AN INSTRUMENTAL INVESTIGATION OF THE DANISH "STØD"

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1. Introduction

In this study the stød is regarded as a phonologically distinctive element. For a discussion of this point, see Hjelmslev (1951) and Martinet (1937).

By means of the commutation test 4 contrasting types of words are established. These differ in the length of the vowel, and in the presence of the stød in the vowel or in the following consonant vs. absence of the stød. Examples: vener [ve·nəʁ] 'veins', Wegner [veʔnəʁ] (a name), vinder [venəʁ] 'winner', vinder [venʔəʁ] 'win' (present tense).

An acoustic analysis of these four types has been undertaken, comprising measurements of vowel and consonant length and of the pitch and intensity movements of the stressed vowel.

Opinions have differed regarding the length of vowels accompanied by the stød (henceforth referred to as stød-vowels) as in [veʔnəʁ]. Martinet (1937) gives arguments for considering a stød-vowel as a long vowel because it has the same quality as the (stød-less) long vowel in cases where there is a difference of quality between long and short vowels (e.g. ɑ-a: and ɔ-o:). In addition the stød-vowel has the same distribution as a long vowel (it is for example never found before [-ŋ]), and this analysis makes the place of the stød predictable: when a syllable has stød it appears in the vowel if the vowel is long: pæn [pɛʔn], otherwise in the following consonant: pen [pɛnʔ].

Jespersen (1949) is of the opinion that the stød-vowel is a long vowel; Uldall (1936), on the other hand, considers it to be short.

The length of the vowel has been investigated by Abrahams (1943) who found that the length of the stød-vowel is always intermediate between that of long and short vowels. He is of the opinion that the length of the stød-vowel is a cue for the stød.

Fischer-Jørgensen (1955) also states that the length of the stød-vowel is between long and short, but normally closest to long; she observes that there is overlapping in absolute duration between long vowels and stød-vowels, but not between stød-vowels and short vowels, which supports the assumption that the stød-vowel is acoustically long.

Lauritsen (1968) finds that a long vowel is twice as long as a short vowel and that a stød-vowel is one and a half times as long as the short vowel.

The stød has been considered as originating from a special pitch movement since the words with stød correspond to words with "accent 1" in Norwegian, Swedish, and some southern Danish dialects, and in accordance with this, some scholars have argued that there is a musical difference also in the standard language between words with stød and words without stød (Verner 1903).

The question whether the stød is a glottal stop or not was investigated by Rousselot (1924) who found that a closure is rare. The same result is obtained by Ekblom (1933) who in addition discovered a steep increasing pitch followed by a decrease. Selmer (1925) found often a real closure, but his recordings were made with emphatic pronunciation.

The most important instrumental investigation of the stød was undertaken by Svend Smith (1944). His investigation includes electro-myographic, oscillographic and kymographic registrations. He discovered that there is a particular kind of innervation in the expiratory muscles in words containing a stød: it seems that the stød-word has a more discontinuous character in comparison with the stød-less word. Pitch and intensity show the same movement: In the stød-word there is a decrease in the intensity accompanied by a decrease in pitch, often ending in irregular oscillations, but his recordings do not give any example of a complete closure. Sometimes there is a reappearance of regular oscillations after the irregular interval. Smith does not observe any difference in the pitch level between stød-words and stød-less words. His conclusion is that the stød is a stress accent: a special "marking movement" made by a thrust-like emphasis of sounds. The stød often appears to be three-phased: 1) a ballistic contraction of the expiratory muscles, 2) cessation of this activity, which causes a lack of balance in the reaction of the vocal cords, 3) sometimes a new activity in the expiratory muscles.

2. The present investigation

2.1. The informants

The speakers comprise 3 males and 3 females, designated 22,25,26 and 11,13,14 respectively. They all speak Copenhagen Standard Danish (Rigsdansk), and all of them have normal healthy voices.

2.2. The material

The material consists of 8 groups of words where the frames are approximately identical; only the length of the vowel and the stød varies.

hyle '(to) yell' [hy·lə]	hyler '(I) yell' [hyʔləʁ]
hylde 'shelf' [hylə]	hylden 'the elder' [hylʔən]
kæle '(to) caress' [kʰɛ·lə]	kæler '(I) caress' [kʰɛʔləʁ]
kælder 'cellar' [kʰɛləʁ]	Keller, a name [kʰɛlʔəʁ]

bene '(to) run' [be·nə]	benet 'the leg' [beʔnəð]
binde '(to) tie' [benə]	binder '(I) tie' [benʔəʁ]
hane 'cock' [ha·nə]	afganer '(an) afghan'[ɑu'gaʔnəʁ]
Hanne, a name [hanə]	hannerne 'the males' [hanʔəʁnə]
læser 'reader' [lɛ·səʁ]	læser '(I) read' [lɛʔsəʁ]
læsser '(I) load' [lɛsəʁ]	
gyse '(to) shiver' [gy·sə]	gyser '(I) shiver' [gyʔsəʁ]
gysser 'dough' (colloquial) [gysəʁ]	
taber '(I) lose' [tʰa·bəʁ]	tabet 'the loss' [tʰaʔbəð]
tapper '(I) drain' [tʰabəʁ]	
piber 'pipes' [pʰi·bəʁ]	piber '(I) squeak' [pʰiʔbəʁ]
pipper '(I) chirp' [pʰibəʁ]	

The test words were all placed in sentences which had an identical rhythm[1], for example:

> Sirenen plejer at hyle om aftenen
> Sjakalen sidder og hyler i ørkenen
> Jeg tror der mangler en hylde i bogskabet
> Jeg tror vi plantede hylden i foråret.

2.3. The recordings

All the sentences were read aloud in random order 6 times by each of the informants. The recordings took place in the recording studio of the Institute of Phonetics, University of Copenhagen, using a Lyrec professional Recorder, 1/1 track at 7½"/sec on Scotch Magnetic Tape.

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1) It is seldom possible to place a stød-word and a stød-less word in exactly the same environment in the same sentence, because the stød in many cases distinguishes classes of words or inflected forms.

2.4. The tracings

For the reproduction the same tape recorder was used as in the recording operation. The signal passed a pitch-meter and an intensity meter, and the curves were registered by means of a 8-channel Elema Mingograph. The traces (see fig.1) were:

1. a pitch curve
2. a logarithmic intensity curve, high-pass filtered at 500 Hz and with an integration time of 2,5 msec for speakers 11,22,13,14, and 5 msec for speakers 25 and 26.
3. a linear, unfiltered intensity curve with an integration time of 5 msec for speakers 11,22,13,14, and 10 msec for speakers 25 and 26.
4. a duplex oscillogram.

All measured values were fed into a computer using a simple program which produces the mean, the standard deviation, and the 95 and 99% confidence limits of the mean.

3. Results

3.1. The manifestation of the stød

In the recorded material the stød behaves in many different ways, different for the various speakers and different in the recordings of the different readings of the same word by one speaker. One extreme is complete closure (occurring a few times). The other extreme is constituted by cases without any visible difference between the curves of words containing stød and words without stød. Between these two extremes all intermediate steps are represented. Figs. 2a-5d

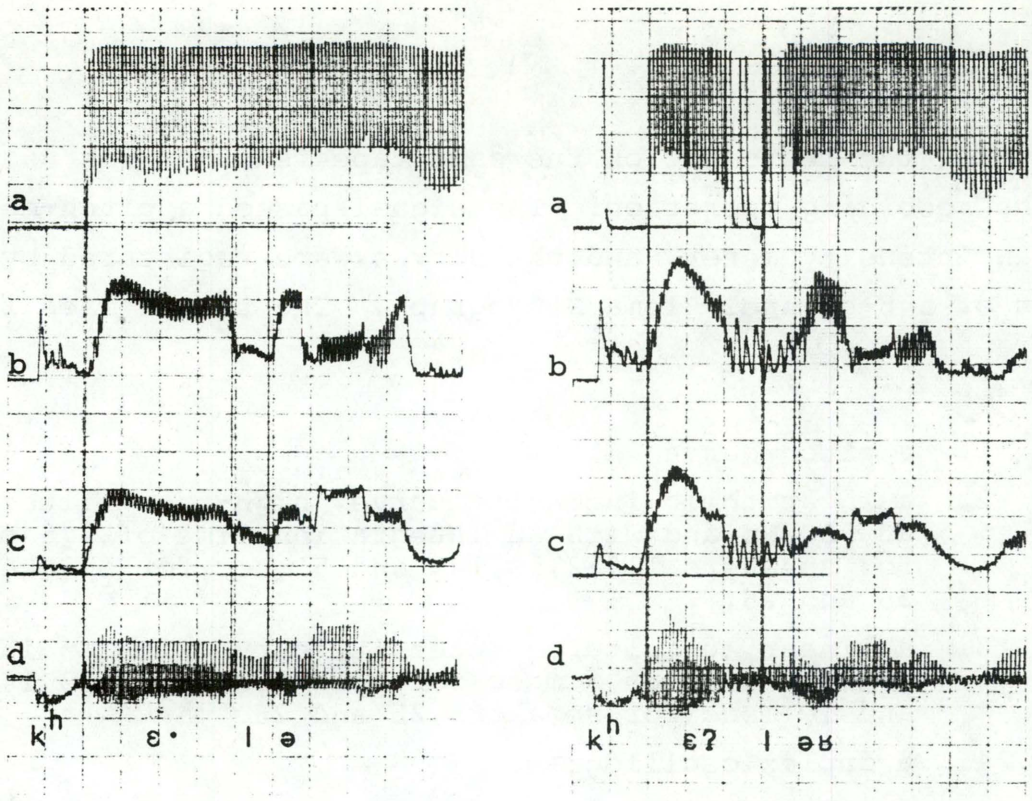

Fig. 1 Mingogram of [k^hε·lə] and [k^hεʔləʁ].
The traces are:
a. a pitch curve
b. a logarithmic intensity curve, highpass filtered at 500 Hz.
c. a linear, unfiltered intensity curve
d. a duplex oscillogram.

