowels [i:'], [u:'] and [o:'] which have a lower
stressed vowel than the following unstressed vowel ( ´ ), both syllables of the
same height ( – – ), or a higher stressed vowel ( ＼ ), for speakers who have ＼
only in these vowels and not in words with [ɛ:'], [æ:'] or [ɛ] + C'.*

I a                                                                    I b

|            | HU ′ | HU -- | HU ＼ | NR ′ | NR -- | NR ＼ | ND ′ | ND -- | ND ＼ | PD ′ | PD -- | PD ＼ | BH ′ | BH -- | BH ＼ | BM ′ | BM -- | BM ＼ | FJ ′ | FJ -- | FJ ＼ |
|------------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|
| pʰiːˈbɒ    | 21   | 3     | 4     | 16   | 3     | 9     |      |       |       |      |       |       | 3    | 1     | 6     | 0    | 0     | 10    | 0    | 0     | 8     |
| fiːˈlɒ     | 6    | 2     | 0     | 9    | 0     | 1     |      |       |       |      |       |       |      |       |       |      |       |       |      |       |       |
| sbiːˈsɒ    |      |       |       |      |       |       | 7    | 3     | 0     | 10   | 0     | 0     |      |       |       |      |       |       |      |       |       |
| viːˈsɒ     |      |       |       | 10   | 0     | 0     |      |       |       |      |       |       |      |       |       |      |       |       |      |       |       |
| huːˈən     | 19   | 1     | 0     | 14   | 0     | 0     |      |       |       |      |       |       | 4    | 1     | 5     | 2    | 5     | 3     | 1,   | 2     | 5     |
| duːˈən     |      |       |       |      |       |       |      |       |       |      |       |       |      |       |       |      |       |       | 1    | 0     | 7     |
| muːˈsən    |      |       |       | 10   | 0     | 0     | 8    | 0     | 2     | 7    | 2     | 1     |      |       |       |      |       |       |      |       |       |
| pʰoːˈsən   |      |       |       | 10   | 0     | 0     | 4    | 3     | 4     | 7    | 1     | 1     |      |       |       |      |       |       |      |       |       |
| buːˈsɒ     | 8    | 0     | 0     | 10   | 0     | 0     |      |       |       |      |       |       |      |       |       |      |       |       | 7    | 2     | 1     |
| sum        | 54   | 6     | 4     | 79   | 3     | 10    | 19   | 6     | 6     | 24   | 3     | 2     | 7    | 2     | 11    | 2    | 5     | 13    | 9    | 4     | 21    |

## Table II

*Number of examples which have a lower stressed vowel than the following unstressed
vowel (´ ), both syllables of the same height (--), or a higher stressed vowel
( ＼ ), for speakers who may have  ＼ in all types of vowels.*

|            | PM |    |    | OB |    |    |
|------------|----|----|----|----|----|----|
| sbiːˈsɒ    | 5  | 1  | 4  | 2  | 2  | 14 |
| pʰeːˈdɒ    |    |    |    | 0  | 0  | 8  |
| muːˈsən    | 5  | 3  | 4  | 5  | 4  | 11 |
| pʰoːˈsən   | 3  | 4  | 3  | 0  | 1  | 9  |
| mæːˈlɒ     | 5  | 2  | 3  | 11 | 4  | 3  |
| sum        | 18 | 10 | 14 | 18 | 11 | 45 |

|            | JR |    |    |
|------------|----|----|----|
| huːˈən     | 0  | 3  | 5  |
| kʰɛːˈlɒ    | 0  | 4  | 4  |
| fiːˈlɒ     | 2  | 2  | 4  |
| beːˈnəð    | 2  | 2  | 4  |
| pʰiːˈbɒ    | 3  | 1  | 4  |
| kʰɛlˈɒ     | 3  | 2  | 3  |
| sæːˈlən    | 4  | 1  | 3  |
| vɛnˈn̩     | 6  | 0  | 2  |
| lɛːˈsɒ     | 7  | 0  | 1  |
| tʰæːˈbəð   | 7  | 0  | 1  |
| gæːˈbəð    | 8  | 0  | 0  |
| buːˈsɒ     | 8  | 0  | 0  |
| sum        | 50 | 15 | 31 |

|            | BF |    |    |
|------------|----|----|----|
| pʰiːˈbɒ    | 6  | 8  | 48 |
| huːˈən     | 4  | 5  | 57 |
| kʰɛlˈɒ     | 2  | 4  | 56 |
| kʰɛːˈlɒ    | 16 | 9  | 37 |
| lɛːˈsɒ     | 30 | 6  | 26 |
| sum        | 58 | 32 | 224 |

*Figure 1a*

*Fo average curves 1974 (list 1), Subject BF (N = 11) and BF 1979b (list 1, N = 17).*
——— *: no stød, --- : stød. A: vowel start (line-up point), B: vowel end ( | no stød,*
⫶ *stød). C: end of following consonant.* ⊔⊔⊔⊔ *10 cs.*

*Figure 1b*

*Fo average curves 1974 (list 1).   BM (N = 10) and JJ (N = 12). ——— : no stød,*
*--- : stød.   See legend to Figure 1a.*

*Figure 2a*

*Fo average curves 1985 (list 8).  FJ (N = 8).* ——— : *no stød,* --- : *stød.*
*See legend to Figure 1a.*

*Figure 2b*

*Fo average curves 1985 (list 8). HU (N = 8).* —— : *no stød,* --- : *stød.*
*See legend to Figure 1a.*

*Figure 2c*

Fo average curves 1985 (list 8). JR (N = 8). —— : no stød, --- : stød.
See legend to Figure 1a.

*Figure 2d*

*Fo average curves 1985 (list 8). NR (N = 8). ——— : no stød, --- : stød.
See legend to Figure 1a.*

*Figure 3a*

*Fo average curves 1986 (list 9). NR (N = 10), OB (N = 10), PD (N = 10),
PM (N = 10).* ——— : *no stød,* --- : *stød.   See legend to Figure 1a.*

*Figure 3b*

*Fo average curves 1986 (list 9). ND (N = 10).* —— *: no stød,* --- *: stød.*
*See legend to Figure 1a.*



*Figure 4*

*Fo average curves 1986 (lists 10,11,12). HU (N = 8), OB (N = 8), BRP (N = 8).*
—— *: no stød,* --- *: stød.   See legend to Figure 1a.*

væːlən   væːˈlən



mæːlɒ   mæːˈlɒ



lɛːsɒ   lɛːˈsɒ

*Figure 1*

*Spectrograms of* [væːlən/væːˈlən], [mæːlɒ/mæːˈlɒ] *and*
[lɛːsɒ/lɛːˈsɒ] *read by BRP and used for inverse
filtering.*

A1    væ:lən          A2    væ:'lən

B1    væ:lən          B2    væ:'lən

*Figure 2a*

A: normal oscillogram and B: inverse filtering, of 1 [væ:lən] and
2 [væ:'lən], read by BRP.

C1  væ:lən                              C2  væ:'lən

Figure 2b

C: integral of inverse filtering of 1 [væ:lən] and 2 [væ:'lən]
read by BRP.



A1  mæ:lɒ                               A2  mæ:'lɒ

Figure 3a

A: normal oscillogram of 1 [mæ:lɒ] and 2 [mæ:'lɒ], read by BRP.

Figure 3b

B: inverse filtering and C: integral of inverse filtering
of 1 [mæːlɒ] and 2 [mæːˈlɒ], read by BRP.

Figure 4

A: normal oscillogram, B: inverse filtering and C: integral of inverse
filtering of 1 [lɛ:sᴅ], 2 [lɛ:'sᴅ], read by BRP.

# APPENDIX VI

## Airflow

### Survey of the material used for the analysis of airflow

| List | Year | Number of pairs | Subjects and number of repetitions |
|------|------|-----------------|-------------------------------------|
| 1    | 1974 | 8 (6)           | BF 10                               |
| 8a   | 1985 | 17              | FJ 8                                |
| 8b   | 1985 | 15              | HU 8, JR 8, NR 8                    |

Average airflow curves of individual word pairs are shown on the following pages (Figs. 1-5). Fig. 1 was averaged by computer, the others manually. BF's words with postvocalic nasal are left out, and for lack of space only 12 of the pairs from list 8 are included.

Since the airflow curves are smoothed, the rise is delayed. Therefore the line-up point was moved 2 cs to the right for male speakers and 1 cs for female speakers compared to its place in acoustic curves. This was not, however, done for BF, whose curves were averaged by computer.

*Table I*

*Number of disyllabic pairs in which the word with stød has a steeper (+), or slower (-) or the same (=) rise in airflow at the start of the word compared to the corresponding word without stød in the same reading. Significance: * < 5%, ** < 1%, *** < 0.1%.*

| | A. Aspirated stops | | | | B. Unasp. stops and fricatives | | | | C. Vowels after l,v. | | | | B+C | | | |
|------|----|----|----|------|----|----|----|------|----|----|----|------|-----|----|----|------|
| | +  | =  | -  | sf.  | +  | =  | -  | sf.  | +  | =  | -  | sf.  | +   | =  | -  | sf.  |
| BF   | 22 | 4  | 5  | **(*) | 8  | 0  | 1  | *    | 13 | 4  | 4  | *    | 21  | 4  | 5  | **   |
| FJ   | 12 | 7  | 5  |      | 15 | 18 | 11 |      | 3  | 6  | 7  |      | 18  | 24 | 18 |      |
| HU   | 19 | 8  | 5  | *(*) | 14 | 20 | 14 |      | 8  | 6  | 2  |      | 22  | 26 | 16 |      |
| JR   | 18 | 6  | 8  | (*)  | 23 | 10 | 15 |      | 4  | 10 | 2  |      | 27  | 20 | 17 |      |
| NR   | 18 | 8  | 6  | *    | 23 | 19 | 6  | **   | 11 | 1  | 4  |      | 34  | 20 | 10 | **(*) |
| Sum  | 89 | 33 | 29 | ***  | 83 | 67 | 47 | **   | 39 | 27 | 19 | ***  | 122 | 94 | 66 | ***  |

## Table II

*Number of disyllabic pairs in which the word with stød has a higher (+) or lower (–) or the same (=) airflow peak at the start of the word compared to the corresponding word without stød in the same reading. Significance: \* <5%, \*\* <1%, \*\*\* < 0.1%.*

| | A. Aspirated stops | | | | B. Unasp. stops and fricatives | | | | C. Vowels after l, v | | | | B+C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | + | = | – | sf. | + | = | – | sf. | + | = | – | sf. | + | = | – | sf. |
| BF | 23 | 2 | 6 | \*\*\* | 7 | 2 | 0 | \*(\*) | 12 | 5 | 4 | \* | 19 | 7 | 4 | \*\* |
| FJ | 15 | 2 | 7 | | 21 | 4 | 19 | | 10 | 2 | 4 | | 31 | 6 | 23 | |
| HU | 24 | 1 | 7 | \*\* | 30 | 6 | 12 | \* | 13 | 2 | 1 | \*\*(\*) | 43 | 8 | 13 | \*\*\* |
| JR | 22 | 1 | 9 | \* | 26 | 5 | 17 | | 10 | 3 | 3 | \* | 36 | 8 | 20 | \* |
| NR | 22 | 0 | 10 | \* | 33 | 7 | 8 | \*\*\* | 11 | 2 | 3 | \* | 44 | 9 | 11 | \*\*\* |
| Sum | 106 | 6 | 39 | \*\*\* | 117 | 24 | 56 | \*\* | 56 | 14 | 15 | \*\*\* | 173 | 38 | 71 | \*\*\* |

## Table III

*Airflow (in l/m) in the second part of long vowels with and without stød in disyllables (measured at the minimum in stød-words) (average of 8 repetitions). Significance: \* < 5%, \*\* < 1%, \*\*\* < 0.1%.*

| | $p^hi{:}b\text{ɒ}$ / $p^hi{:}{}'b\text{ɒ}$ | $k^h\varepsilon{:}l\text{ə}$ / $k^h\varepsilon{:}{}'l\text{ɒ}$ | $hu{:}\text{ə}n$ / $hu{:}{}'\text{ə}n$ | $l\varepsilon{:}s\text{ɒ}$ / $l\varepsilon{:}{}'s\text{ɒ}$ | $bu{:}s\text{ə}$ / $bu{:}{}'s\text{ɒ}$ | $g\text{æ}{:}b\text{ə}$ / $g\text{æ}{:}{}'b\text{ə}\eth$ | $be{:}n\text{ə}$ / $be{:}{}'n\text{ə}\eth$ | $fi{:}l\text{ə}$ / $fi{:}{}'l\text{ɒ}$ | $du{:}\text{ə}n$ / $du{:}{}'\text{ə}n$ |
|---|---|---|---|---|---|---|---|---|---|
| BF | 18.5 / 13.0 | 19.5 / 9.0 | 17.5 / 9.0 | 19.0 / 9.5 | | | | | |
| diff. | 5.5\*\*\* | 10.5\*\*\* | 8.5\* | 9.5\*\*\* | | | | | |
| FJ | 7.5 / 4.0 | 6.5 / 4.0 | 9.0 / 3.0 | 7.0 / 10.0 | 6.0 / 5.0 | | | | 6.0 / 2.0 |
| diff. | 3.5\* | 2.5 | 6.0\*\* | -3.0 | 1.0\* | | | | 4.0\*\* |
| HU | 8.0 / 4.0 | 7.5 / 3.0 | 7.0 / 2.0 | 8.5 / 6.0 | 6.0 / 3.5 | 6.0 / 1.5 | 6.0 / 1.5 | 6.0 / 2.5 | |
| diff. | 4.0\*\* | 4.5\*\* | 5.0\*\* | 2.5\*\* | 2.5\*\* | 4.5\*\* | 4.5\*\* | 3.5\*\* | |
| JR | 22.0 / 12.0 | 19.0 / 12.0 | 13.0 / 9.0 | 23.0 / 14.0 | 9.0 / 6.0 | 16.0 / 13.0 | 22.0 / 11.0 | 16.0 / 8.0 | |
| diff. | 10.0\*\* | 7.0\*\* | 4.0\*\* | 9.0\*\* | 3.0\*\* | 3.0\*\* | 11.0\*\* | 8.0\*\* | |
| NR | 5.0 / 4.0 | 6.5 / 4.5 | 6.0 / 3.5 | 8.0 / 7.0 | 2.5 / 2.0 | 10.0 / 8.0 | 4.0 / 2.5 | 3.5 / 1.0 | |
| diff. | 1.0\*\* | 2.0\*\* | 2.5\* | 1.0 | 0.5 | 2.0\*\* | 1.5\* | 2.5\* | |