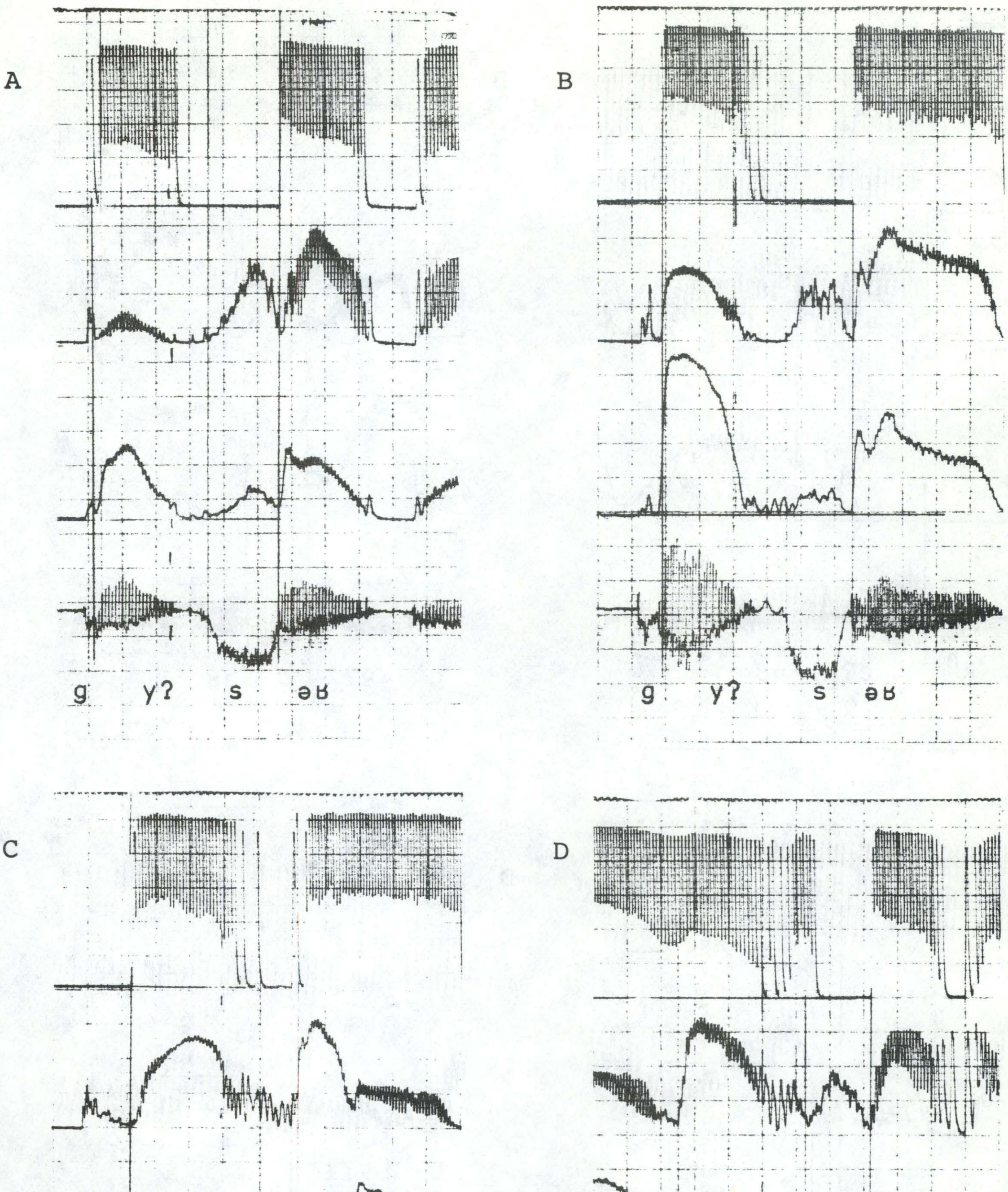

Fig. 2 A-D   Different types of stød in the vowel.

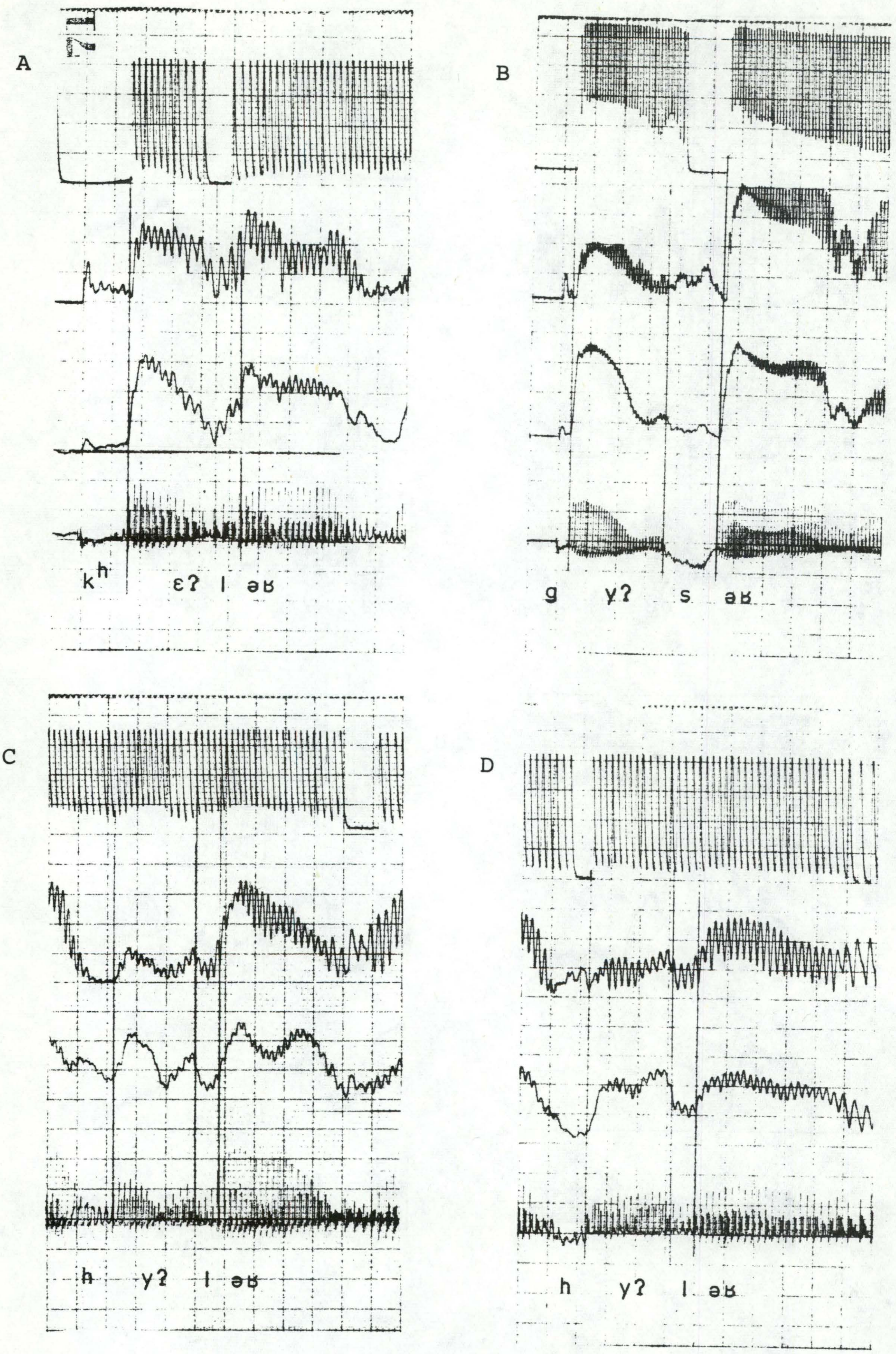

Fig. 3 A-D Different types of stød in the vowel.

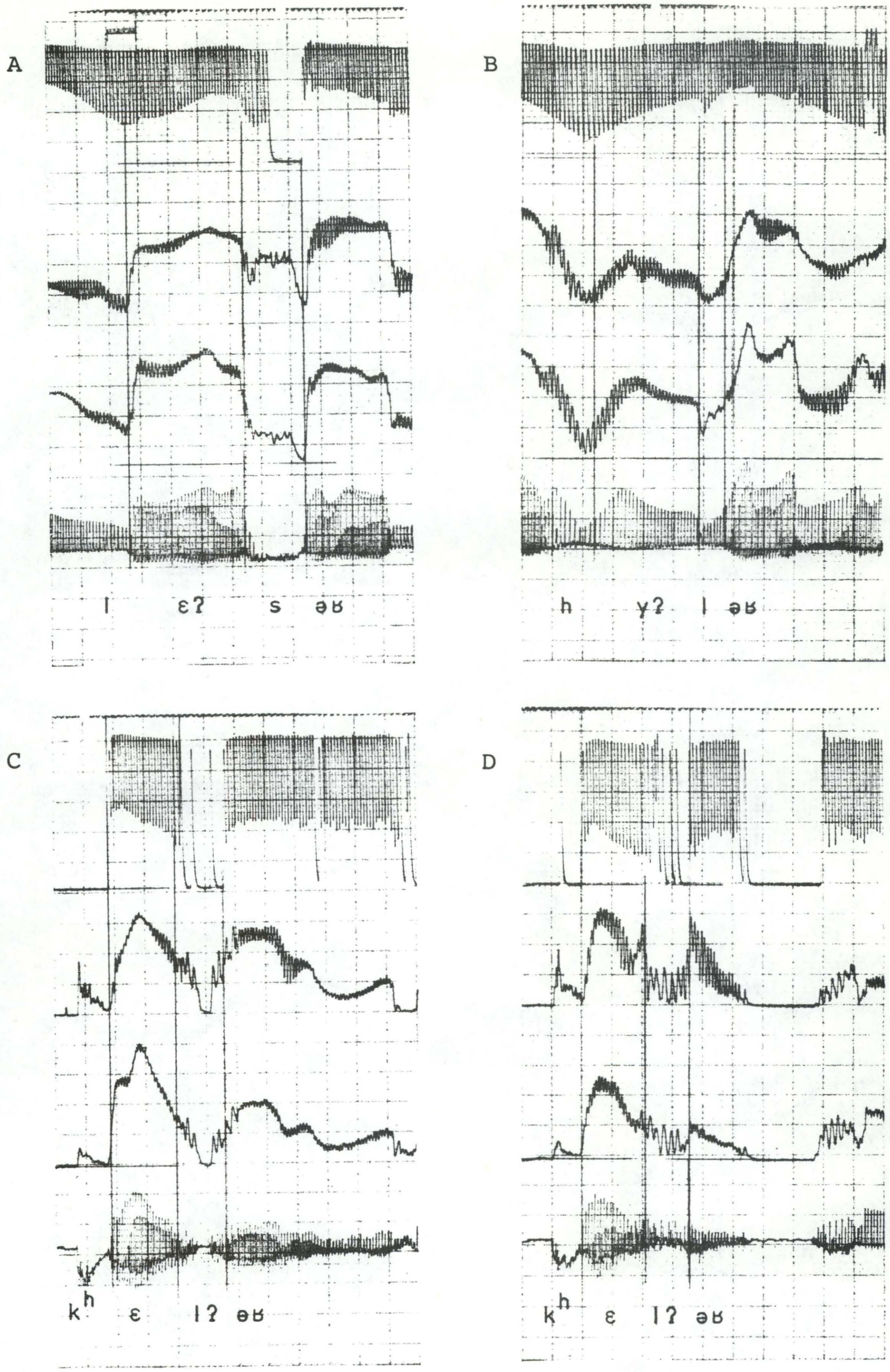

Fig. 4 A-B Different types of stød in the vowel
C-D Different types of stød in the consonant.

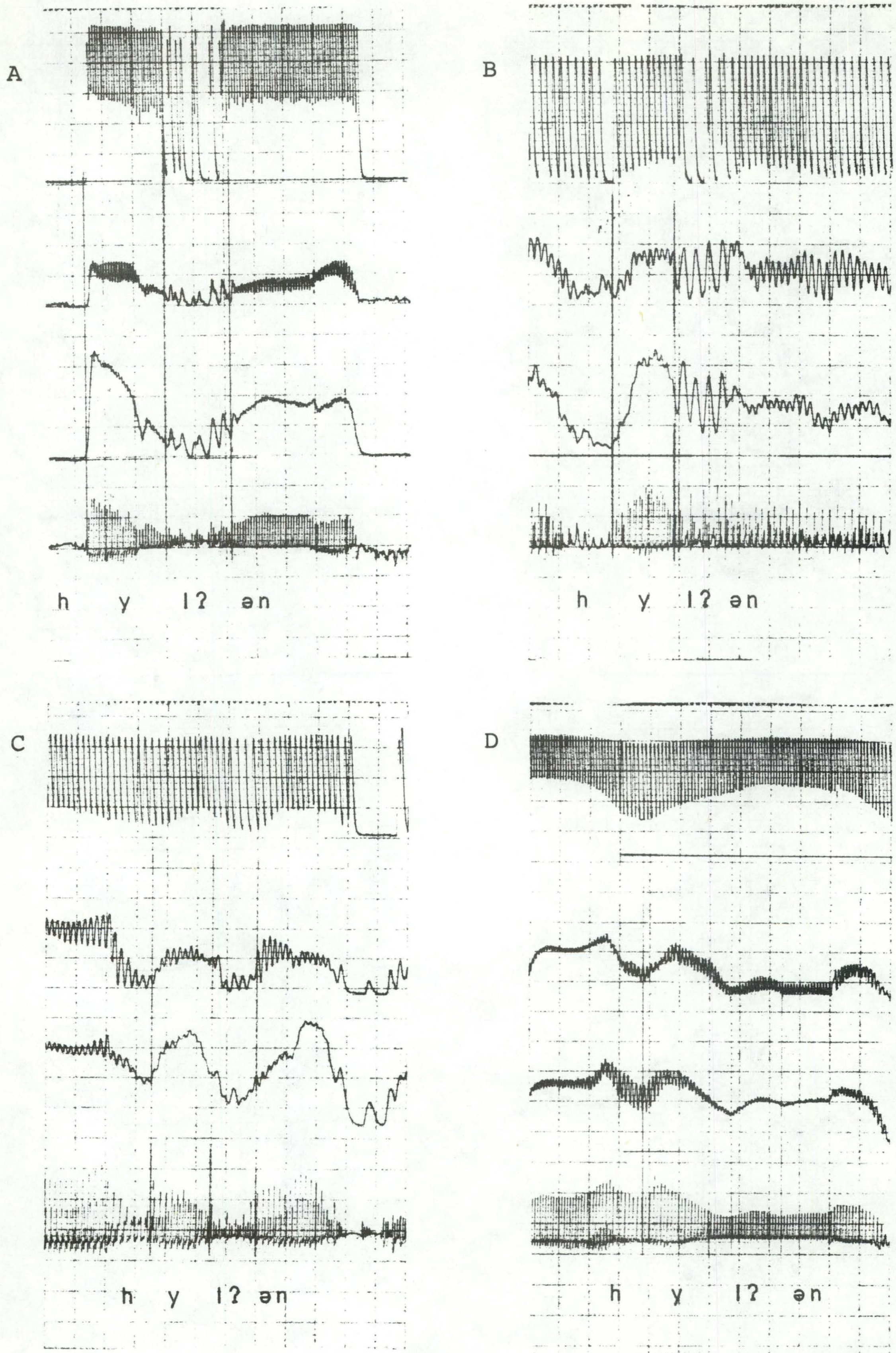

Fig. 5 Different types of stød in the consonant.

illustrate different types of the stød; these are representative of the whole material.

Fig. 2a. An example of closure. This is not found very often.

Fig. 2b. Almost complete closure at the end of the stød phase.

Fig. 2c. Strong stød with complete change of the oscillatory pattern. Steep decrease in intensity and pitch.

Fig. 2d. The same as in 2c, the regularly jagged oscillation in the beginning of the stød phase is remarkable.

Fig. 3a. A stød of minor strength in contradistinction to the preceding types, which is not distinctly localized but seems to have a gradually increasing effect on the vowel. The jagged oscillations continue into the following consonant.

Fig. 3b. Weaker stød, influencing pitch and intensity, both of which show a steep decrease.

Fig. 3c. Stød in the middle of the vowel. All the preceding types of stød are placed at the end of the vowel and there is sometimes an influence also on the oscillations in the following consonant. The present type where the stød is in the middle of the vowel, is characterized by a reduction and a jagged form of the oscillations after which the oscillations gradually return to their normal regular form. As a rule there is an accompanying decrease and increase of the intensity, whereas the pitch does not rise again.

Fig. 3d. Illustration of the same phenomenon as in fig. 3c, but weaker.

Figs. 4a-4b. These are examples where there is no visible difference between words with and without stød. In 4a the pitch and intensity curves show the same movement, in 4b the pitch is increasing and the intensity decreasing.

The figures referred to so far are all illustrations of stød in the vowel; the following figures show stød in the consonant. In contradistinction to the stød in the vowel the stød in the consonant often extends over the whole segment and can also influence the surroundings.

Fig. 4c. Closure in the stød phase.

Fig. 4d. Locally concentrated stød, with complete change of the form of the oscillations.

Fig. 5a. Strong stød in the whole consonant. The clear influence on the last 5 cs of the preceding vowel is remarkable.

Fig. 5b. Strong stød in the beginning of the consonant and a return to regular oscillation at the end of the consonant.

Fig. 5c. Weak stød.

Fig. 5d. Here the stød is not visible, although it can be heard on the tape.

The manifestations of the stød in the consonant and in the vowel of the same speaker are more or less alike. All the types of manifestations are not represented by the same speaker, the variation comprising 2 or 3 degrees of the scale illustrated by figs. 2a to 4b, or figs. 4c to 5d. For speaker 11 the most common type is the one shown in fig. 3b, for speaker 22 those shown in figs. 4b and 5d are the normal types. Only speakers 13 and 14 may have a closure in the stød phase, although rarely. The most common type used by these two speakers is the locally concentrated type, represented by figs. 2c-2d. Speakers 25 and 26 have seldom the local stød, more often the type shown in fig. 3b. The stød in the middle of the vowel is found only in the recordings of these two speakers (figs. 3c-3d).

3.1.2. The type of stød which is not visible in the curves

Figs. 3a-3b show that the stød may be almost invisible in the curves. This type of stød was observed for speaker 22 in particular, only in rare cases for others. Some spectrograms were taken of the words without stød, and the corresponding words with stød for this speaker. See fig. 6. In the words with stød there seems to be a weakening of the higher formants at the end of the vowel and some irregular transitions of the higher formants which do not seem to be caused by the steeply increasing pitch alone. But the material is at this point rather limited, and further investigations are required.

These very small differences between words with and without the stød demanded an investigation of the audibility of the stød, when the stød-word has been removed from its context.

A listening-test was made with one word-pair: <u>læser</u> 'reader' [lɛ·səʁ] and <u>læser</u> '(I) read' [lɛʔsəʁ], where the surrounding sounds were so similar that they could not influence the two words differently. The words were cut out of the original material by means of a segmentator (Thorvaldsen 1969). For the sake of comparison a second test was set up with the same words spoken by speaker 26, whose stød was clearly manifested in the curves, although he did not have the strongest stød phase among the speakers.