*Figure 1*

*Airflow average curves 1974 (list 1). Subject BF (N = 10).*
——— : *no stød,* --- : *stød.*  *A: vowel start (line-up point),*
*B: vowel end ( | no stød,  ⋮ stød), C: end of following con-*
*sonant.  l/m = liter per minute,* ⊢———⊣ *10 cs.*

*Figure 2*

*Airflow average curves 1985 (list 8a). Subject FJ (N = 8).* ——— : *no stød,*
--- : *stød. See legend to Figure 1.*

Figure 3

*Airflow average curves 1985 (list 8b). Subject HU (N = 8).* ——— *: no stød, --- : stød. See legend to Figure 1.*

*Figure 4*

*Airflow average curves 1985 (list 8b). Subject JR (N = 8). ——— : no stød, --- : stød. See legend to Figure 1.*

*Figure 5*

*Airflow average curves 1985 (list 8b). Subject NR (N = 8).* ——— *: no stød,* --- *: stød.   See legend to Figure 1.*

# APPENDIX VII

## Subglottal and esophageal pressure

Survey of the material used for the analysis of subglottal and esophageal pressure

| List | Year | Number of pairs | Subjects and number of repetitions |
|------|------|-----------------|-------------------------------------|
| 1 | 1974 | 8 | BF 5 |
| (1 | 1974 | 8 | JR 2 ) |
| (3 | 1974 | 6 | JR 4 ) |
| 7 | 1981 | 4 | FJ 12 |

*Table I*

*Subglottal pressure (in cm $H_2O$) at vowel start and maximum for words with and without stød. Subject BF. List 1 ( based on measurements of individual examples , average of 5 repetitions).*

| | Vowel start | max. | rise | | Vowel start | max. | rise |
|------|------|------|------|------|------|------|------|
| pʰi:'bɒ | 13.0 | 13.3 | 0.3 | kʰɛl'ɒ | 11.0 | 12.5 | 1.5 |
| pʰi:bɒ | 12.1 | 12.2 | 0.1 | kʰɛlɒ | 10.3 | 11.0 | 0.7 |
| diff. | 0.9 | 1.1 | 0.2 | diff. | 0.7 | 1.5 | 0.8 |
| kʰɛ:'lɒ | 10.8 | 11.8 | 1.0 | vɛn'n̩ | 12.4 | 12.9 | 0.5 |
| kʰɛ:lə | 10.6 | 11.4 | 0.8 | vɛnɒ | 11.9 | 11.9 | 0.0 |
| diff. | 0.2 | 0.4 | 0.2 | diff. | 0.5 | 1.0 | 0.5 |
| lɛ:'sɒ | 11.3 | 11.7 | 0.4 | vɛn' | 12.3 | 12.5 | 0.2 |
| lɛ:sɒ | 11.1 | 11.3 | 0.2 | vɛn | 11.6 | 11.8 | 0.2 |
| diff. | 0.2 | 0.4 | 0.2 | diff. | 0.7 | 0.7 | 0.0 |
| hu:'ən | 11.2 | 12.4 | 1.2 | du ' | 12.9 | 13.4 | 0.4 |
| hu:ən | 10.4 | 11.3 | 0.9 | du | 12.9 | 13.2 | 0.2 |
| diff. | 0.8 | 1.1 | 0.3 | diff. | 0.0 | 0.2 | 0.2 |

Figure 1a

Average curves of subglottal pressure 1974 (list 1). Subject
BF (N = 5). —— : no stød, --- : stød. A: vowel start (line-
up point), B: vowel end, C: end of following consonant.
| : no stød, ⋮ : stød. Time in cs.