The material comprises 6 different recordings of the word with stød and the word without stød, all used twice in the test, that is, 24 test words in total. Each test word was presented just once, and after every test word there was a pause of 5 msec. The subjects were asked to identify the test word with one of the underlined words in the sentences:

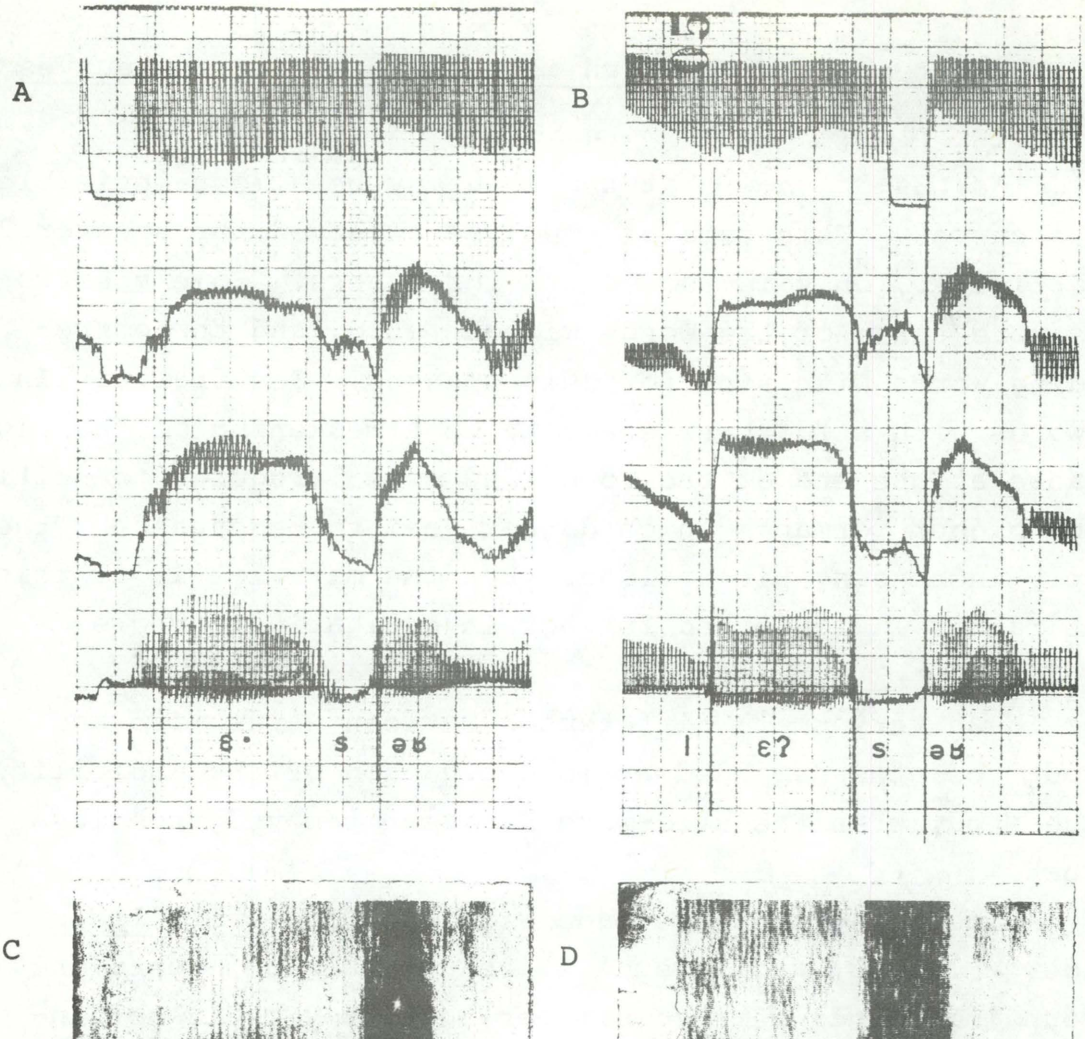

Fig. 6 Mingograms (A-B) and spectrograms (C-D) of non-stød (A-C) versus stød (B-D) at the speaker 22.

Bogens <u>læser</u> undrer sig
Drengen <u>læser</u> om aftenen.

There was forced choice. The tests were played first in the order speakers 26-22 for 7 subjects and next in the reverse order for another 7 subjects. There were thus 168 answers in all.

3.1.2.1. Results

The stød is identified rather badly, but not worse for speaker 22 than for speaker 26, in fact the stød is heard best for the former. It should be noticed that most of the mistakes are made in the words with stød: these are often identified as words without stød, rarely vice-versa.

TABLE 1

Errors in the listening test.

speaker order	26	22	22	26
number of errors	50	16	25	31
errors in words with stød	42	7	20	29
errors in stød-less words	8	9	5	2
N=168				

TABLE 2

The errors in %

speaker order	26	22	22	26
number of errors	30	10	15	19
errors in words with stød	50	8	24	36
errors in stød-less words	10	11	6	2

The stød words of the same speaker are identified better when he comes last in the test, but the difference between speakers 22 and 26 is clear in both cases. The errors for speaker 22 are below 25%.

3.2. Length

The length of the vowel and the length of the following consonant have been investigated in all four types of words which from now on are designated as V:C, V?C, VC, and VC?.[1] In addition, the length of the stød phase was measured in the cases where it was possible, keeping in mind that the stød cannot always be delimitated. The length was measured with an accuracy of 1 cs.

3.2.1. The length of the vowel

The reader is referred to fig. 7 where the average length of each vowel for two typical speakers and the 95% limits are shown.

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1) ? indicates stød, : length, V vowel, and C consonant.

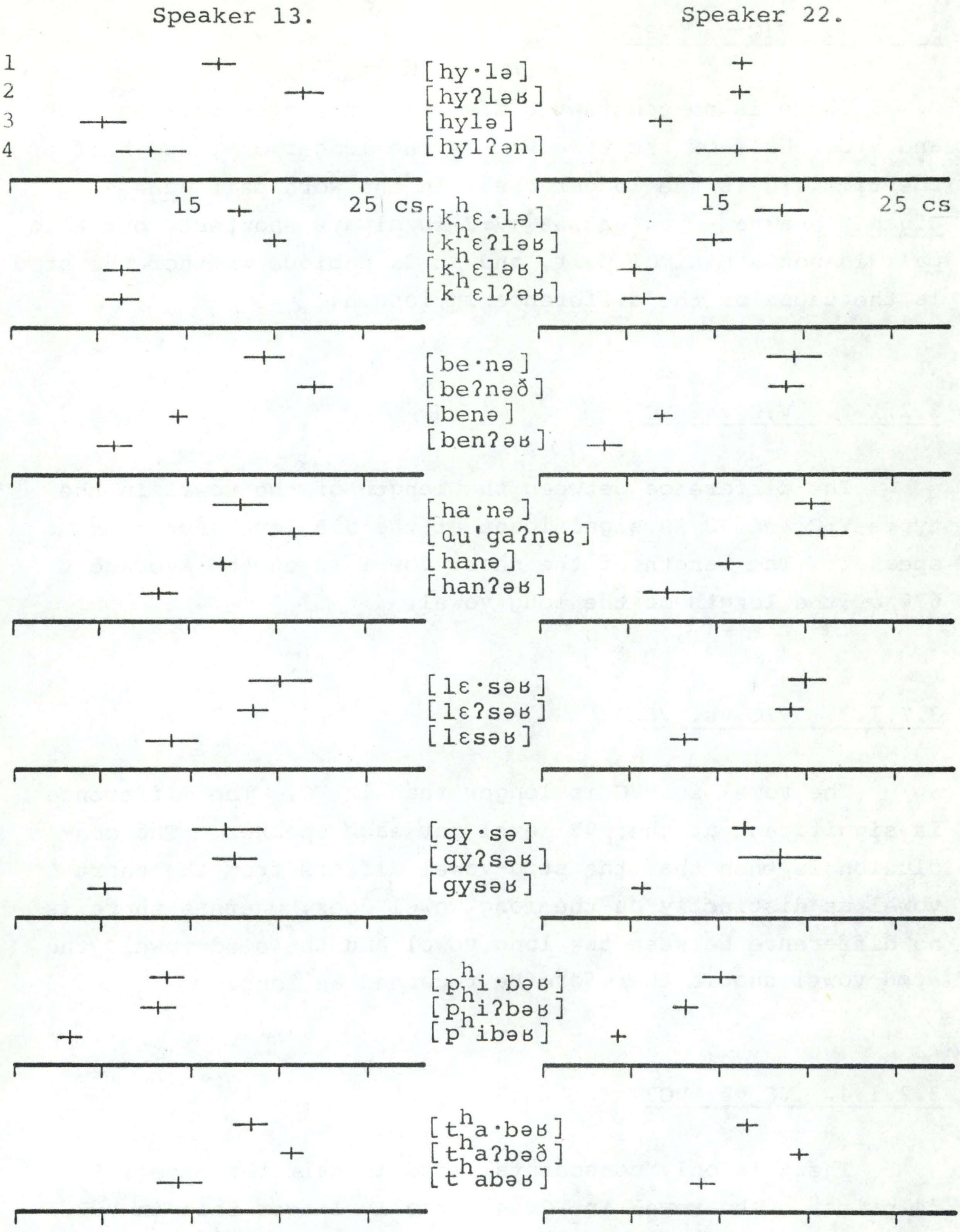

Fig. 7. Average length of the vowel in the four word types V:C, VʔC, VC, and VCʔ.
The vertical stroke indicates the average and the endpoints of the horizontal line indicate the 95% confidence limits.

1 = V:C, 2 = VʔC, 3 = VC, 4 = VCʔ.

3.2.1.1. V:C vs. V?C

There is no constant difference in length between V:C and V?C. Half of the time V:C is the longer one, and half of the time V?C is the longer one. In the word pair hane - afganer [ha·nə]- [au'gaʔnəʁ] V:C is always shortest, but this pair is not a minimal pair, and it is dubious whether the stød is the cause of the difference in length.

3.2.1.2. V:C vs. VC

The difference between the length of the vowel in the types V:C and VC is significant at the 99% level for each speaker. The length of the short vowel is on the average 67% of the length of the long vowel.