cm H₂O



```
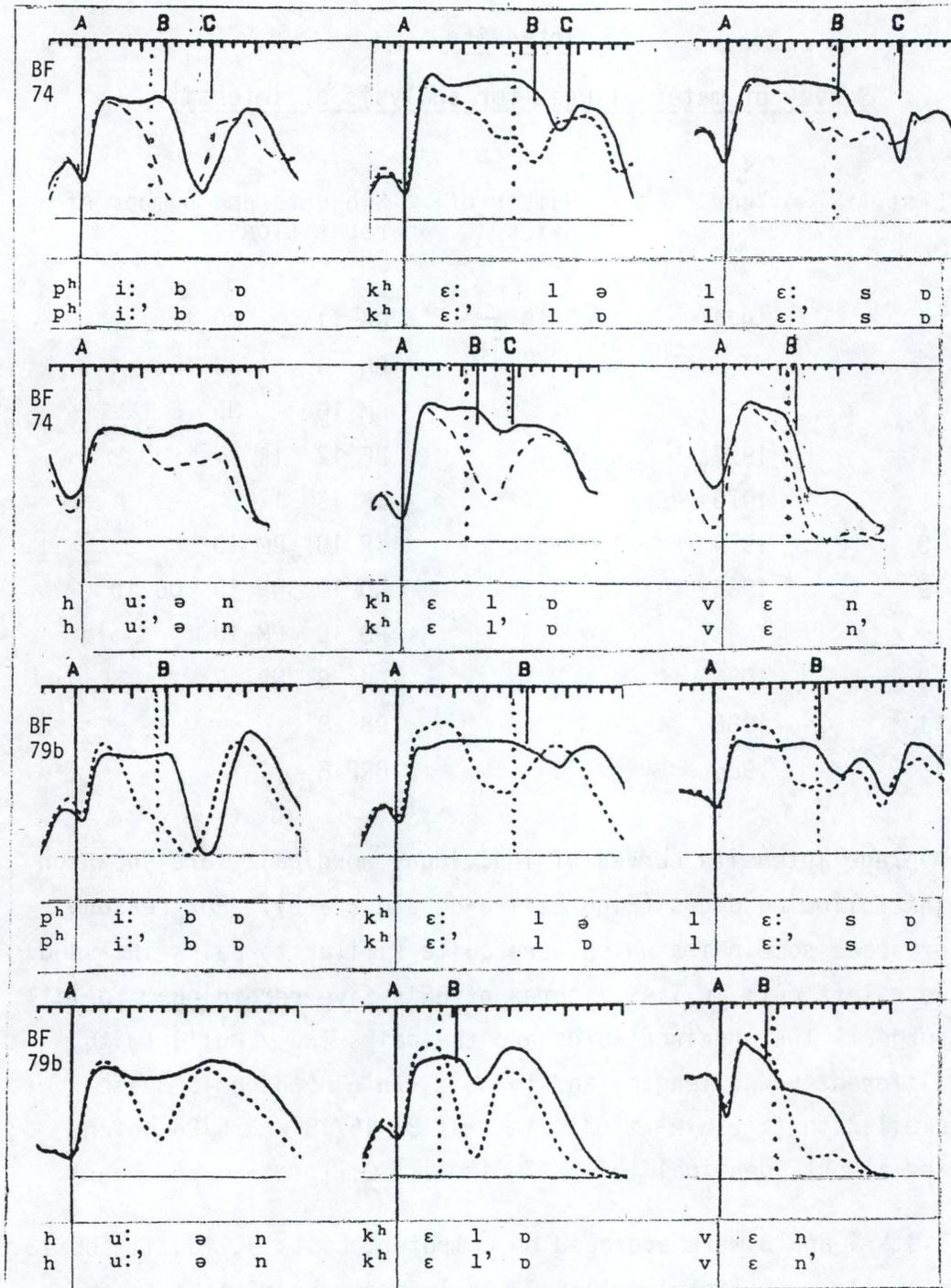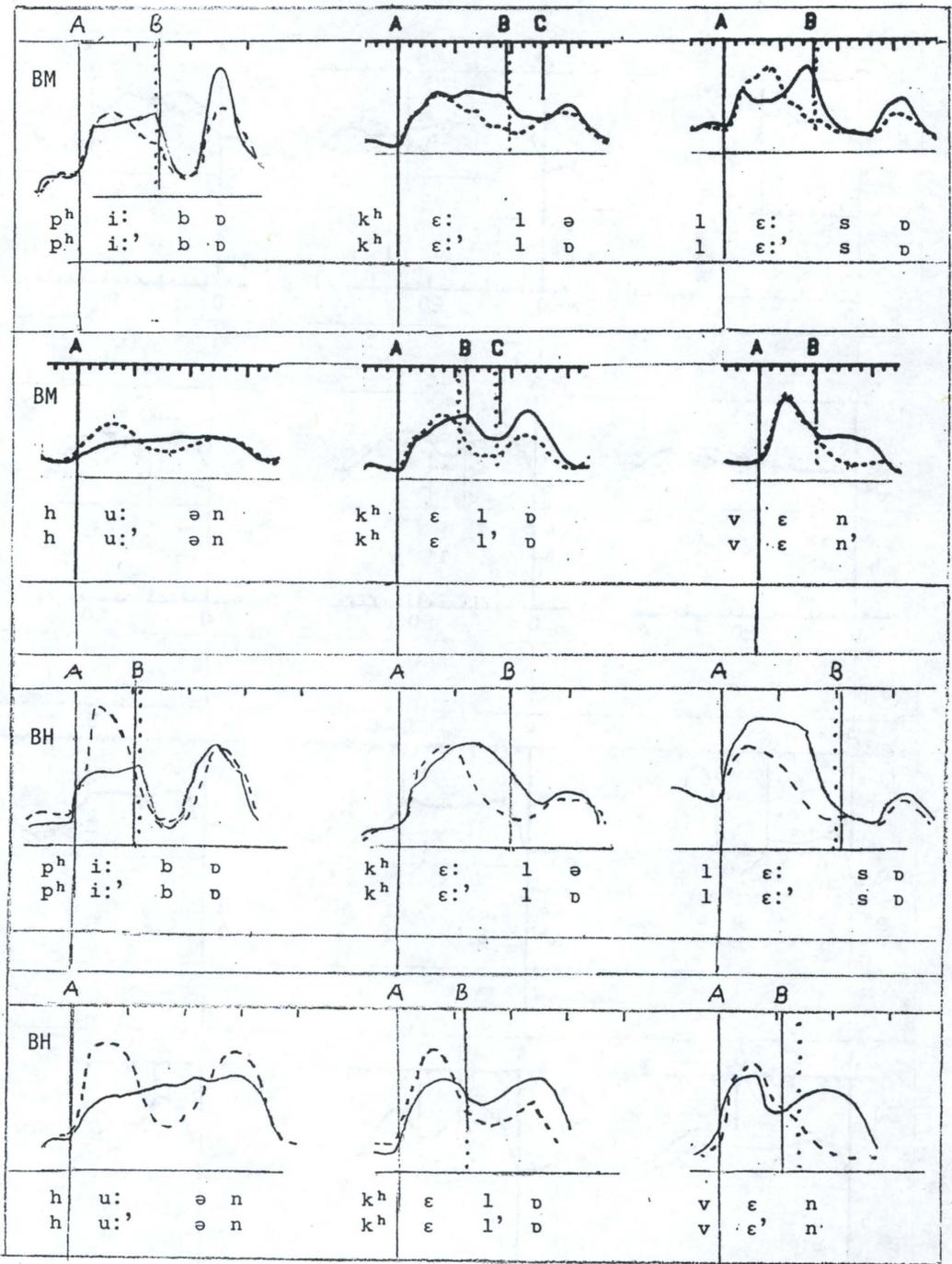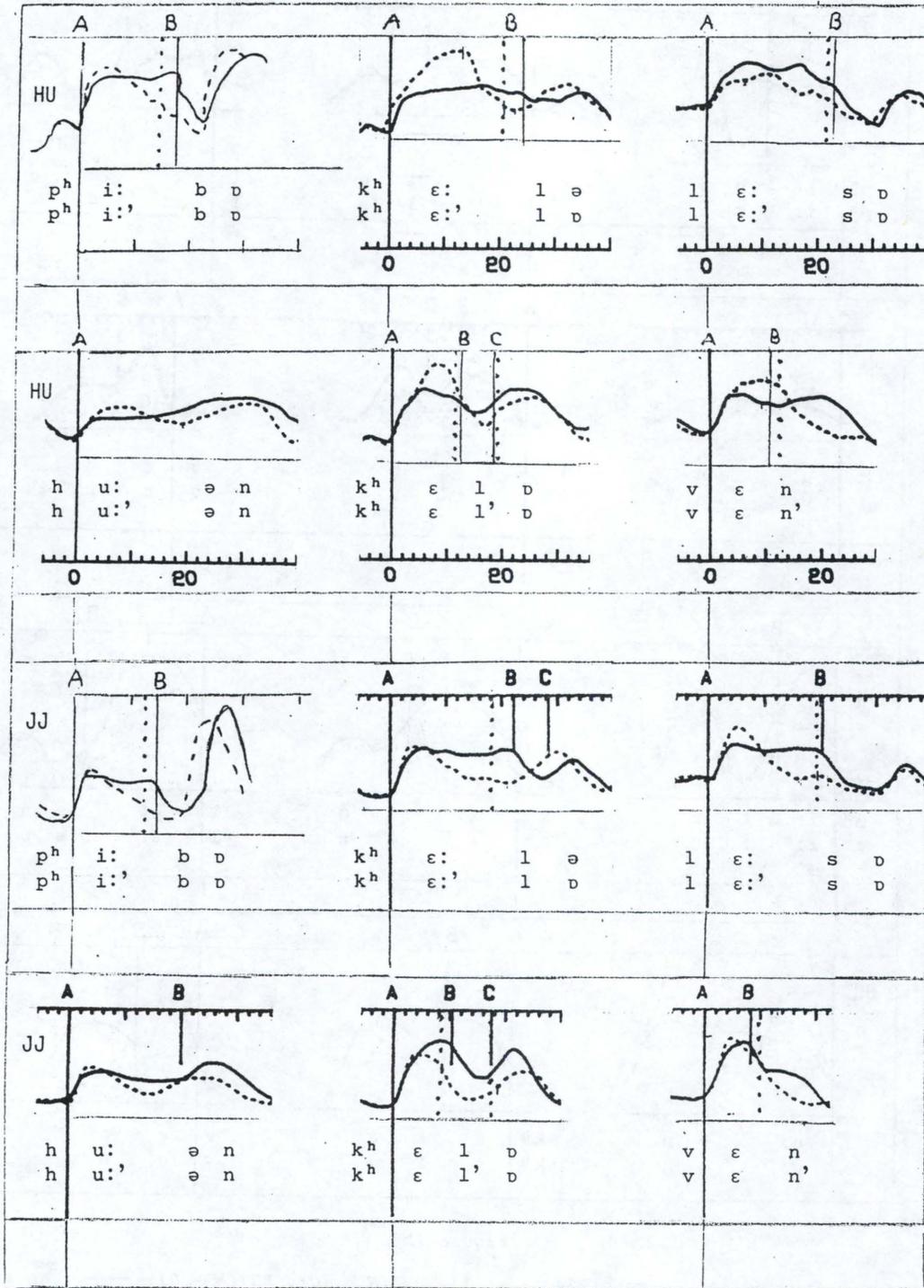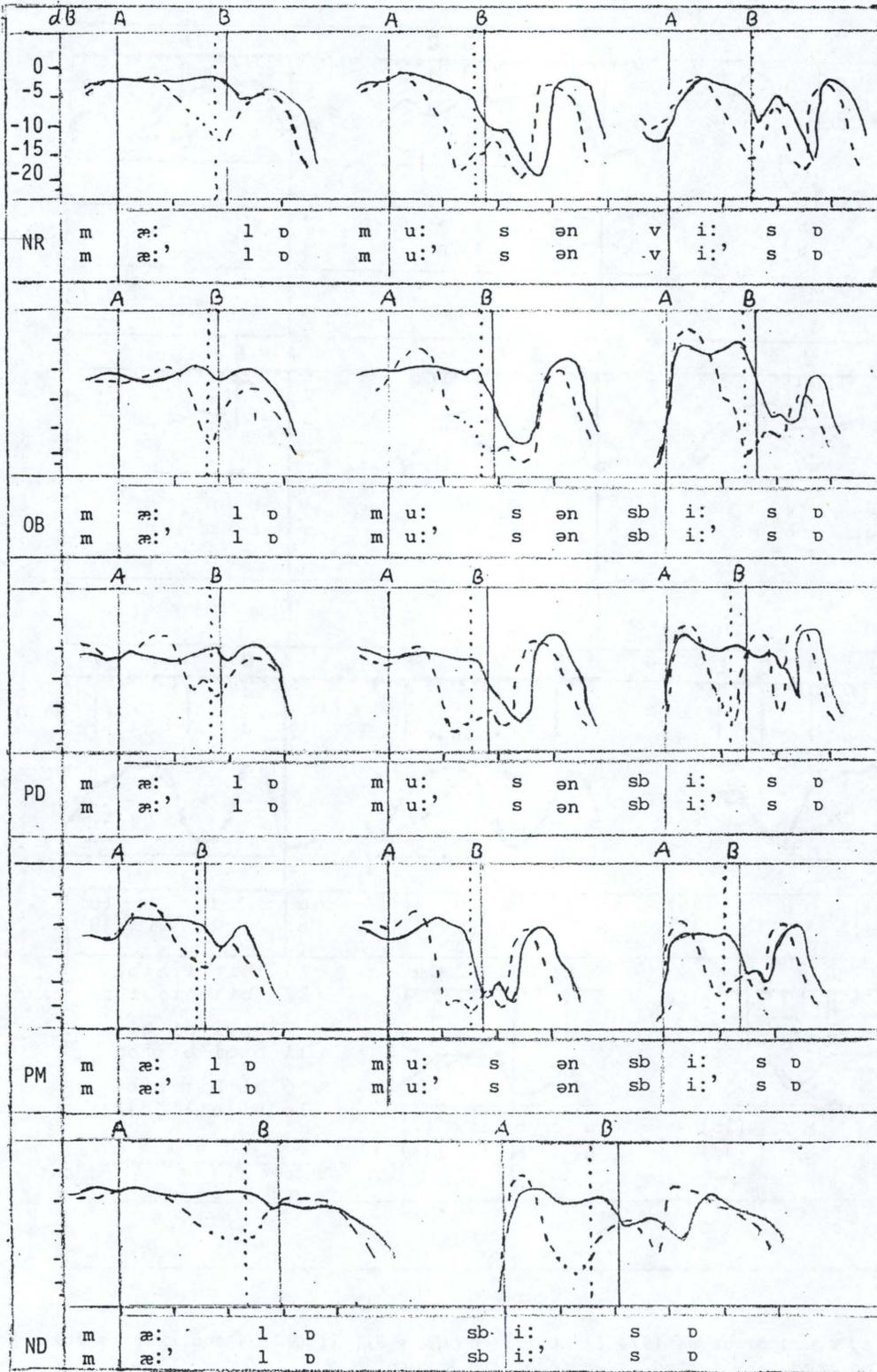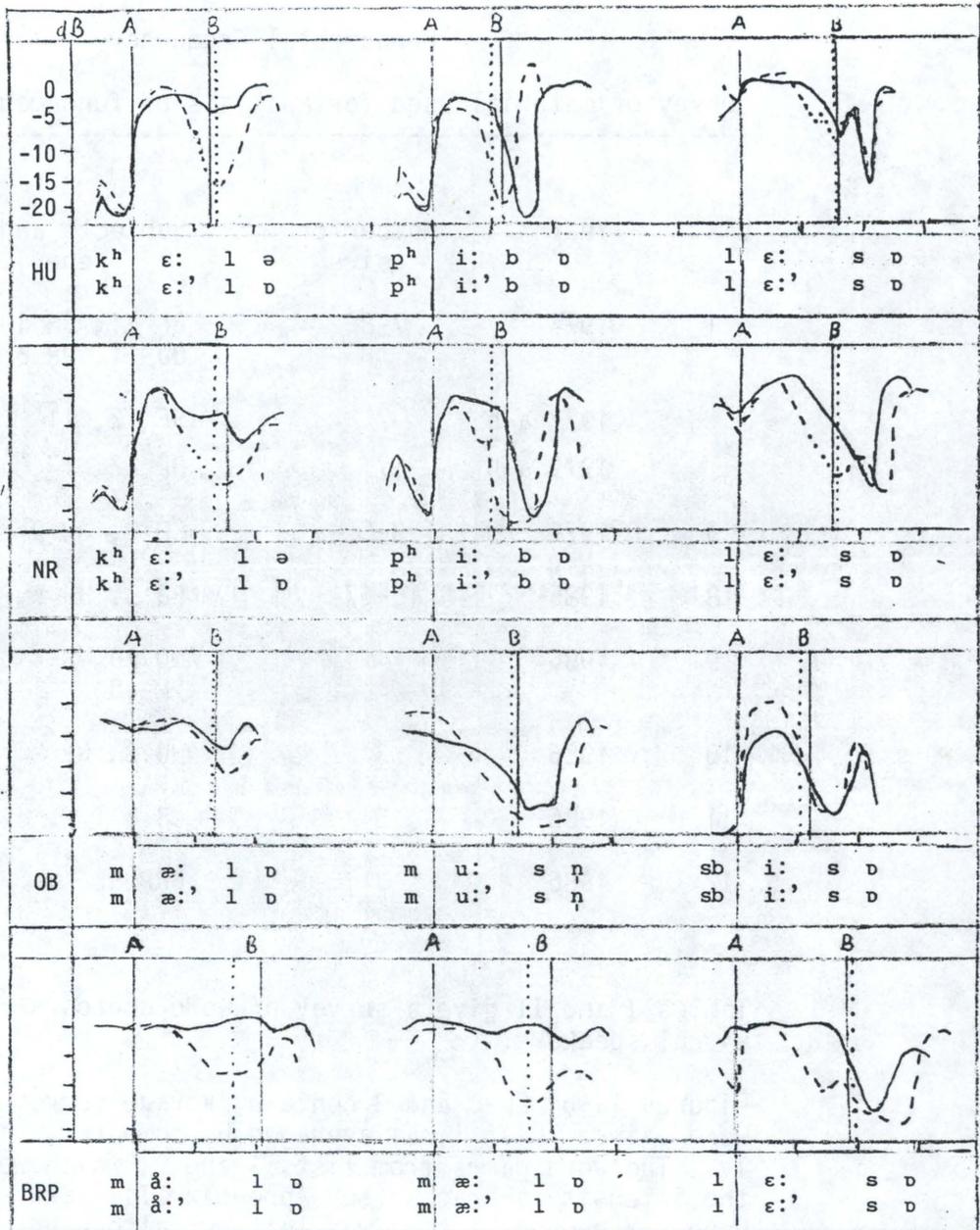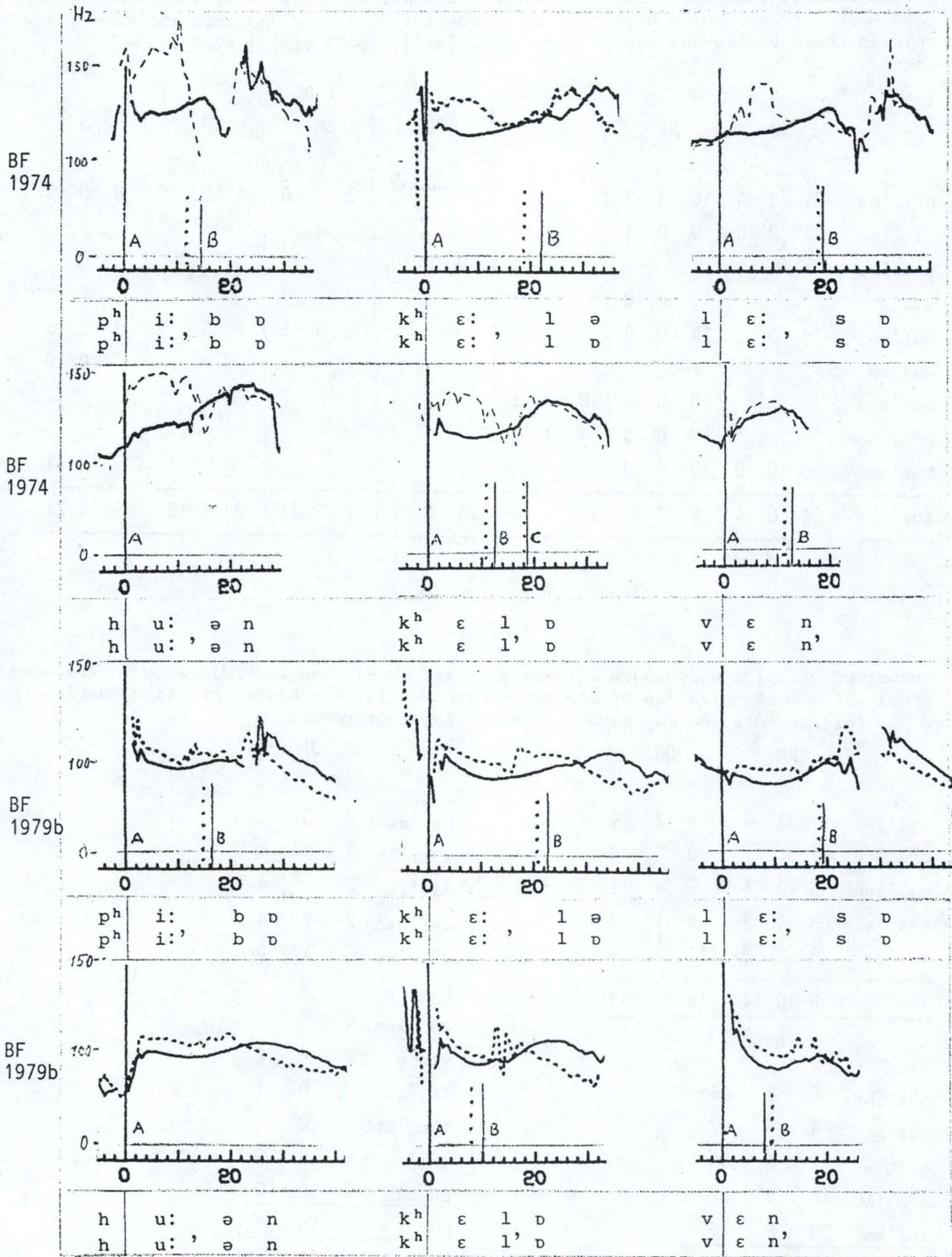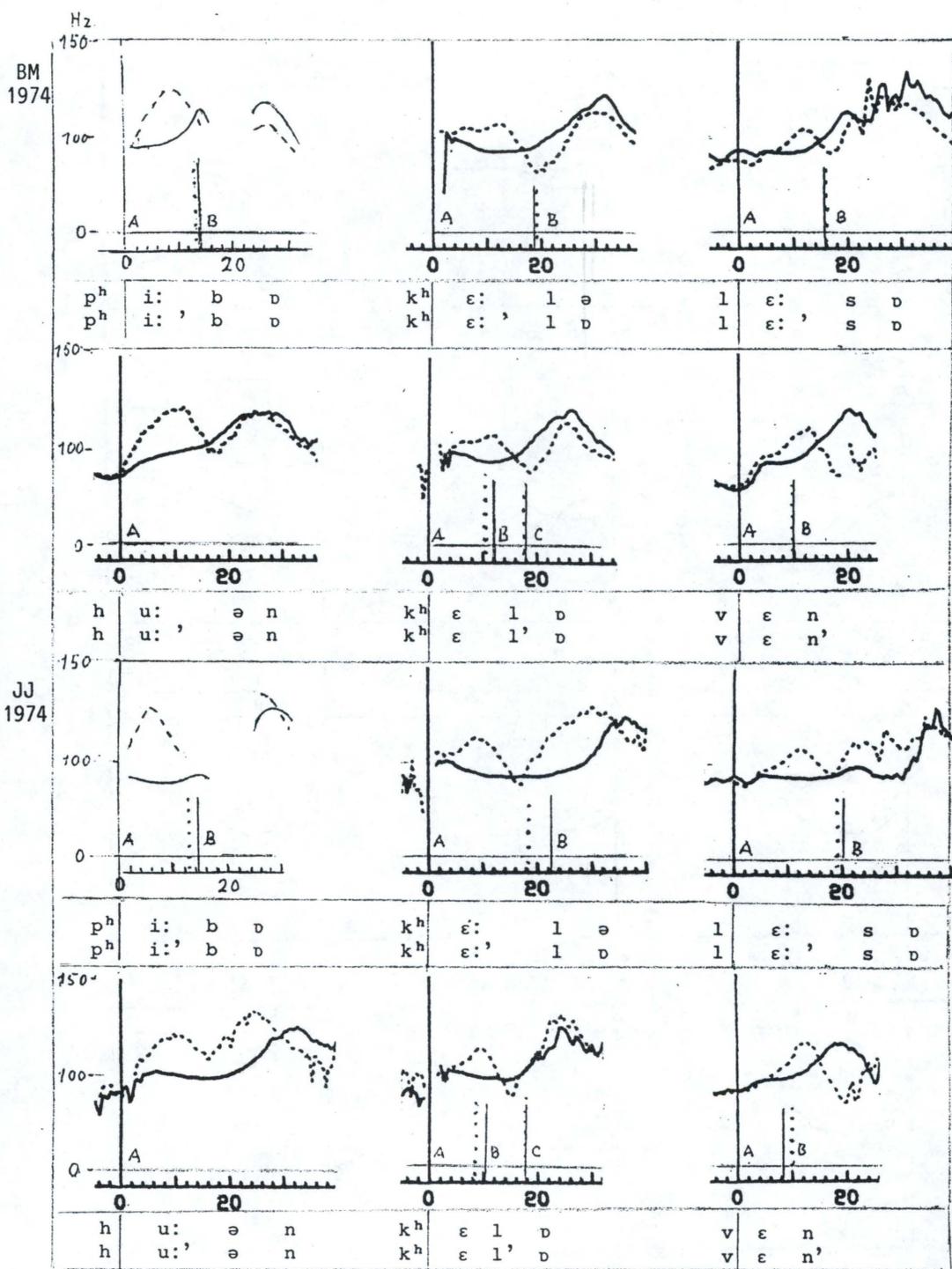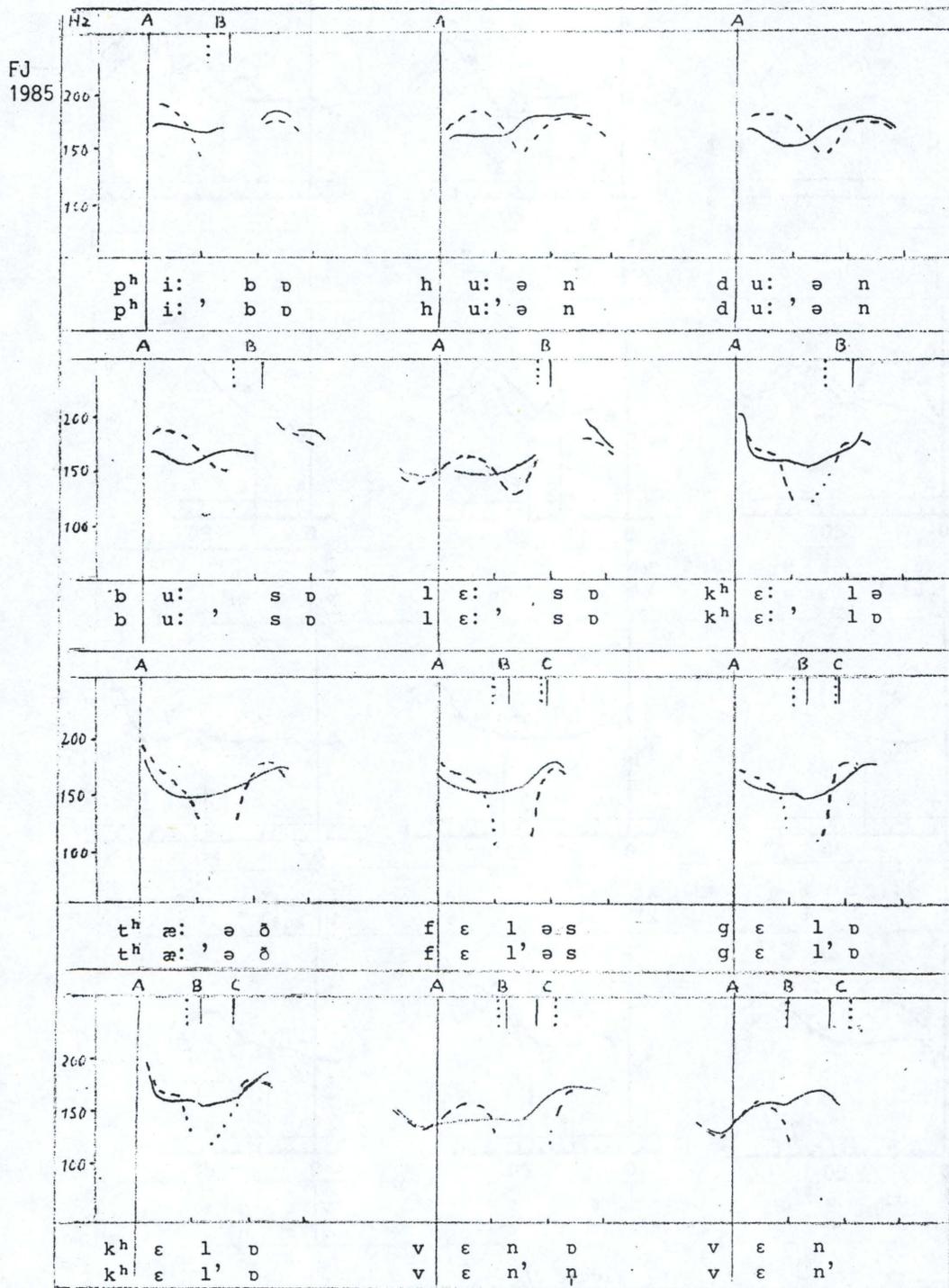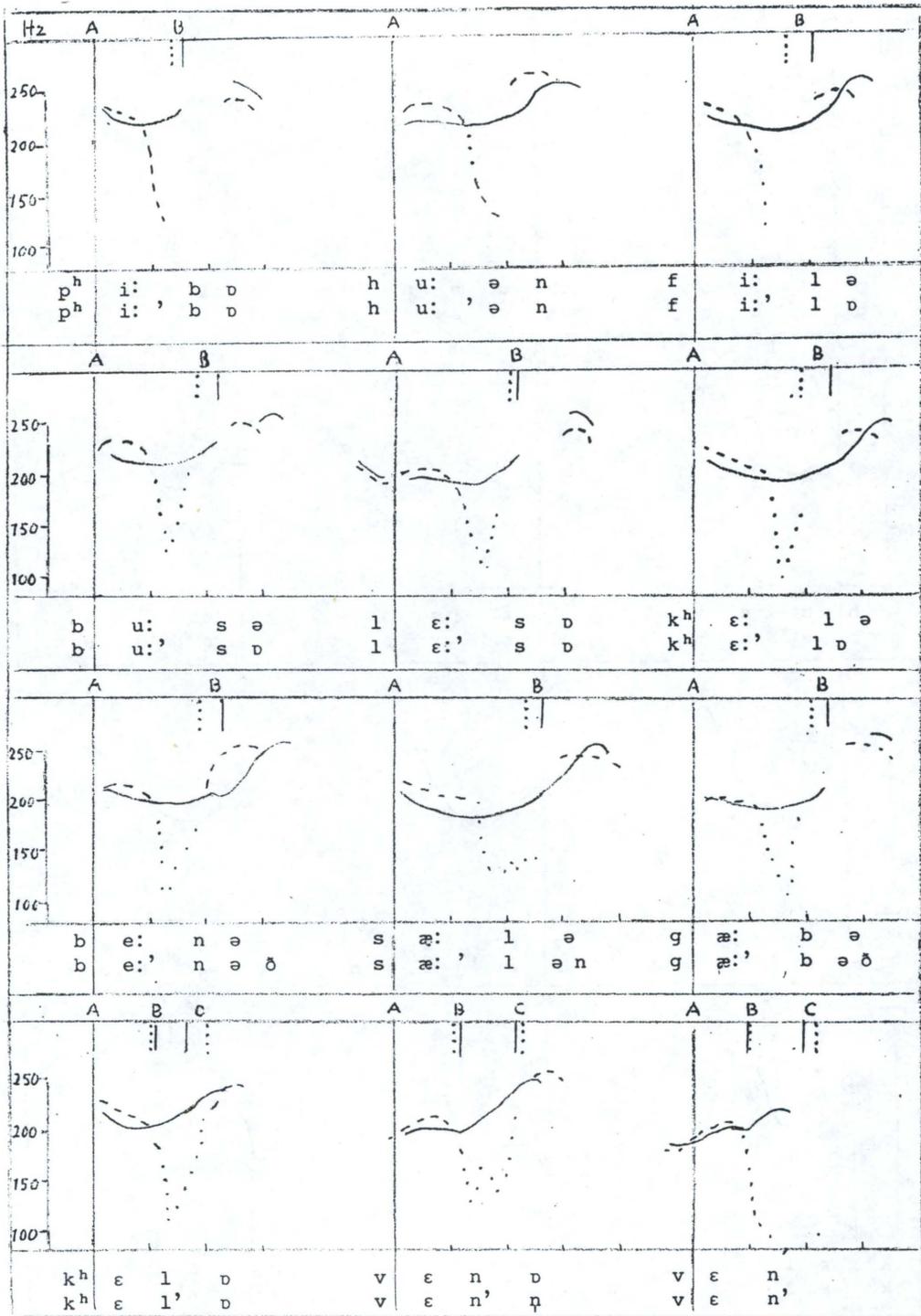