3.2.1.3. V?C vs. VC

The vowel in V?C is longer than in VC. The difference is significant at the 99% level for each speaker. The conclusion is then that the stød-vowel differs from the short vowel as distinctly as the long vowel does, whereas there is no difference between the long vowel and the stød-vowel, the stød-vowel should therefore be regarded as long.

3.2.1.4. VC vs. VC?

There is only consonantal stød in half the material (4 pairs). The vowel in VC is normally longer than in VC?, except in the word pair hylde - hylden [hylə]- [hylʔən] 'shelf' - 'the elder', where the vowel in VCʔ is the longest for 4 of the 6 speakers. The difference between the four word types was calculated, and the significance of the average difference for all speakers was tested. See table 3.

TABLE 3

The difference between the length of the vowel in VC and VCʔ (VC-VCʔ). Measured in cs.

speaker	[benə/ benʔəʁ]	[hanə/ hanʔəʁ]	[kʰɛləʁ/ kʰɛlʔəʁ]	[hylə/ hylʔən]		
11	4,3	1,2	3,2	-2,9		
22	4,4	3,6	-0,4	-4,5		
13	3,7	2,1	0,1	-2,6		
14	3,6	2,8	0,8	-0,9		
25	3,0	1,5	1,3	-2,1		
26	1,2	2,3	1,3	0,1		
average	3,4	2,3	1,1	-2,2	total	1,2
standard deviation	1,2	0,9	1,3	2,0		2,2
significance level	99%	99%	90%	90%		-

The result is that the difference between VC and VCʔ is significant at the 99% level in [beṇə/benʔəʁ] [hanə/ hanʔəʁ], but only 90% in [kʰɛləʁ/kʰɛlʔəʁ] and 90% in [hylə/ hylʔən] where VCʔ is the longest. When all word pairs are taken together the difference is not significant.

It is evident that the stød on the consonant causes a reduction of the short vowel in most cases, but the length of the vowel also seems to depend on the type of the following consonant, the difference being larger before [n] than before [l].

3.2.2. The length of the following consonant

Knowing that in other languages (e.g. Swedish and Italian) there may be an inverse relation between the length of the vowel and that of the following consonant, i.e. a long vowel is followed by a short consonant and a short vowel by a long consonant, also the length of the consonant in the different word types (V:C, VʔC, VC, VCʔ) was measured.

3.2.2.1. VC vs. V:C

The differences are very small, and there is no constant difference between the length of the consonant in VC and V:C. See table 4.

TABLE 4

The difference in length of the consonant in VC and V:C (VC-V:C). The difference is calculated for each speaker and the average is reproduced below.

kæle	pibe	læse	bene	tabe	gyse	hyle	hane
0,2	-0,2	0,3	0,2	-0,4	-2,9	0,7	0,2

3.2.2.2. VC vs. V?C

The same appears for a comparison between V?C and VC, the consonant of V?C having almost the same length as in V:C. The length of the consonant is thus independent of the length of the preceding vowel.

3.2.2.3. VC vs. VC?

The consonant in VC? (7,2cs) is longer than in VC (5,4cs). The consonant in VC? is thus 134% of the consonant in VC. The difference is calculated for each word pair and it is computed that the difference is significant at the 99% level. See table 5.

TABLE 5

The difference between the length of the consonant in VC and VC? (VC?-VC). Measured in cs.

speaker	[ben?əʁ/ benə]	[han?əʁ/ hanə]	[k^hɛl?əʁ/ k^hɛləʁ]	[hylə/ hyl?ən]
11	0,7	2,3	1,9	1,9
22	1,9	-1,0	0,9	5,0
13	0,5	1,3	2,3	3,6
14	0,6	0,9	1,2	6,1
25	2,1	-0,9	1,3	5,0
26	0,9	-0,5	1,8	3,3
average	1,1	0,3	1,5	4,1

The difference is biggest in [hylə/hyl?ən] and smallest in [hanə/han?əʁ]. As stated above (3.2.1.4.) the vowel is generally longer in VC than in VC?, i.e., there is a certain (weak) inverse relation between vowel and consonant length. The pair [hylə/hyl?ən] constitutes an exception to this tendency, however: both vowel and consonant are longer in the stød word [hyl?ən] than in [hylə].

3.2.3. The length of the stød phase (defined by irregular oscillations)

Only examples in which the stød phase is clearly visible in the curves, as in figs. 2a-b-c (stød in the vowel) or in figs. 4c-d (stød in the consonant), have been measured. The types 3c and 3d (with the stød in the middle of the vowel) have been left out. These types are very rare.

3.2.3.1. The length of the stød in the vowel

Table 6 shows the length of the stød phase in percentage of the total length of the vowel. The raised numbers indicate the cases in which it has been possible to determine the limits of the stød phase.

The stød phase has a rather constant relative length of about 1/3 of the total length of the vowel.

TABLE 6

The length of the stød phase in percentage of the total length of the vowel.

speaker	11	22	13	14	25	26	all
kæler	-	-	37^{6}	28^{6}	57^{1}	-	33^{2}
piber	38^{3}	-	25^{6}	42^{6}	-	-	34^{2}
læser	-	-	39^{6}	30^{6}	-	-	35^{2}
tabet	32^{6}	-	27^{6}	34^{6}	47^{2}	34^{4}	33^{3}
gyser	-	-	41^{6}	34^{5}	-	40^{1}	38^{2}
hyler	35^{6}	-	37^{6}	42^{6}	43^{2}	40^{6}	38^{4}
benet	-	-	47^{6}	33^{2}	37^{6}	33^{3}	42^{2}
afganer	30^{6}	-	36^{6}	30^{6}	-	38^{2}	32^{3}

3.2.3.2. The length of the stød phase in the consonant

There is a tendency toward a longer interval of irregular oscillations, but the material is too small for any definite conclusion to be made.

3.2.3.3. The place of the stød phase compared to the onset of the vowel

The average distance from the onset of the vowel to the beginning of irregular oscillations is 11,2 cs for the type VʔC, and 11,9 cs for the type VCʔ.

4. Results concerning pitch and intensity

4.1. Measuring the curves

The pitch and intensity movements were only measured in the vowel. (They were measured according to the same principles.) The following points in the curves were measured: The first maximum (max_1), the following minimum (min), and the second maximum (max_2). The positions of these points were indicated by the distance from the start of the vowel. The curves fall into three classes according to the presence or absence of either of the two maxima:

A: The falling-rising type[1] (max_1-min-max_2)
B: The purely rising type (min-max_2)
C: The purely falling type (max_1-min)

Rising-falling curves are not represented in this classification as an independent type, but will be registered as purely falling. This may give a wrong impression of the movement if max_1 occurs late in the vowel; the type was, however, excluded because it was a very rare type and would have cost another measuring point, which would complicate the calculations.

4.2. The accuracy of the measurements

The pitch was measured with an accuracy of ± 5 Hz, intensity with ± 1 dB, and length with ± 1 cs.

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1) The level type, which is very rare, has been included in type A, with identical values for max_1, min, and max_2.

4.3. The pitch

In figs. 8-13 the averages of max_1, min and max_2 of 6 recordings of each word have been calculated for all speakers and placed in a co-ordinate system, where the axis of the abcissa is the length measured in cs, and the axis of the ordinate is the pitch measured in Hz. For considerations of space only words with voiced consonants are included.

4.3.1. V:C vs. VʔC

4.3.1.1. The shape of the curves of V:C vs. VʔC

There is no constant difference between the shapes of the curves in stød words and stød-less words. All types of curves can be observed in both word types, if the speakers are taken en bloc. The individual speakers show some differences.

Speakers 13 and 14 have all three types of curves (A-B-C) in V:C, but only the falling type in VʔC. Speaker 26 has generally a rising curve in V:C and a falling curve in VʔC. Speaker 11 has a falling-rising curve as the predominant type both in V:C and VʔC. Speaker 25 has generally a falling-rising curve in V:C, and either the same or a purely falling type in VʔC. Speaker 22 has no clear difference.

In general it is not rare that the fall starts later in VʔC, and in almost all cases the minimum is closer to the end of the vowel than it is in V:C.

4.3.1.2. The pitch of max_1, min and max_2

When both V:C and VʔC exhibit a max_1 (i.e., the curves are falling or falling-rising), this max is clearly highest

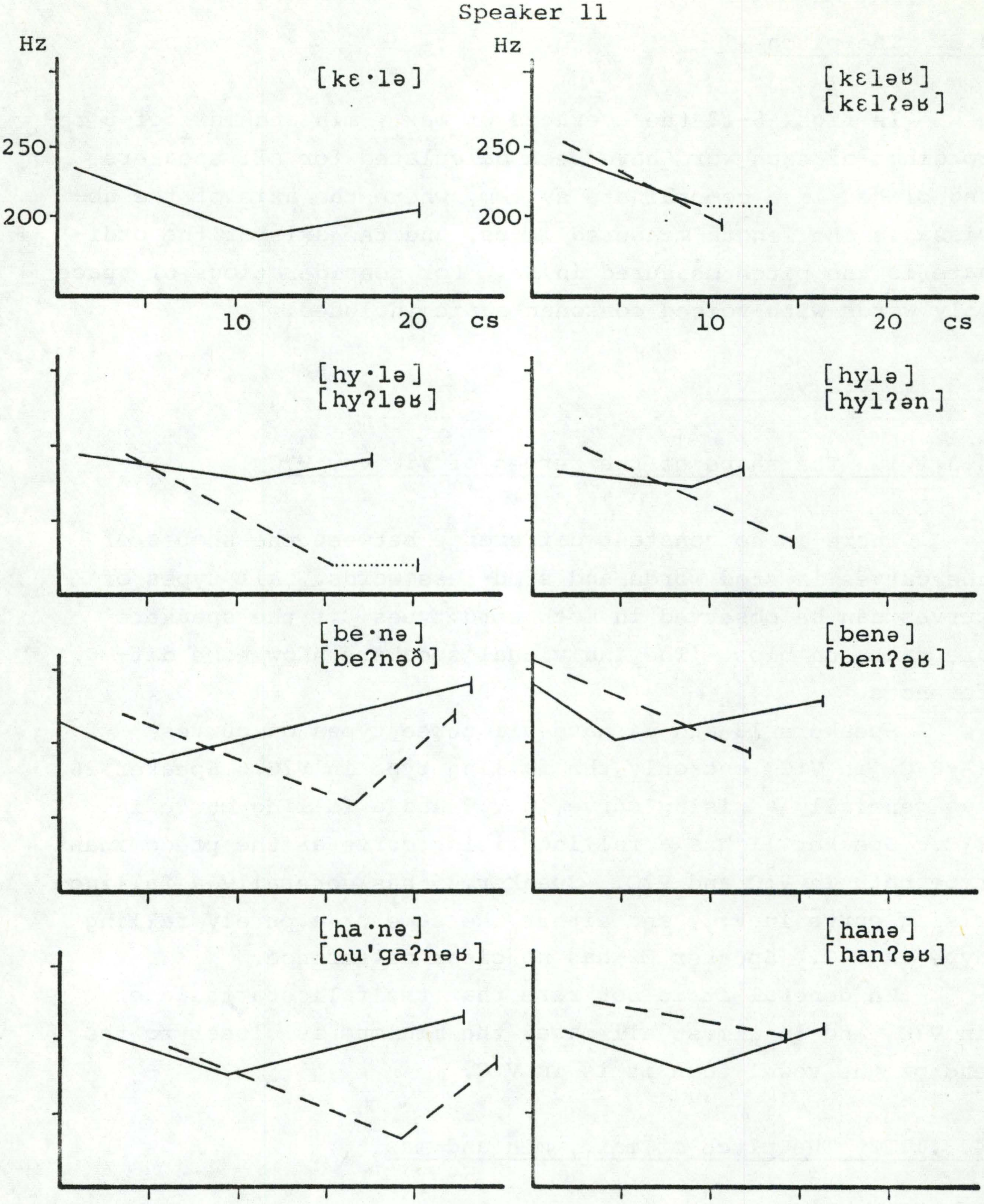

Fig. 8. Average pitch movement of the vowel in the word types with voiced consonants for speaker 11.

V:C and VC ————

V?C and VC? -------

The vowel begins at the vertical axis and ends at the vertical stroke.

Speaker 22

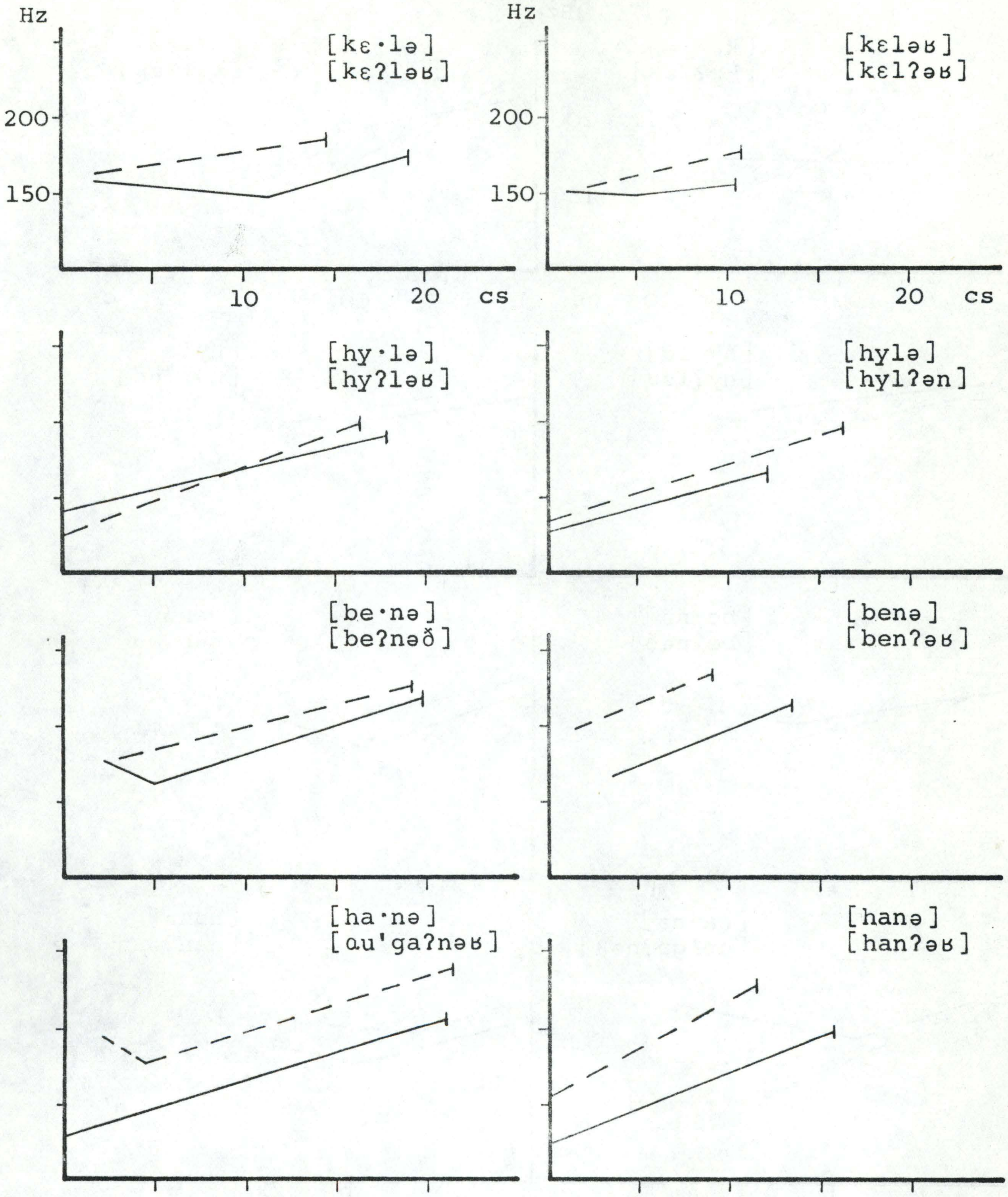

Fig. 9. Average pitch movement of the vowel in the word types with voiced consonants for speaker 22.

V:C and VC ————

VʔC and VCʔ -------

The vowel begins at the vertical axis and ends at the vertical stroke.

Speaker 13

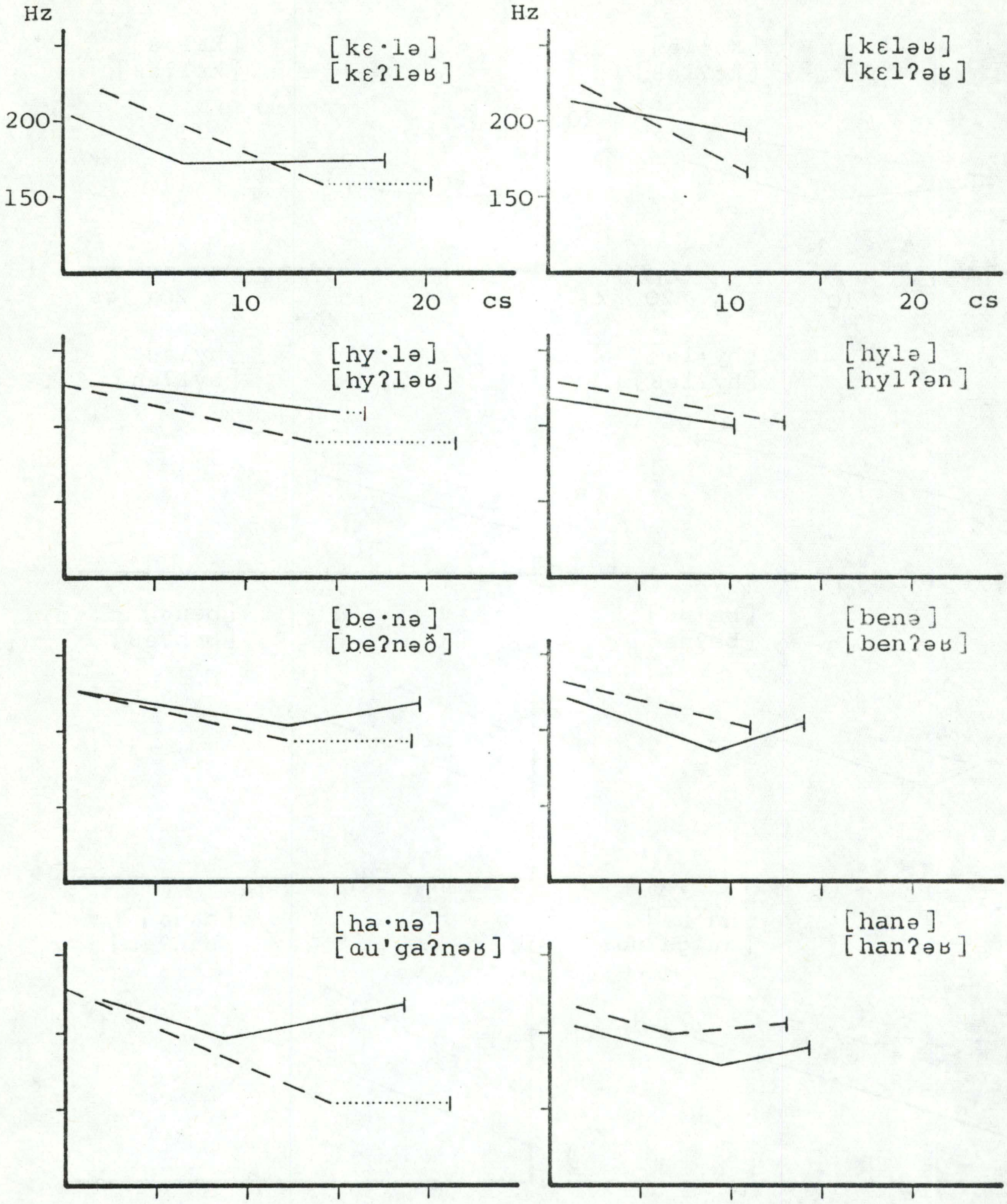

Fig. 10. Average pitch movement of the vowel in the word types with voiced consonants for speaker 13.