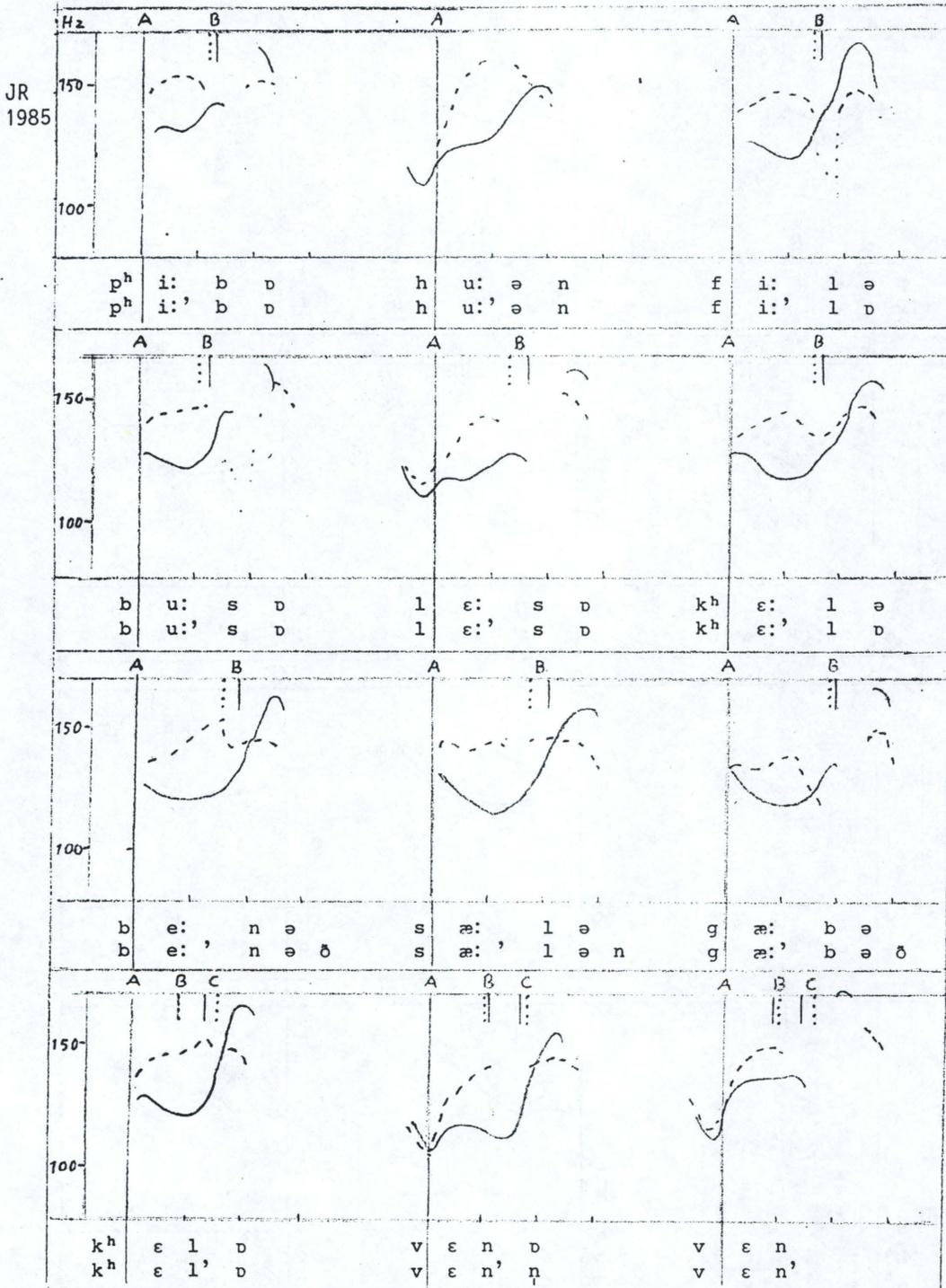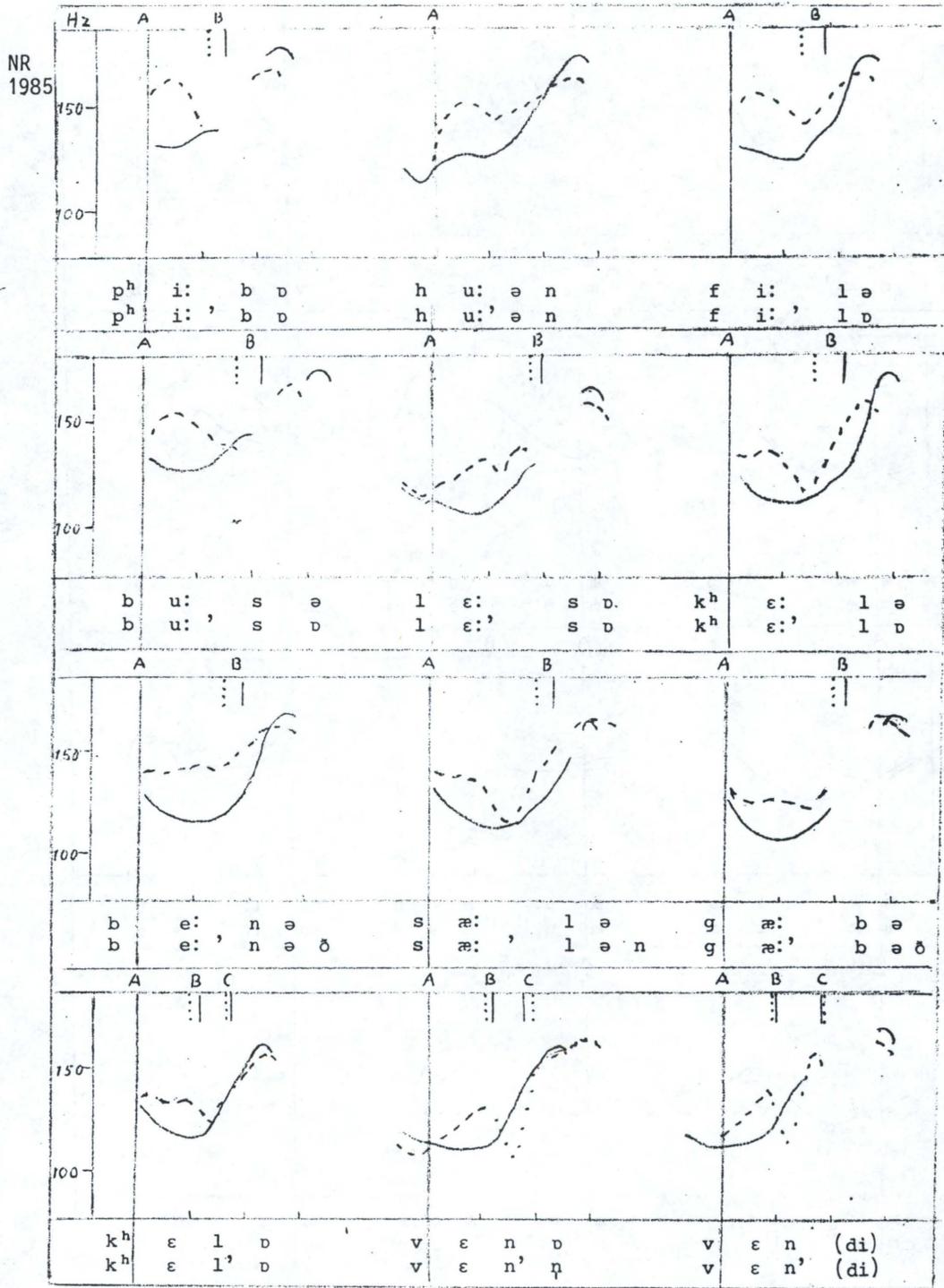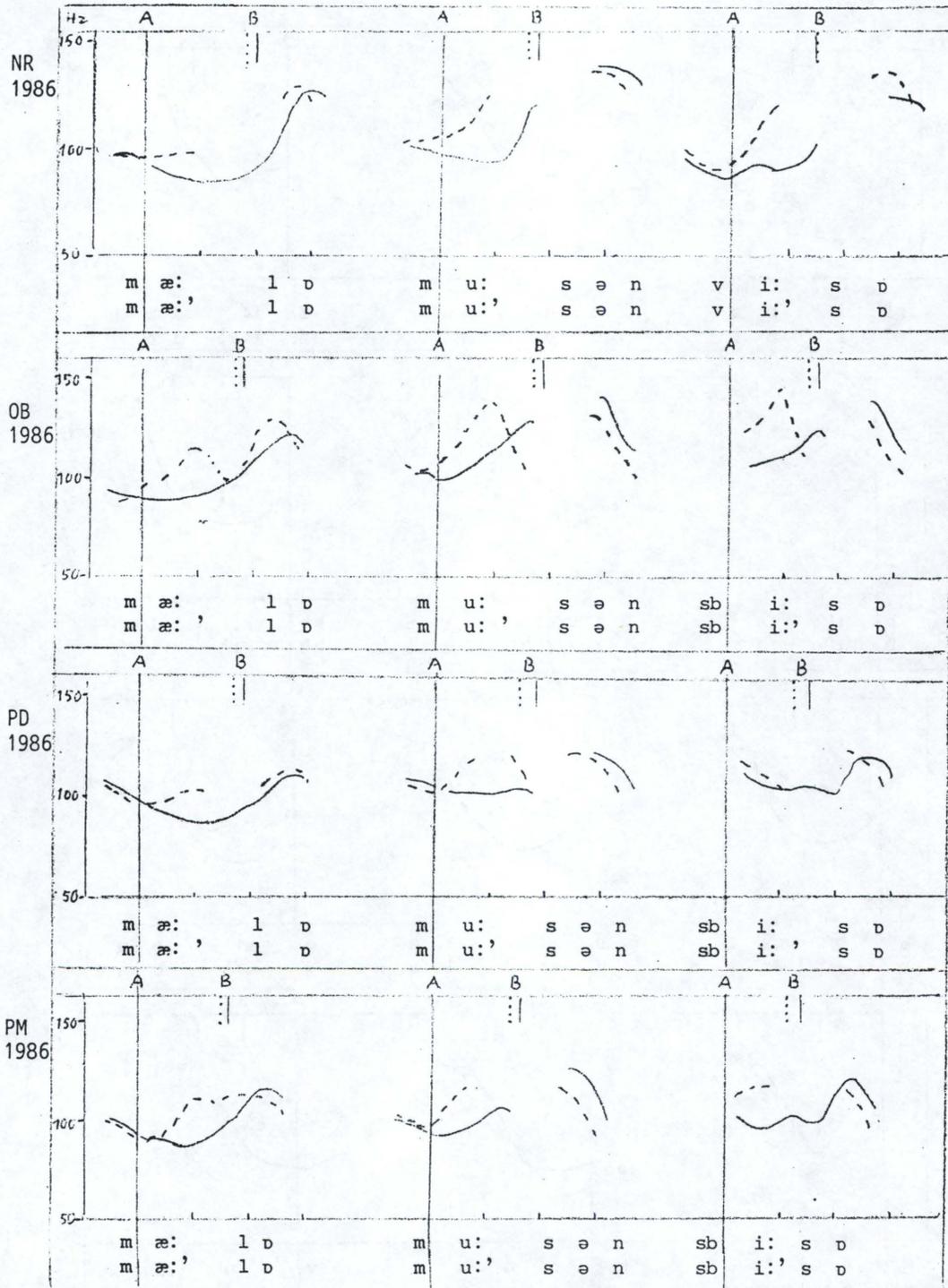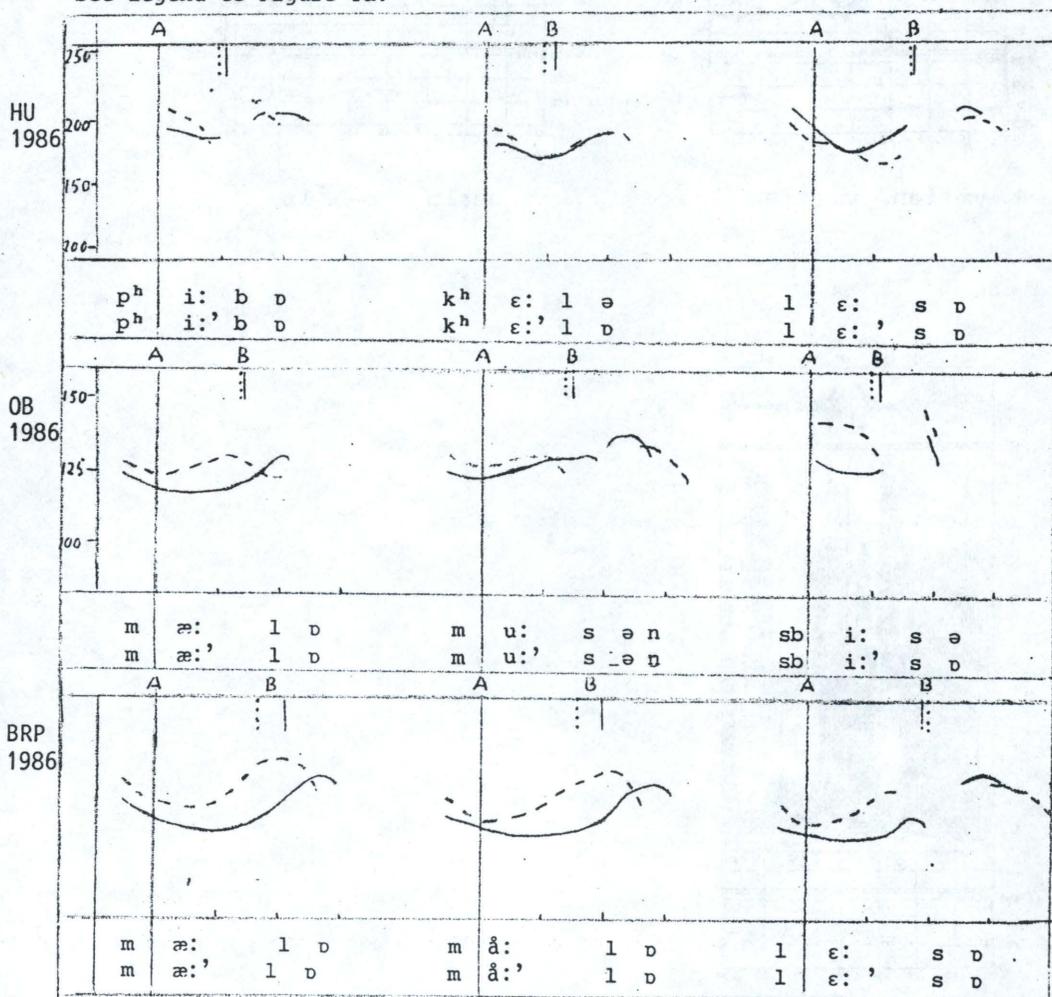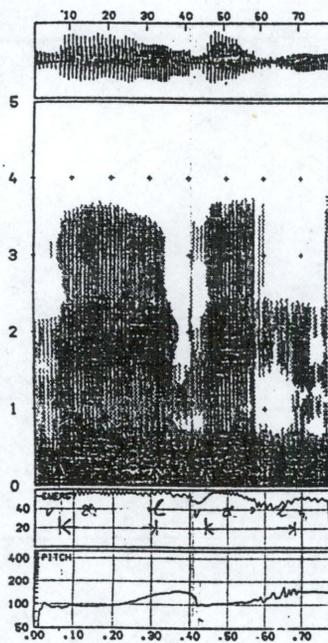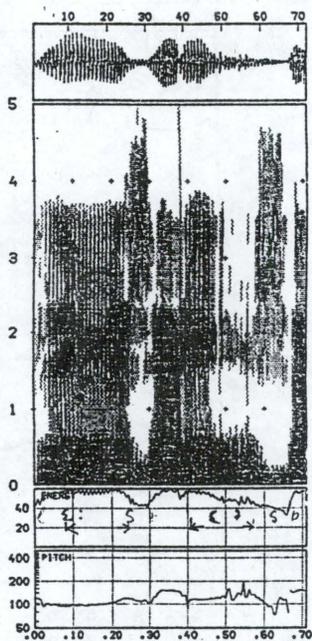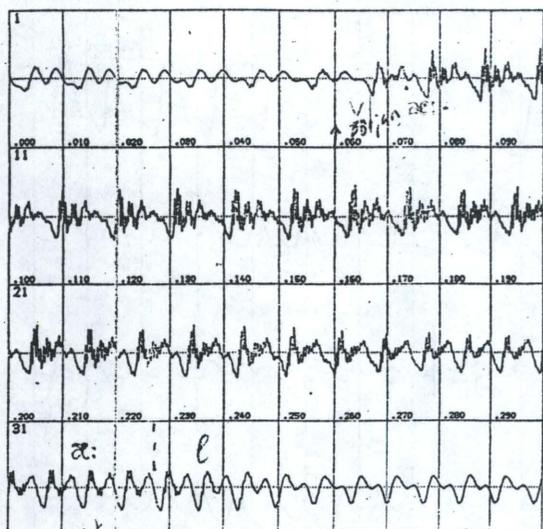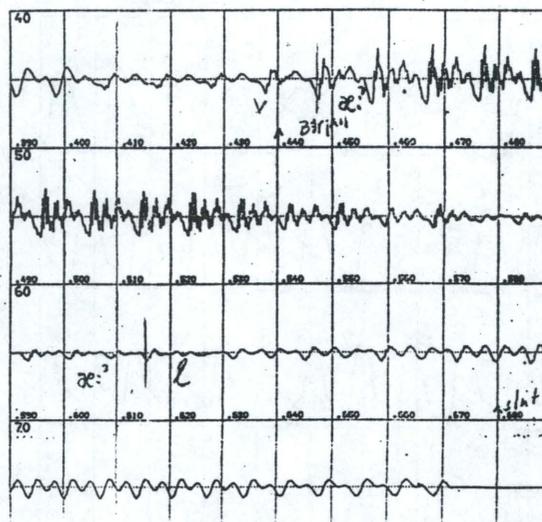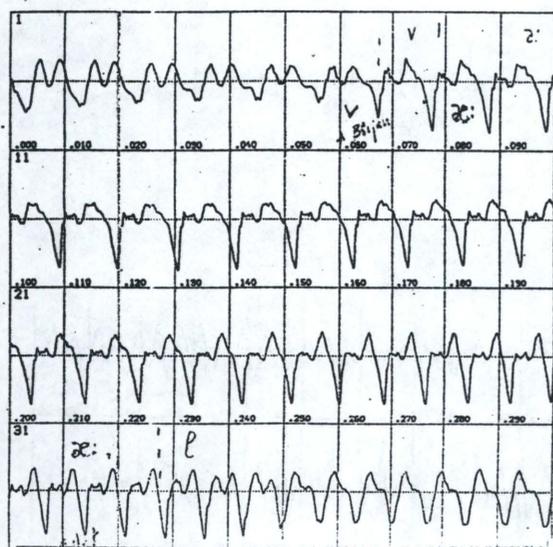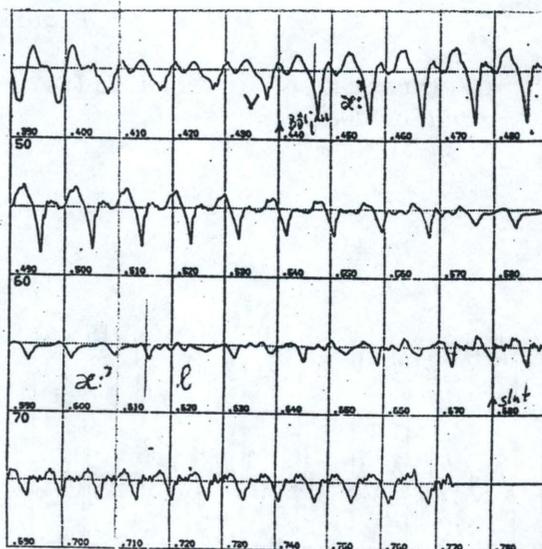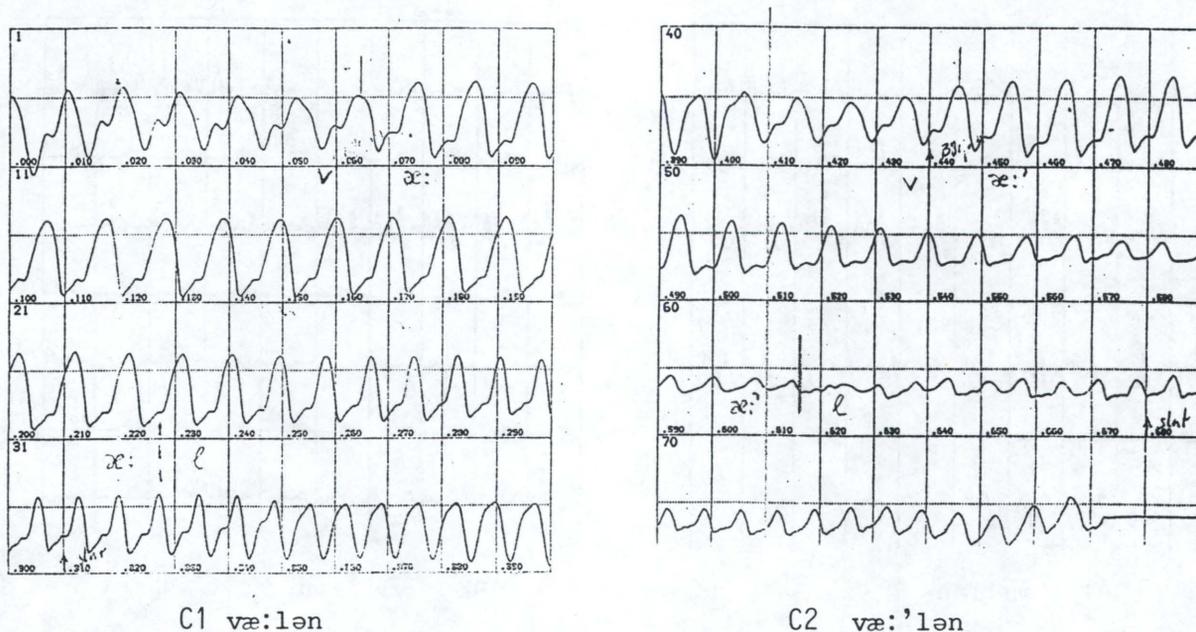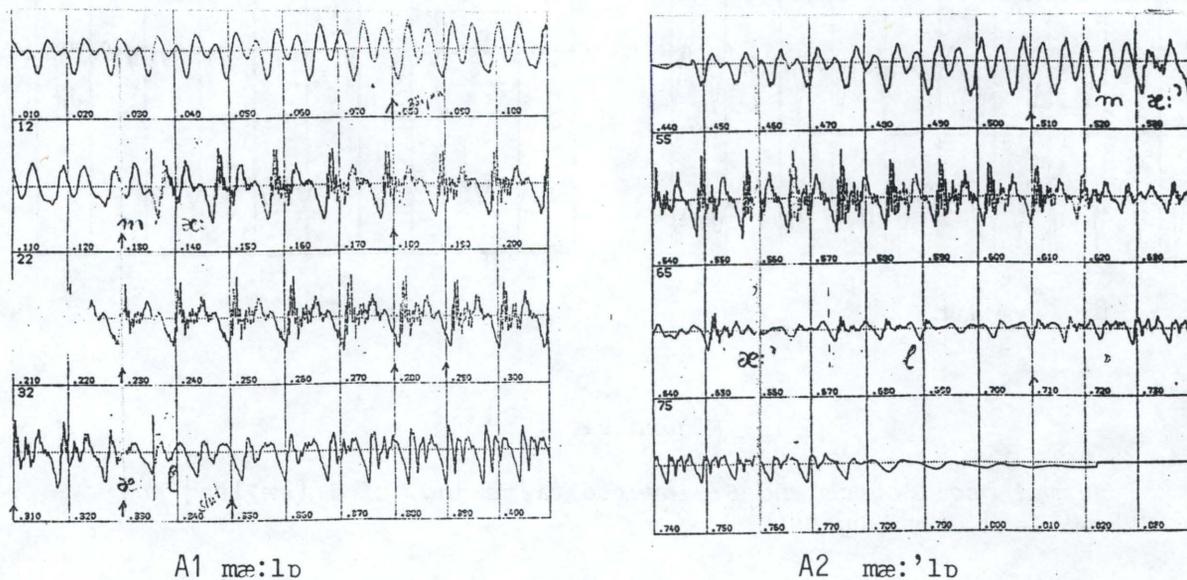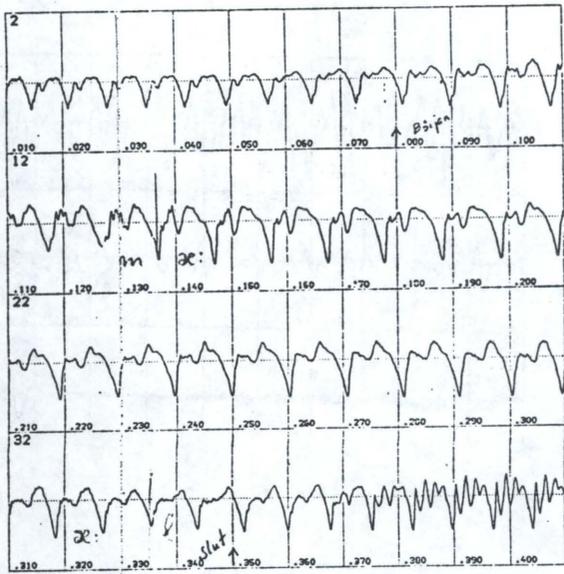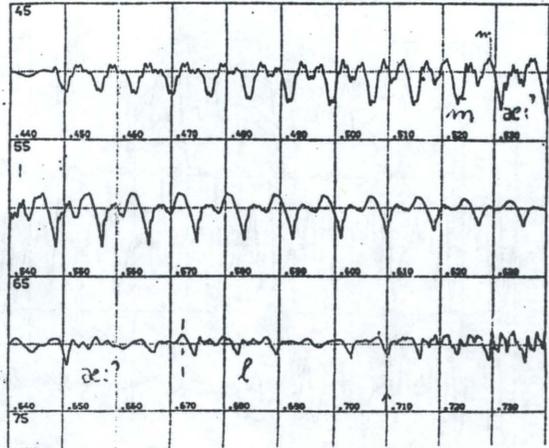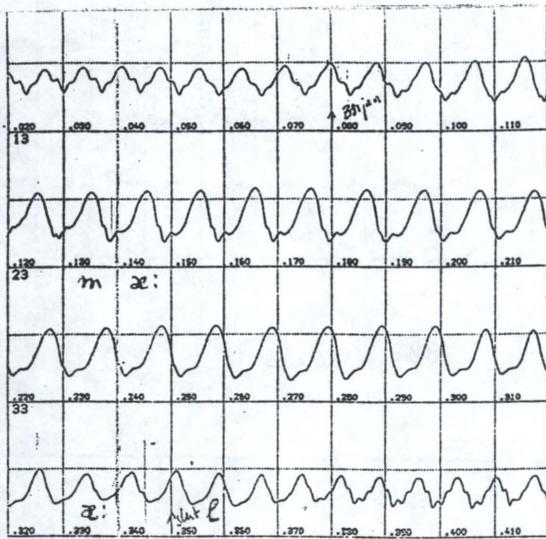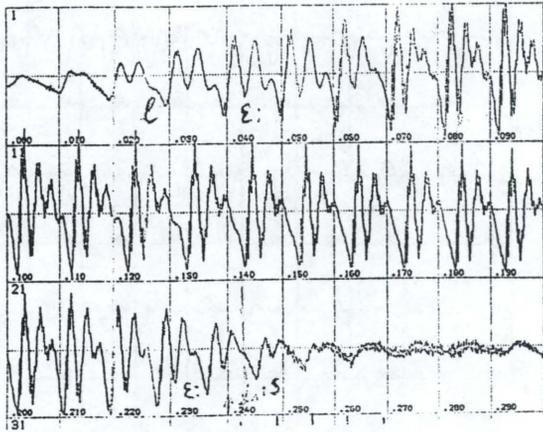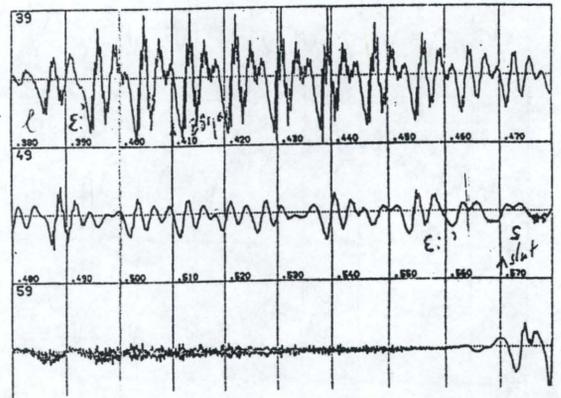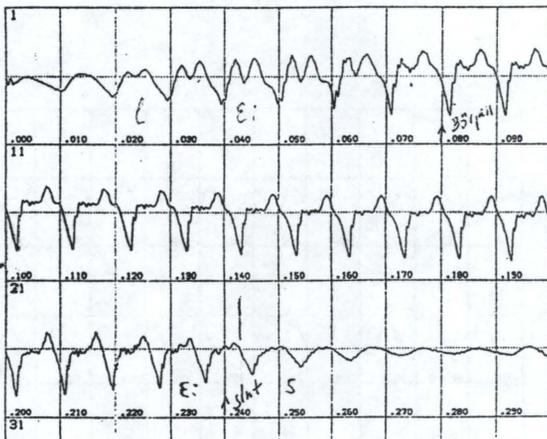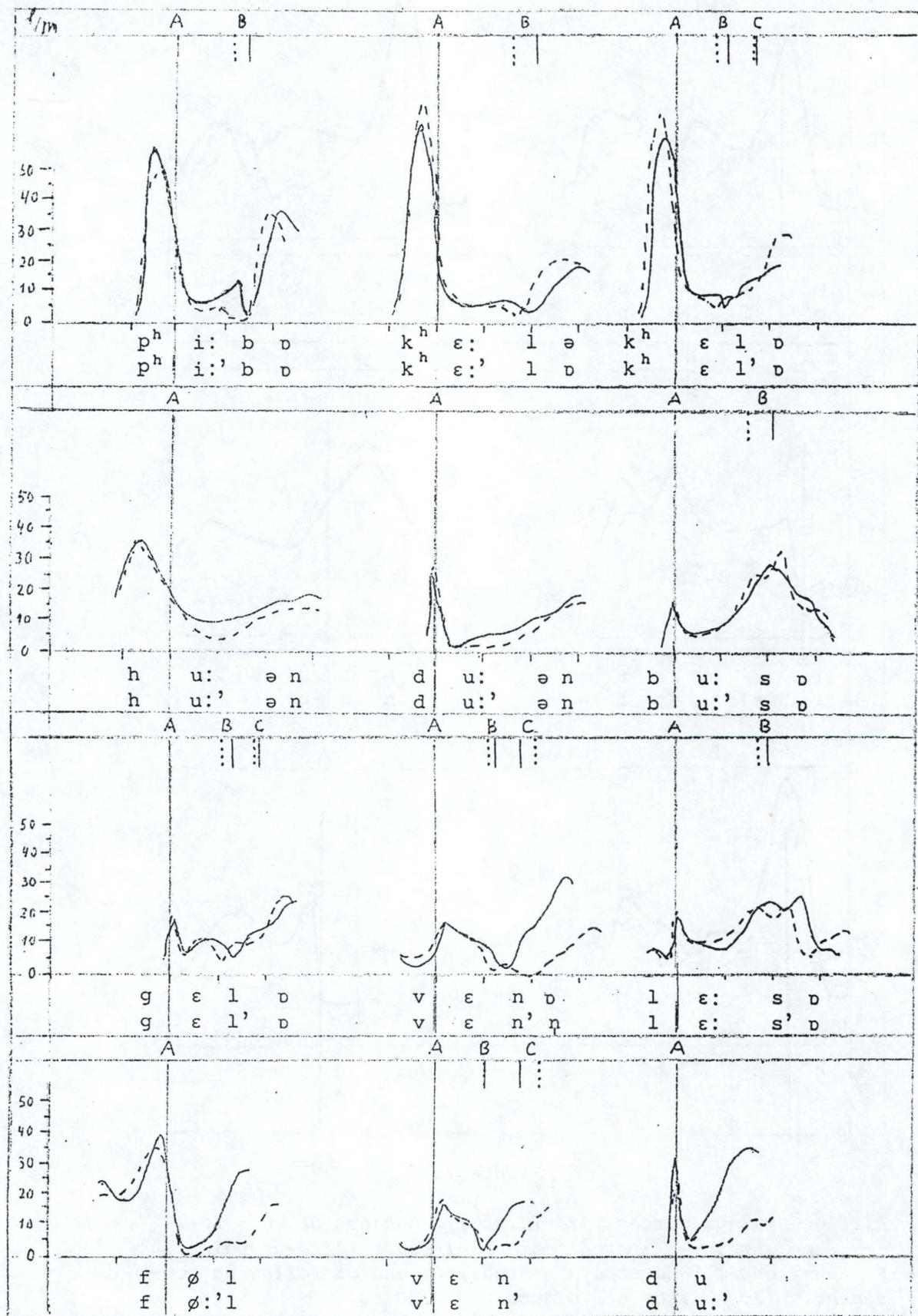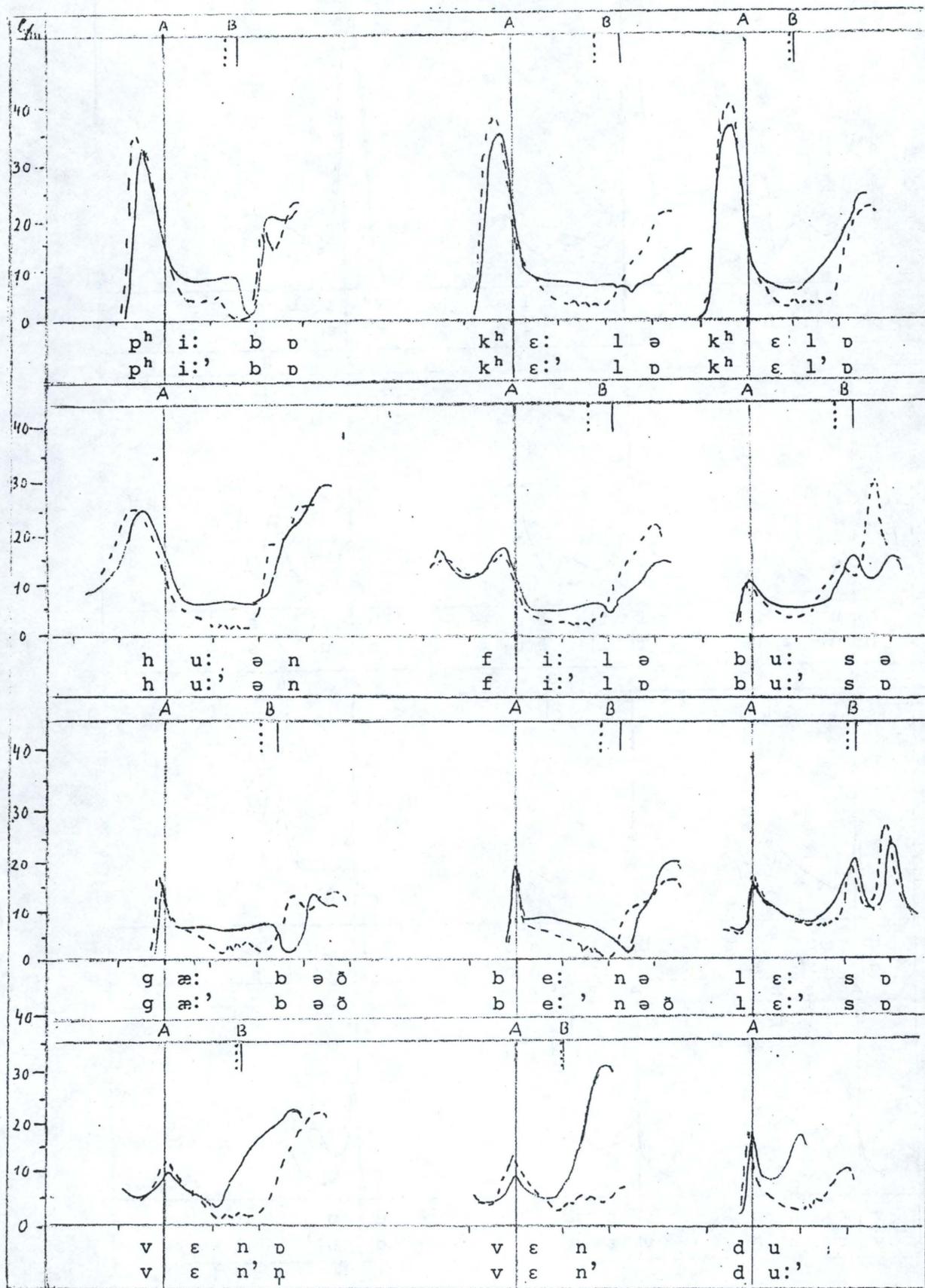