V:C and VC ————

VʔC and VCʔ --------

The vowel begins at the vertical axis and ends at the vertical stroke.

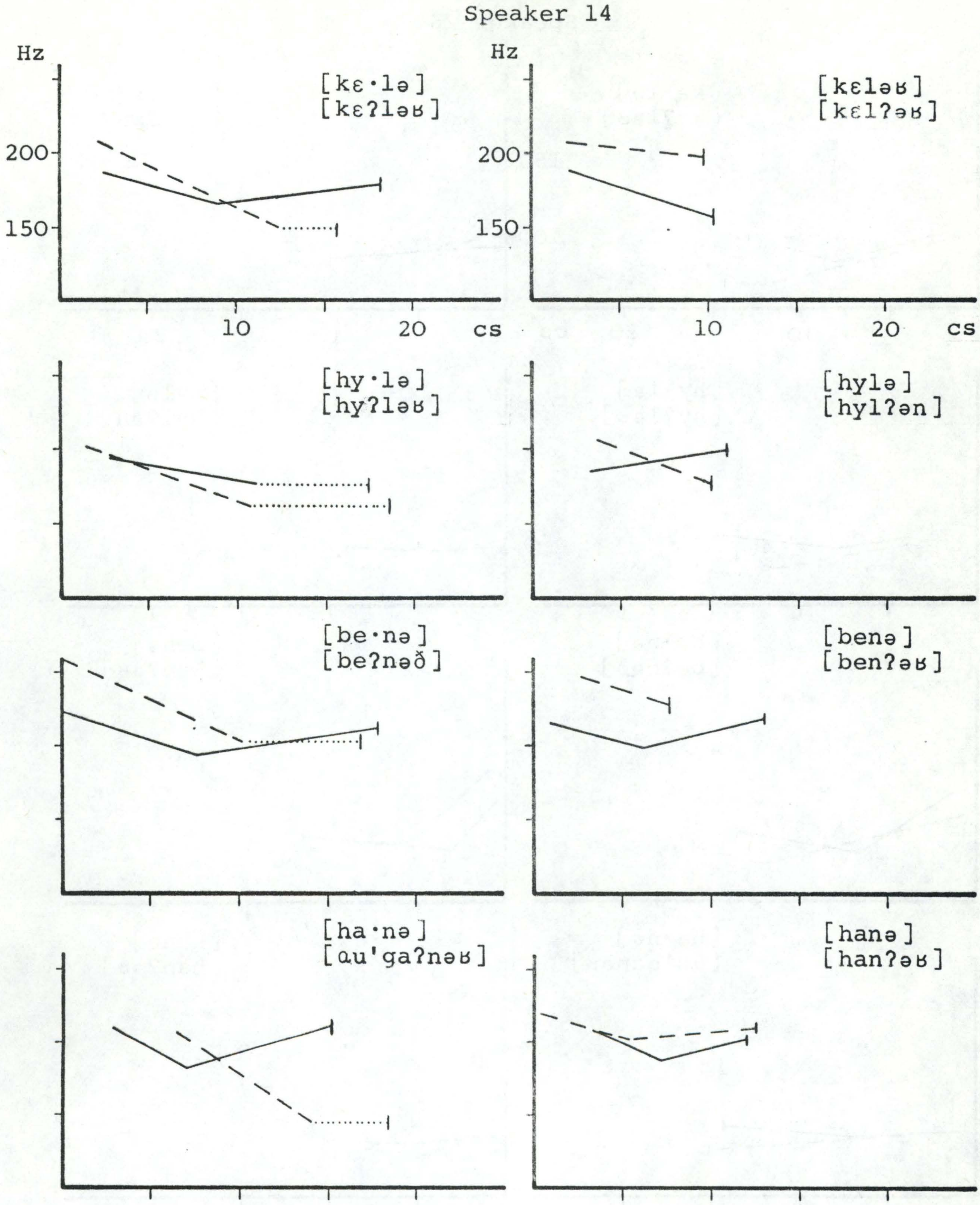

Fig. 11. Average pitch movement of the vowel in the word types with voiced consonants for speaker 14.

V:C and VC ————

VʔC and VCʔ --------

The vowel begins at the vertical axis and ends at the vertical stroke.

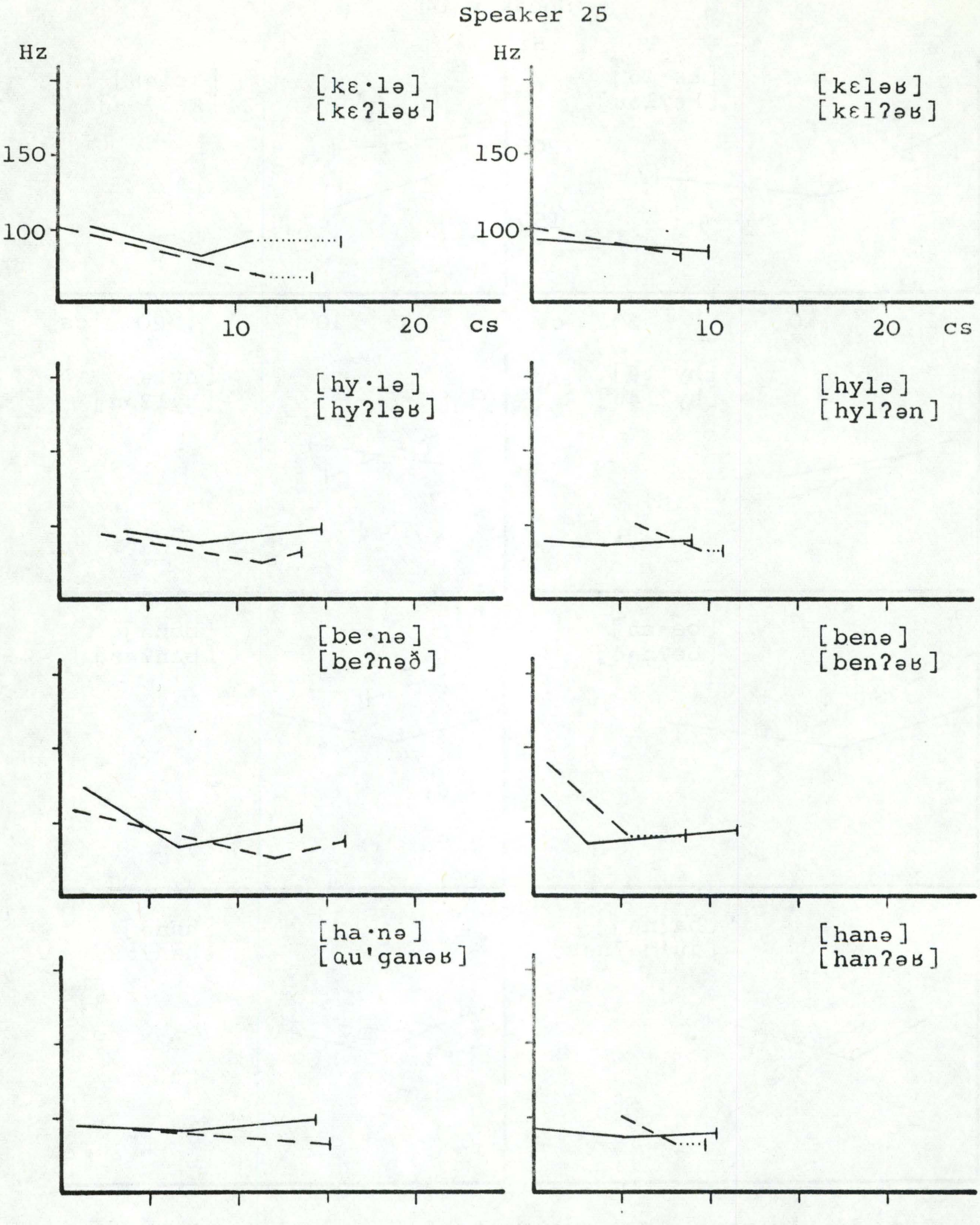

Fig. 12. Average pitch movement of the vowel in the word types with voiced consonants for speaker 25.

V:C and VC ————

VʔC and VCʔ --------

The vowel begins at the vertical axis and ends at the vertical stroke.