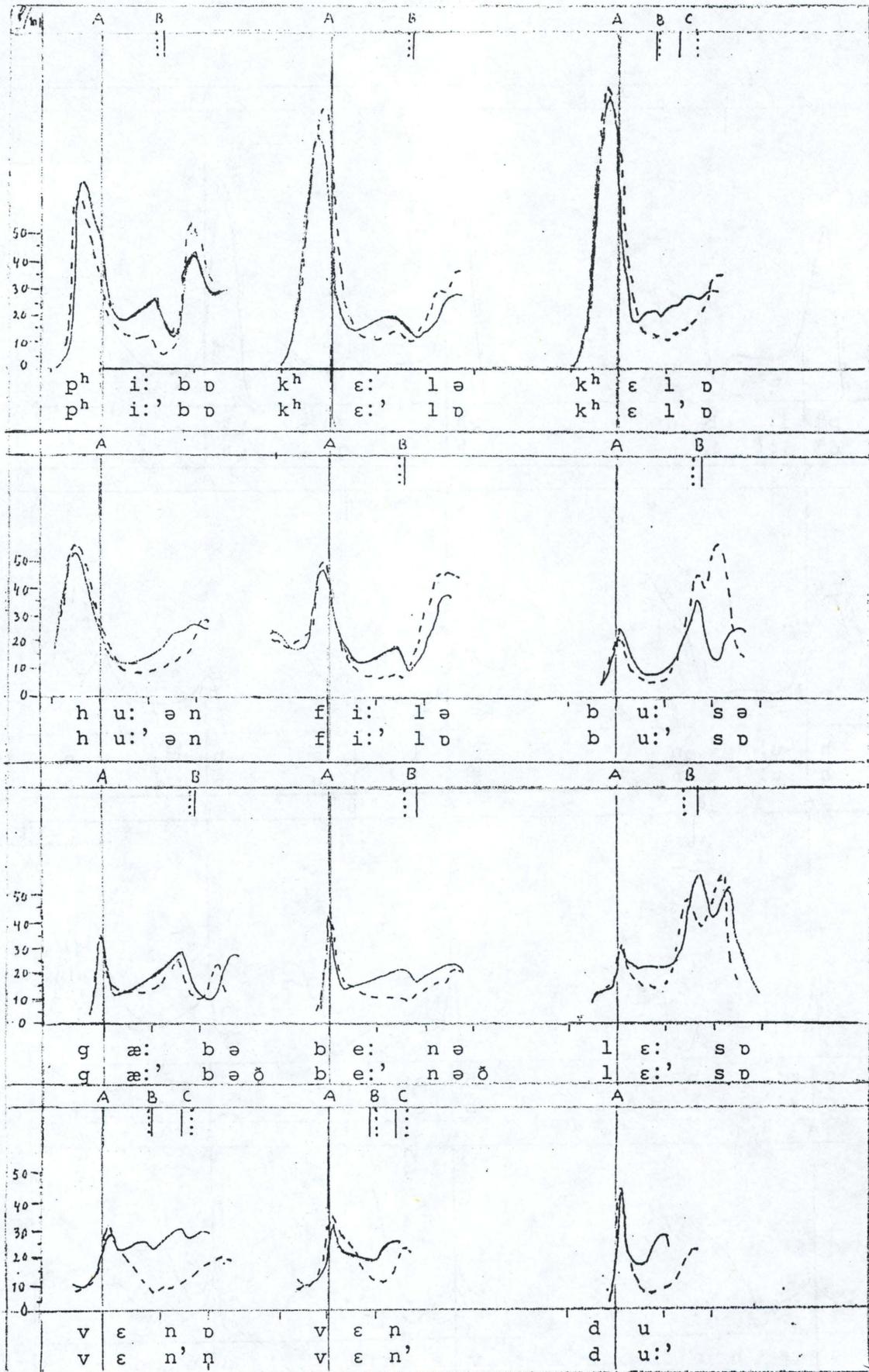                    kʰ        ε      l    ɒ
                    kʰ        ε      l'   ɒ
```



```
                    v     ε     n    ɒ
                    v     ε     n    ɳ
```



```
                    v     ε     n
                    v     ε     n'
```



```
                    d     u
                    d     u:'
```

Figure 1b

Average curves of subglottal pressure 1974 (list 1). Subject
BF. ——— : no stød, --- : stød. See legend to Figure 1a.

d   i: s   ə   ð
d   i:'   s   ə   n

s   i: l   ə
s   i:'   l

m   i: l   ə
m   i:'l

v   ɛ   n
v   ɛ   n'

Figure 2

Average curves of esophageal pressure 1981 (list 7). Subject FJ
(N = 12). —— : *no stød,* --- : *stød. See legend to Figure 1a.*
⌞____⌟ : *10 cs.*

APPENDIX VIII

Pharyngeal Pressure

Survey of the material used for the analysis of pharyngeal pressure.

List	Year	Number of pairs	Subjects and number of repetitions
1	1974	8	BF 10
1	1974	8	JR 2
3	1974	6	JR 4
7	1981	4	FJ 12

Table I

Pharyngeal pressure (in cm H_2O) in initial consonant and in the stød phase. (Subject BF), measured on average curves.

	peak in cons.	stød phase		peak in cons.	stød phase
$p^hi:$'bɒ	8.0	1.5	$k^h\varepsilon l$'ɒ	7.5	1.5
$p^hi:$bɒ	7.8	1.8	$k^h\varepsilon l$ɒ	7.4	2.3
diff.	0.2	-0.3		0.1	-0.8
$k^h\varepsilon:$'lɒ	7.6	1.3	vɛn'n	5.0	0.9
$k^h\varepsilon:$lə	7.3	1.3	vɛnɒ	4.5	1.4
diff.	0.3	0.		0.5	-0.5
lɛ:s'ɒ	4.6	1.2	vɛn'	4.8	1.1
lɛ:sɒ	4.2	1.5	vɛn	4.3	1.6
diff.	0.4	-0.3		0.5	-0.5
hu:'ən	5.2	1.5	du:'	4.0	1.8
hu:ən	4.8	2.5	du	3.9	2.1
diff.	0.4	-1.0		0.1	-0.3

Figure 1

Average curves of pharyngeal pressure 1974 (list 1). Subject BF (N = 10).
—— : no stød, --- : stød. A: vowel start (line-up point), B: vowel end,
C: end of following consonant. | : no stød, :: stød. ⌐——┘ = 10 cs.

APPENDIX IX

Electromyography

Survey of material used for the electromyogrphic analysis

List	Year	Number of pairs	Subjects and number of repetitions
1	1974	8	BF 10, BM 10, HU 11, JJ 12, NR 6
3	1974	3-5	JR 10, BM 10
1	1977 a-b	7	BF 12, BF 11
1	1979 a-b	7	BF 12, BF 17
2	1977	2	BF 12
2	1979	2	BF 12
6	1977		FJ 16

Average electromyograms of the activity of the vocalis muscle in individual word pairs (with the same omissions as in the intensity averages, Appendix III) are shown on the following pages, Fig. 1, a-e. The averages are made by computer except for the pair [pʰi:bɒ/pʰi:'bɒ] where it had to be made manually for most subjects.

Figure 1a

Average electromyograms of VOC, subject BF 1974 (N = 10) and 1977a (N = 12).
——— : no stød, --- : stød. A: vowel start (line-up point), B: vowel end
(no stød, stød), C: end of following consonant. 10 cs.

BF
77b

pʰ i: b ɒ	kʰ ɛ: l ə	l ɛ: s ɒ
pʰ i: ' b ɒ	kʰ ɛ: ' l ɒ	l ɛ: ' s ɒ

BF
77b

h u: ə n	kʰ ɛ l ɒ	v ɛ n
h u: ' ə n	kʰ ɛ l' ɒ	v ɛ n'

BF
79a

pʰ i: b ɒ	kʰ ɛ: l ə	l ɛ: s ɒ
pʰ i: ' b ɒ	kʰ ɛ: ' l ɒ	l ɛ: ' s ɒ

BF
79a

h u: ə n	kʰ ɛ l ɒ	v ɛ n
h u: ' ə n	kʰ ɛ l' ɒ	v ɛ n'

Figure 1b

Average electromyograms of VOC. Subject BF 1977b (N = 11) and 1979a (N = 12).
—— : *no stød,* --- : *stød.   See legend to Fig. 1a.*

Figure 1c

Average electromyograms of VOC. Subjects BF 1979b (N = 17) and BM 1974 (N = 10).
—— : no stød, --- : stød. See legend to Fig. 1a.

HU

p^h	i:	b	ɒ
p^h	i:'	b	ɒ

k^h	ɛ:	l	ə
k^h	ɛ:'	l	ɒ

l	ɛ:	s	ɒ
l	ɛ:'	s	ɒ

HU

h	u:	ə	n
h	u:'	ə	n

k^h	ɛ	l	ɒ
k^h	ɛ	l'	ɒ

v	ɛ	n
v	ɛ	n'

JJ

p^h	i:	b	ɒ
p^h	i:'	b	ɒ

k^h	ɛ:	l	ə
k^h	ɛ:'	l	ɒ

l	ɛ:	s	ɒ
l	ɛ:'	s	ɒ

JJ

h	u:	ə	n
h	u:'	ə	n

k^h	ɛ	l	ɒ
k^h	ɛ	l'	ɒ

v	ɛ	n
v	ɛ	n'

Figure 1d

Average electromyograms of VOC. Subjects HU (N = 11) and JJ (N = 10). ——— : no stød, --- : stød. See legend to Fig. 1a.

Figure 1e

Average electromyograms of VOC.   Subject NR (N = 6).   See legend to Fig. 1a.

INSTITUTE OF PHONETICS
JANUARY 1, 1986 - DECEMBER 31, 1986

I. PERSONNEL OF THE INSTITUTE

PROFESSOR:
Jørgen Rischel, dr.phil.

ASSOCIATE PROFESSORS:
Børge Frøkjær-Jensen, cand.mag. (seconded to the Audiologo-
                                          pedic Centre)
Peter Holtse, cand.phil. (on leave from April 1, 1984)
Birgit Hutters, cand.mag.
Niels Reinholt Petersen, cand.phil.
Nina Grønnum Thorsen, lic.phil.
Oluf Thorsen, cand.mag.

RESEARCH FELLOWS:
Jan Leon Katlev, lic.phil.
Peter Molbæk Hansen, cand.mag.
Peter Holtse, cand.phil.

RESEARCH ASSISTANTS:
Michael Bundgaard, cand.scient.
Carsten Henriksen, cand.mag. (from September 1st)

ENGINEERS:
Otto Bertelsen, M.Sc.
Preben Dømler, B.Sc.

TECHNICIAN:
Svend-Erik Lystlund

SECRETARY:
Else Parkmann

GUEST RESEARCHER:
Eli Fischer-Jørgensen, dr.phil.h.c.

II. PUBLICATIONS BY STAFF MEMBERS AND GUESTS

Eli Fischer-Jørgensen: Review article of Eberhard und Kurt
Zwirner: Grundlagen der phonometrischen Linguistik, 3. Auflage
1982, Phonetica 42, 1985, 198-213

Birgit Hutters og Kirsten Brøndsted: "Talestrategier ved gane-
spalte", Nordisk Tidsskrift for Logopedi og Foniatri 11, 1986,
57-67

Niels Reinholt Petersen: "Perceptual compensation for segmental-
ly conditioned fundamental frequency perturbation", Phonetica 43,
1986, 31-42

Jørgen Rischel: "Is there just one level of prosodic represen-
tation?", in Dressler, W. et al. (eds.) Phonologica 1984, Pro-
ceedings of the Fifth International Phonology Meeting, 1986

Jørgen Rischel & Knut Bergsland: Pioneers of Eskimo Grammar:
Hans Egede's and Albert Top's Early Manuscripts on Greenlandic,
Travaux du Cercle Linguistique de Copenhague XXI, 1986, 188 pp.

Jørgen Rischel: "Dialektfordeling og lydforandringer i grøn-
landsk", in Vort sprog - vor kultur, Pilersuiffik, Nuuk 1986,
p. 123-141 (also in a Greenlandic version in the publication
Oqaatsivut kulturerpullu, Pilersuiffik 1986)

Nina Grønnum Thorsen: "Sentence intonation in textual context -
Supplementary data", J. Acoust. Soc. Am. 80, 1986, 1041-1047

Nina Grønnum Thorsen: "Intonation and text in Standard Danish -
with special reference to the abstract representation of in-
tonation", in Dressler, W. et al. (eds.) Phonologica 1984, Pro-
ceedings of the Fifth International Phonology Meeting, 1986

Nina Thorsen and Oluf Thorsen: Fonetik for Sprogstuderende,
3. rev. udg., 8. oplag, Institut for Fonetik, København, 170 pp.

Ole Kongsdal Jensen og Oluf Thorsen: Fonetik for Franskstuderende,
Romansk Institut, København, 206 pp.