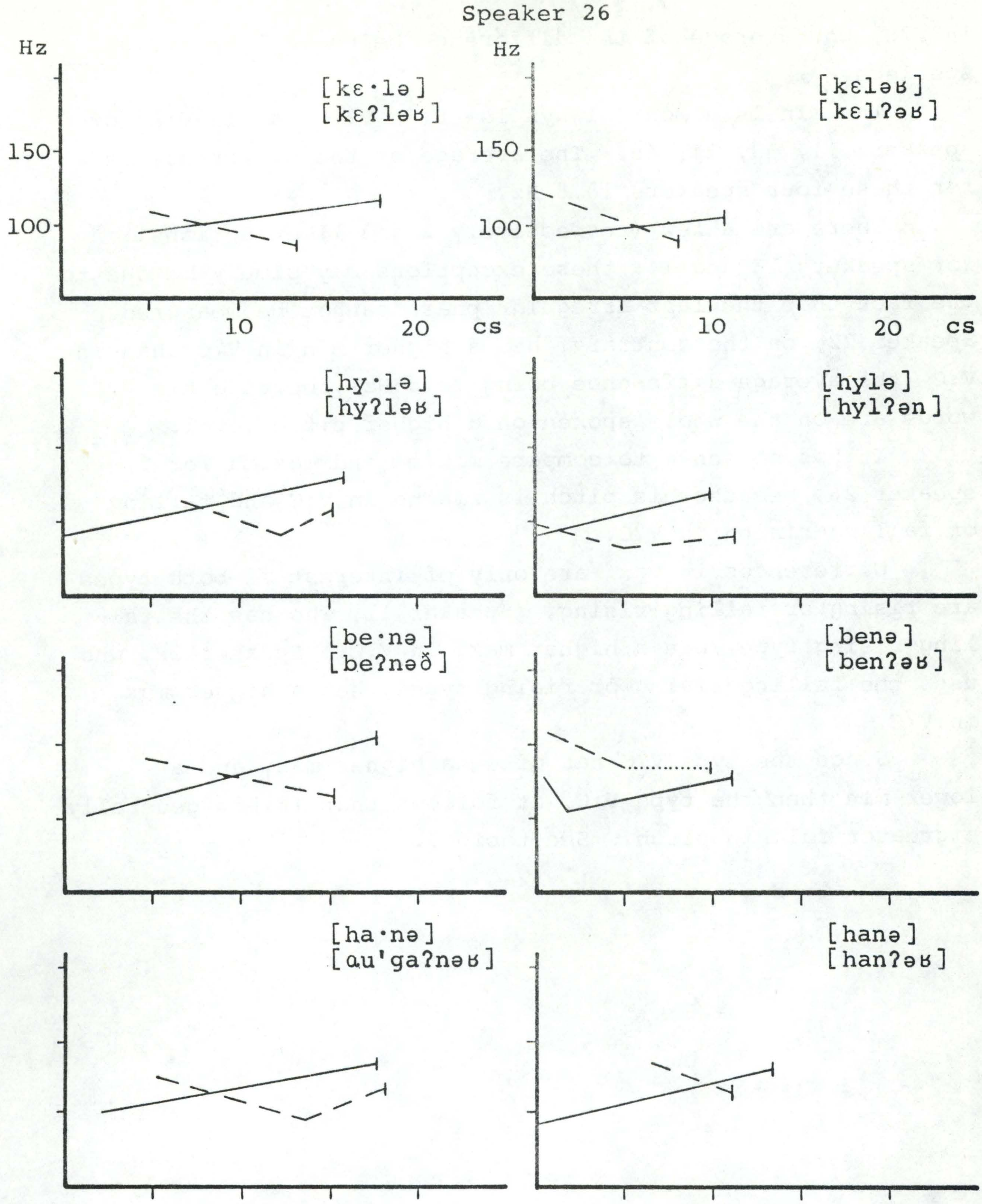

Fig. 13. Average pitch movement of the vowel in the word types with voiced consonants for speaker 26.

V:C and VC ———

VʔC and VCʔ -------

The vowel begins at the vertical axis and ends at the vertical stroke.

in V?C, the average of the difference being 10,2 Hz for all speakers.

The min is almost always lower in V?C than in V:C for speakers 11, 13, 14, 25. The average of the difference is for these four speakers 18,8 Hz.

There are a few (respectively 2 and 1) exceptions for speakers 13 and 14; these exceptions may simply be due to the fact that the last irregular phase cannot be measured. Speaker 22, on the contrary, has a higher min in V?C than in V:C (the average difference being 25,8 Hz), because his V?C words are on the whole spoken on a higher pitch level.

It has no sense to compare minima and maxima for speaker 26, because his pitch is rising in V:C and falling or falling-rising in V?C.

Differences in max_2 are only of interest if both types are rising or falling-rising. Speaker 11, who has the falling-rising type, has a higher max_2 in V:C. Speaker 22, who uses the falling-rising or rising types, has a higher max_2 in V?C.

Since the type V?C has often a higher max_1 and a lower min than the type V:C, it follows that it has generally a greater fall in pitch. See table 7.

TABLE 7

The average fall in V:C and V?C words (in Hz). N is the number of words which have a fall in V:C and V?C.

Fall in V:C						
speaker	11	22	13	14	25	26
average	25,5	14,3	29,3	20,8	13,9	-
N	45	24	48	48	48	-
Fall in V?C						
average	66,6	20,3	45,9	64,6	24,1	22,4
N	42	29	48	48	48	42

The fall is obviously greater in V?C than in V:C; the average difference is 26,2 Hz. The significance has been calculated by means of a pair test, and the difference was found to be significant at the 99% level.

The rise, which in some cases follows after the fall may be steeper in V?C (cp sp. 11), but it does not reach the same height as in V:C.

Speaker 22 differs from the others. In general the whole pitch curve in V?C is placed higher than in V:C. The curves are mainly rising, and the rise is greatest in V?C.

4.3.2. The pitch in VC and VCʔ

VC and VCʔ words were analysed in the same way as the V:C and VʔC words. It must be kept in mind that only the vowels have been measured. For illustrations see figs. 8-13.

4.3.2.1. The shape of the curves

In general the VC words resemble the V:C words, but the curve is often simpler and the rise and fall less extensive.

Speakers 11, 13, 14, 25 have the falling-rising or the falling type in VC words, the falling type dominates in VCʔ. Speaker 22 generally has the rising type in both VC and VCʔ, and speaker 26 has the rising type in VC and the falling type in VCʔ. The differences are thus approximately the same as for V:C vs. VʔC.

4.3.2.2. The pitch of max_1, min and max_2

Speakers 11, 13, 14, 25 have a higher max_1 in VCʔ, the average difference between VCʔ and VC being 14,8 Hz. No constant difference in min and max_2 was observed.

The fall will, therefore, be greater in VCʔ than in VC (see table 8). The fall is often followed by a rise of the same size in VC, but this is rarely the case in VCʔ.

TABLE 8

The pitch fall in VC and VC?. N is the number of words showing a fall. The total number of words is 24.

Fall in VC						
speaker	11	22	13	14	25	26
average	23,2	-	30,0	21,0	12,2	23,0
N	24	-	23	19	23	4
Fall in VC?						
average	52,2	-	30,5	23,2	22,2	19,0
N	24	-	23	21	22	21

Speaker 22 has not only a higher pitch level, but also a stronger rise in VC?. Speaker 26 has a rise of 25,8 Hz in VC and a fall of 19,0 Hz in VC?.

On the whole the general pitch level is higher in VC? than in VC for all speakers, as was also the case with the pitch level in the beginning of long vowels. An inclusion of the pitch of the following consonant might have shown a further fall in VC? words.

4.4. The intensity

There is a tendency toward a difference in intensity movement between V:C and V?C. An exclusively rising intensity movement has not been observed in V?C, but it can be found in V:C, and an exclusively falling movement is dominating in V?C.

whereas both the falling and falling-rising types are found in V:C. See table 9.

TABLE 9

The tokens representing the different types of movements in V:C and VʔC.

	V:C	VʔC
exclusively rising	23	0
falling-rising	128	91
exclusively falling	137	187

It should be remembered that the falling type includes the rising-falling type, which is more common for intensity than for pitch.

Normally the first max is a little higher in VʔC. The average difference is 1,2 dB. The min is nearly always lower in VʔC, the average difference is 4,9 dB, i.e. the stød word starts higher and falls more, and there is rarely any rise.

The average fall in VʔC is 9,2 dB and in V:C 3,2 dB. See table 10. The significance has been calculated by means of a pair test. The difference was found to be significant at the 99% level. This is also valid for speaker 22.

TABLE 10

The fall in V:C and VʔC.

speaker	11	22	13	14	25	26
V:C	4,1	1,6	5,0	5,0	2,4	3,2
VʔC	11,6	5,4	14,1	11,8	5,0	7,5

In the cases where the fall in $V^{?}C$ is followed by a rise the end point will not be as high as in V:C.

4.4.1. The intensity in VC and $VC^{?}$

The intensity movements of the vowel in VC and $VC^{?}$ words show differences similar to those found for V:C vs. $V^{?}C$. There are more often falling curves in $VC^{?}$, the max_1 is placed higher, and the fall is greater in $VC^{?}$ than in VC, except for speaker 22.

5. Summary and conclusion

5.1. The manifestation of the stød

There is a great difference between the manifestation of the stød for the various speakers. The two extremes are complete closure in the stød word and almost no visible difference between the stød word and the stød-less word.

5.2. The length

There is a significant difference between long and short vowel in words without stød. The stød vowel does not differ from the long vowel, but there is a tendency to reduce the length of the short vowel when it is followed by a consonant with stød.

There is no difference in the length of the consonant after long and short vowels. The length of the consonant with stød is greater than the length of the consonant without stød.

5.3. Pitch and intensity

There is a pitch difference between the stød words and the stød-less words (both Vˀ C vs. V:C and VCˀ vs. VC). One speaker (22), who had rising pitch in both stød words and stød-less words, had a higher pitch-level in the stød word than in the stød-less word. One speaker (26) had falling pitch in the stød word and rising pitch in the stød-less word. The rest of the speakers have a smaller fall in the stød-less words, often followed by a rise, whereas the stød words had a more extensive fall which is rarely followed by a rise. If there is a rise the end point is not as high as in the stød-less word. In addition the first maximum in the stød word is higher than in the stød-less word. The difference between the fall in V:C and VCˀ is significant.

The intensity movement shows less variability among the speakers. There is a significantly greater fall in VˀC.

Both pitch and intensity movement differ in the same way in V:C vs. VˀC and VC vs. VCˀ, which supports the assumption that the stød is a phenomenon belonging to the syllable (Martinet 1937).

This is confirmed by the fact that the distance from the start of the vowel to the start of the irregular oscillations is approximately the same in the two cases.

Pitch and intensity have normally a parallel movement, but the fall does not always start at the same time. Speaker 22 who has rising pitch both in VˀC and V:C, has falling intensity in VˀC.

According to Sv. Smith stød versus non-stød is due to a difference in the expiratory muscles accompanied by a passive reaction in the larynx.

This explanation does not fit very well with the instances of rising pitch combined with falling intensity found in the present material. Here the pitch movement seems to be independent of the intensity, and this may be an independent action of the larynx.

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