III. GUEST LECTURES AND SEMINARS

April 16 - Diana Krull, Stockholm University: "Spectrum and
dynamics in the perception of Swedish stops".

May 26-30 - Wilhelm Vieregge, Catholic University, Nijmegen,
gave an intensive course in the transcription of pathological
speech.

November 24 - Albertas Steponavicius, Vilna, Lithuania: "Re-
search activities within descriptive and historical phonology
in Lithuania".

December 17 - Briony Williams, IBM Scientific Centre, Winchester:
"Synthesizing British English intonation from a tonetic stress
notation".

IV. PARTICIPATION IN CONGRESSES, ETC.

Jan Katlev participated in Sociolinguistics Symposium 6, Newcastle upon Tyne, April 16-18, and gave a paper: "A comparison of Danish and English allegro phonology".

Jan Katlev gave a guest lecture at Aalborg University, May 2: "Nordjysk regionalt rigsmål?"

Peter Molbæk Hansen participated in two meetings of the COST 209 Working Group No. 1, at Die Postschule des FTZ, Heidelberg, West Germany, May 27-28 and at PTT Dr. Neher Laboratories, Leidschendam, the Netherlands.

Jørgen Rischel participated in the Fourth Nordic Prosody Meeting, Middelfart (Denmark) June 6-8 and gave a paper: "Some reflexions on levels of prosodic representation and prosodic categories". He also participated in the meeting of the Chicago Linguistics Society and the Conference on Southeast Asia as a Linguistic Area at the University of Chicago in April 1986, and gave a paper at the last-mentioned conference: "Areal features and linguistic theory", April 16. Jørgen Rischel furthermore participated as a guest in the meeting of the British prosodic school (symposium on non-linear phonology) in York, April 1986.

Jørgen Rischel gave a guest lecture: "A critical view of tonogenesis in Thai" at Cornell University, 22 April.
Jørgen Rischel reported on his phonetic studies in Southeast Asia and Greenland at UCLA, May 5.
Jørgen Rischel lectured at the University of Vienna and the University of Salzburg, respectively, June 9-10 and June 11, on non-linear phonology.
Jørgen Rischel gave an opening lecture on linguistic aspects of speech synthesis at the opening celebration of the Videnscentret, Laboratoriet for elektroniske systemer, Aalborg universitetscenter (Denmark), August 27.
Jørgen Rischel gave a guest lecture on the IPUC speech synthesis project at the University of Bergen, November 20.

Nina Grønnum Thorsen participated in the Fourth Nordic Prosody Meeting, Middelfart, June 6-8, and gave a paper: "Text and intonation - a case study".
Nina Grønnum Thorsen gave a guest lecture at Stockholm University, May 21: "Text and intonation - a case study".
Nina Grønnum Thorsen gave a guest lecture at Université de Genève, June 24: "Suprasegmental transcription".

V. INSTRUMENTAL EQUIPMENT OF THE LABORATORY

The following is a list of instruments that have been purchased or built during the period January 1 - December 31, 1986.

OUTFIT FOR PHOTOGRAPHY

    1 camera, Minolta, 7000 (with various accessories)
    1 enlarger, Durst, M370.

TAPE RECORDERS

    1 cassette recorder, SONY, BM80

GENERAL PURPOSE ELECTRONIC INSTRUMENTATION

    1 Logic analyzer.

EQUIPMENT FOR EDP

    1 printer, Printstar, 5025
    1 CTR terminal, Nokia, VDU
    1 Masscomp 5600 computer system consisting of:
        1 single processor system with
            1 MC68020 cpu
            1 parallel floating point accelerator
            4 Mb RAM
        1 8-chan. high speed terminal multiplexor
        1 XMC peripheral controller with
            2 80Mb winchester disk drives
            1 40Mb streaming cartridge tape unit
            1 1.2Mb floppy disk unit
        1 DACP front end I/O processor with
            1 EP12M analogue I/O card (A/D: 8-chan., D/A:
            (2-chan.)

    Operating system: Masscomp RTU-1 (Real Time Unix).

PAPERS PUBLISHED IN ARIPUC 1-20, 1966 - 1986:

Andersen, P.: Spectral properties of German and Danish
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Fischer-Jørgensen, Eli: Some basic vowel features, their articulatory correlates and their explanatory power in phonology (ARIPUC 18, 1984, p. 255-276)

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Fischer-Jørgensen, Eli, Børge Frøkjær-Jensen & Jørgen Rischel: Preliminary experiments with the Fabre glottograph (ARIPUC 1, 1966, p. 22-30)

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Frøkjær-Jensen, Børge & Svend Prytz: Evaluation of speech dis-
    orders by means of long-time-average-spectra (ARIPUC 8,
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Frøkjær-Jensen, Børge & Svend Prytz: Registration of voice
    quality (ARIPUC 9, 1975, p. 237-251)

Frøkjær-Jensen, Børge & Jørgen Rischel: Fourier analyses of
    photo-electric glottograms (ARIPUC 3, 1968, p. 128-134)

Frøkjær-Jensen, Børge & Poul Thorvaldsen: Construction of a
    Fabre glottograph (ARIPUC 3, 1968, p. 1-8)

Ghai, Ved Kumari: Word tones in Dogri (ARIPUC 2, 1967, p. 133-
    157)

Ghai, Ved Kumari: Contributions to Dogri phonetics and phonology
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Gregersen, Kirsten: A study of internal open juncture in British
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Greiffenberg, Mette & Niels Reinholt Petersen: The effect of
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Heger, Steffen: Danish r and adjacent short stressed vowels
    (ARIPUC 9, 1975, p. 137-169)

Holtse, Peter: Spectrographic analysis of English vowels
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Holtse, Peter: Identification and discrimination of closely
    spaced synthetic vowels (ARIPUC 7, 1973, p. 235-264)

Holtse, Peter: Preliminary experiments with synthesis by rule
    of Standard Danish (ARIPUC 8, 1974, p. 239-251)

Holtse, Peter: Speech synthesis at the Institute of Phonetics
    (ARIPUC 16, 1982, p. 117-126)

Holtse, Peter & Anders Olsen: SPL: A speech synthesis program-
    ming language (ARIPUC 19, 1985, p. 1-42)

Holtse, Peter & Jens Stellinger: A system for computer aided
    processing of phonetic measurements (ARIPUC 10, 1976,
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Hutters, Birgit: Problems in the use of the photo-electric glottograph (ARIPUC 10, 1976, p. 275-312)

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Jacobsen, Per: Vowel quantity in Czech (ARIPUC 3, 1968, p. 135-142)

Jacobsen, Per: Falling word tones in Serbo-Croatian (ARIPUC 4, 1969, p. 81-88)

Jacobsen, Per: Falling word tones in Serbo-Croatian (II), (ARIPUC 7, 1973, p. 265-268)

Jeel, Vivi: An investigation of the fundamental frequency of vowels after various consonants, in particular stop consonants (ARIPUC 9, 1975, p. 191-211)

Jørgensen, Hans-Peter: Acoustic analysis of tense and lax vowels in German (ARIPUC 1, 1966, p. 77-84)

Jørgensen, John: "Stød" and unexpected substitutions in the speech of Danish 2-year-old children (ARIPUC 12, 1978, p. S25-29)

Jørgensen, John: The acquisition of stop consonants by Danish two-year-old children (ARIPUC 13, 1979, p. 9-25)

Karlsson, Inger: Synthesis of a female voice, a preliminary study (ARIPUC 12, 1978, p. S63-70)

Kongsdal Jensen, Ole: Features of the acoustical and physiological structure of the French nasal vowels (ARIPUC 1, 1966, p. 59-66)

Landschultz, Karen: Duration of French vowels before fricatives (ARIPUC 2, 1967, p. 109-118)

Lauritzen, Kai & Børge Frøkjær-Jensen: Comparative phonetic-acoustic analysis before and after speech therapy of voices suffering from recurrens paresis (ARIPUC 4, 1969, p. 145-165)

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Lindblad, Per: On the production of the Swedish tje-sound
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Ludvigsen, Carl: An attempt to register lip pressure and lip
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     1969, p. 1-7)

Ludvigsen, Carl: Energy measurements of speech sounds (ARIPUC
     5, 1971, p. 153-162)

Ludvigsen, Carl: Comparison between auditive and audio-visual
     perception of PB-words masked with white noise (ARIPUC 6,
     1972, p. 229-244)

Ludvigsen, Carl: Influence from dialectal background on the
     score in hearing tests employing speech stimuli (ARIPUC 7,
     1973, p. 99-102)

Ludvigsen, Carl: Influence of microphone position in the re-
     cording of speech signals (ARIPUC 13, 1979, p. 171-187)

Ludvigsen, Carl & Nina G. Thorsen: Comparison of sound pressure
     level and loudness (GF) measurements on speech sounds
     (ARIPUC 5, 1971, p. 163-174)

Lyberg, Bertil: Final lengthening - a consequence of articul-
     atory and perceptual restrictions? (ARIPUC 12, 1978,
     p. S79-85)

Mansell, P.: A study on peak amplitude measures (ARIPUC 5,
     1971, p. 91-122)

Mansell, Philip: Some airflow and glottogram data on Danish
     whisper (ARIPUC 8, 1974, p. 133-171)

Mase, Hideo: Acoustic cues for the perception of accent in
     Japanese when the accented vowel is devoiced (ARIPUC 3,
     1968, p. 143-176)

Mase, Hideo: Measurements of the length of some Japanese vowels
     with special reference to their devoicing (ARIPUC 4, 1969,
     p. 89-110)

Mase, Hideo: Syllable and accent in Japanese (ARIPUC 5, 1971,
     p. 123-152)

Mase, Hideo: A study of the role of syllable and mora for the
     tonal manifestation in Greenlandic (ARIPUC 7, 1973, p. 1-
     98)

Mase, Hideo & Jørgen Rischel: A study of consonant quantity in
     West Greenlandic (ARIPUC 5, 1971, p. 175-247)

Molbæk Hansen, Peter: Stød and syllabicity in a Jutlandish
     dialect (ARIPUC 12, 1978, p. S15-24)

278

Molbæk Hansen, Peter: A comment on Basbøll's phonological syllabification as applied to Danish (ARIPUC 13, 1979, p. 87-120)

Molbæk Hansen, Peter: The construction of a grapheme-to-phone algorithm for Danish (ARIPUC 16, 1982, p. 127-136)

Molbæk Hansen, Peter: An orthography normalizing program for Danish (ARIPUC 17, 1983, p. 87-109)

Molbæk Hansen, Peter & Bent Møller: The influence of acoustic and physiological factors on some vowel changes in Danish (ARIPUC 9, 1975, p. 171-190)

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Reinholt Petersen, Niels: The influence of tongue height on the perception of vowel duration in Danish (ARIPUC 8, 1974, p. 1-10)

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Reinholt Petersen, Niels: Variation in inherent Fo level differences between vowels as a function of position in the utterance and in the stress group (ARIPUC 13, 1979, p. 27-57)

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    mental frequency levels between syllables (ARIPUC 14,
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Reinholt Petersen, Niels: The effect of consonant type on fun-
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Reinholt Petersen, Niels: Global and local fundamental fre-
    quency variation and larynx height: Some preliminary
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Reinholt Petersen, Niels: Fundamental frequency and larynx
    height in sentence and stress groups (ARIPUC 19, 1985,
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Rischel, Jørgen: Heterodyne filter (ARIPUC 1, 1966, p. 13-14)

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Rischel, Jørgen & Svend-Erik Lystlund: Speech synthesizer (ARIPUC 2, 1967, p. 34)

Rischel, Jørgen & Svend-Erik Lystlund: A formant-coded speech synthesizer (ARIPUC 6, 1972, p. IX-XXX)

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Smith, Svend & Kirsten Thyme: Statistic research on changes in speech due to pedagogic treatment (the accent method) (ARIPUC 9, 1975, p. 293-301)

Spang-Thomsen, Børge: Analyses of French accent (ARIPUC 1, 1966, p. 58)

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Thorsen, Nina G.: Voicing in British English t and d in contact with other consonants (ARIPUC 5, 1971, p. 1-39)

Thorsen, Nina G.: Acoustical and perceptual properties of the Danish stød (ARIPUC 8, 1974, p. 207-213)

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Thorsen, Nina: A simplified explanation, in physical terms, of the acoustical consequences of tongue and lip movement in vowel production (ARIPUC 12, 1978, p. 1-15)

Thorsen, Nina: On the identification of selected Danish intonation contours (ARIPUC 12, 1978, p. 17-73)

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Thorsen, Nina: Lexical stress, emphasis for contrast, and sentence intonation in Advanced Standard Copenhagen Danish (ARIPUC 13, 1979, p. 59-85)

Thorsen, Nina: Word boundaries and Fo patterns in Advanced Standard Copenhagen Danish (ARIPUC 13, 1979, p. 121-134)

Thorsen, Nina: Intonation contours and stress group patterns in declarative sentences of varying length in ASC Danish (ARIPUC 14, 1980, p. 1-29)

Thorsen, Nina: Neutral stress, emphatic stress, and sentence intonation in Advanced Standard Copenhagen Danish (ARIPUC 14, 1980, p. 121-205)

Thorsen, Nina: Intonation contours and stress group patterns in declarative sentences of varying length in ASC Danish - supplementary data (ARIPUC 15, 1981, p. 13-47)

Thorsen, Nina: The present state of the description of Danish utterance prosody (ARIPUC 15, 1981, p. 49-60)

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Thorsen, Nina: Two issues in the prosody of Standard Danish: The lack of sentence accent and the representation of sentence intonation (ARIPUC 16, 1982, p. 19-35)

Thorsen, Nina: Selected problems in the tonal manifestation of words containing assimilated or elided schwa (ARIPUC 16, 1982, p. 37-100)

Thorsen, Nina: Two experiments in the perception of Fo timing in Danish (ARIPUC 17, 1983, p. 1-20)

Thorsen, Nina Grønnum: Variability and invariance in Danish stress group patterns (ARIPUC 18, 1984, p. 13-43)

Thorsen, Nina Grønnum: Intonation and text in Standard Danish (ARIPUC 18, 1984, p. 185-242)

Thorsen, Nina Grønnum: Sentence intonation in textual context - supplementary data (ARIPUC 20, 1986, p. 35-44)

Thorsen, Nina & Bent Jul Nielsen: Fundamental frequency patterning and sentence intonation in two Jutlandic dialects - a first approach (ARIPUC 15, 1981, p. 1-12)

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Thorvaldsen, Poul: Construction of an automatic data collecting system (ARIPUC 6, 1972, p. 260-268)

Traunmüller, Hartmut: Perception of stationary formant patterns (ARIPUC 12, 1978, p. S43-45)

Uldall, Elizabeth: EMG investigation of labial articulations (ARIPUC 19, 1985, p. 143-168)

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