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ANNUAL REPORT
OF THE
INSTITUTE OF PHONETICS
UNIVERSITY OF COPENHAGEN

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OF THE UNIVERSITY OF COPENHAGEN

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(continued)

PERSONNEL OF THE INSTITUTE OF PHONETICS

1969

Permanent Staff:

Eli Fischer-Jørgensen (professor, director of the Institute)
Jørgen Rischel (lecturer and amanuensis of general phonetics)
Hans Peter Jørgensen (amanuensis of general phonetics)
Oluf M. Thorsen (amanuensis of general and French phonetics)
Børge Frøkjær-Jensen (amanuensis of experimental phonetics)
Hans Basbøll (amanuensis of general phonetics)
Ole Kongsdal Jensen (amanuensis of general and French phonetics)
Poul Thorvaldsen (engineer)
Svend-Erik Lystlund (technician)
Inger Østergaard (secretary)
Inge Lindemark (secretary)

Part Time Teachers of General Phonetics:

Mogens Baumann Larsen (amanuensis of Danish phonetics)
Karen Landschultz (teaching assistant)

Guest Research Workers:

Hideo Mase (Japan)

INSTRUMENTAL EQUIPMENT OF THE LABORATORY BY THE 1ST OF JANUARY, 1970

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1. Instrumentation for speech analysis

2 Sona-Graphs, Kay-Electric, type 6o61 A

2 amplitude display/scale magnifier units, Kay-Electric, type 6o76 A

1 contour display unit, Kay-Electric, type 6o7o A

1 fundamental frequency extractor ("Trans Pitchmeter")

1 intensity meter (dual channel, with active variable highpass and lowpass filters)

1 electro aerometer (dual channel for ingressive and egressive air)

2 air-pressure manometers, Simonsen & Weel, type HB 66 (modified)

1 photo-electric glottograph

1 Fabre-Glottograph

1 palatoscope with complete outfit for palatography

1 segmentator, model IPO (Eindhoven)

1 Meyer-Schneider pitchmeter

1 stroboscope, Philips, type PR 91o3

2. Instrumentation for speech synthesis

1 provisional vowel synthesizer

1 voice-source generator

1 larynx vibrator with power supply

3. Filters

1 LC highpass filter (with stepwise variation of cutoff frequency)

1 active RC lowpass filter

4. Instrumentation for visual recordings

1 mingograph, Elema 42 (4 channels)

1 mingograph, Elema 8oo (8 channels)

1 kymograph (with electro-motor)

1 automatic frequency response and spectrum recorder, Brüel & Kjær, type 3332

1 oscilloscope, Telequipment (single beam)

1 oscilloscope, Solartron, type CD 14oo (dual beam)

1 oscilloscope, Tektronix, type 5o2 A

2 oscilloscopes, Tektronix, type 564 storage

1 dual-trace amplifier, Tektronix, type 3A1

1 four-trace amplifier, Tektronix, type 3A74

1 dual-trace differential amplifier, Tektronix, type 3A3

1 time-base, Tektronix, type 3B3

1 time-base, Tektronix, type 2B67

5. Tape recorders

1 professional recorder, Lyrec (stereo, speeds 7.5" and 15")

2 professional recorders, Lyrec (mono, speeds 7.5" and 15")

1 semi-professional recorder, Movic (stereo, speeds 3 3/4" and 7.5")

3 semi-professional recorders, Revox (stereo, speeds 3 3/4" and 7.5")

1 portable semi-professional recorder, Uher, type 4000, stereo

4 recorders, Tandberg, type 92 SL

1 recorder, Tandberg, type 7, stereo

6. Gramophones

1 gramophone, B & O (mono, Ortofon pick-up)

3 gramophones, Delphon (mono, Ortofon pick-up)

7. Microphones

1 microphone, Neuman, type KM 56

1 dynamic microphone, Sennheiser, type MD 21

2 crystal microphones, of different brands

2 microphones, Altec

1 1" microphone, Brüel & Kjær, type 4131/32

1 1/4" microphone, Brüel & Kjær, type 4135/36

1 larynx microphone

8. Amplifiers

1 microphone pre-amplifier, Telefunken

1 microphone amplifier, Brüel & Kjær, type 26o3

1 laboratory amplifier (mono/stereo, with matching for for different impedances)

9. Loudspeakers/headphones

7 different loudspeaker systems

5 headphones, AKG, type K 58

1o. General-purpose electronic instrumentation

1 oscillator, Hewlett & Packard, type CD 2oo

1 function generator, Wavetec VGC III (o.oo3 c/s-1 Mc/S)

1 frequency counter, Rochar, type A 136o CH (5 digits)

2 vacuum-tube voltmeters, Brüel & Kjær, type 24o9

1 vacuum-tube voltmeter, Heathkit, type V-7A

1 vacuum-tube voltmeter, Radiometer, type RV 23 b

1 DC millivoltmeter, Danameter, type 2o5

1 DC nanoammeter, Danameter, type 2o6

1 universal meter, Philips, type P 817

1 transistor tester, Taylor, model 44

1 Piston-phone, Brüel & Kjær, type 422o

1 component bridge C/L/R, Wayne Kerr, type B 522

1 AC automatic voltage stabilizer, Claude Lyons, type BTR-5F

4 resistance decades, Danbridge, type DR 4

1 condenser decade, Danbridge, type DK 4 AV

6 stabilized rectifiers

Additional oscillators, rectifiers, etc., for special purposes

11. Outfit for photography

1 Minolta camera SR-1 (with various accessories)

1 complete outfit for reproduction (including 1 Liesegang UNI-RAX with frame)

1 Telford oscilloscope camera, type "A" (polaroid)

12. Equipment for EDP

1 IBM 29 punch card machine, model A 22

(has been granted to the laboratory on the 1st of October, 1969, and delivered from IBM in February, 197o)

13. Projectors

1 Liesegang epidiascope

1 Leitz projector for slides

1 Voigtländer Perkeo Automat - J 15o

1 16 m/m tone film projector, Bell & Howell "Filmsound 644".

2 overhead projectors with accessories

Some of the instruments belong to The State Institute of Speech Disorders, Copenhagen. (Reference: the instrumentation list in ARIPUC vol. 3.)

LECTURES AND COURSES IN 1969

1. Elementary phonetics courses

One-semester courses (two hours a week) in elementary phonetics (intended for all students of foreign languages except French) were given by Hans Basbøll, Hans Peter Jørgensen, Mogens Baumann Larsen, and Jørgen Rischel. There were 3 parallel classes in the spring semester and 1o in the autumn semester (about 3oo students in all).

Two-semester courses (two hours a week) in general and French phonetics (intended for all students of French) were given by Ole Kongsdal Jensen, Karen Landschultz, and Oluf M. Thorsen. These courses were given for the first time in the autumn semester 1969, and there were 9 parallel classes (slightly less than 2oo students in all).

2. Practical training in sound perception and transcription

Courses for beginners as well as courses for more advanced students were given through 1969 by Eli Fischer-Jørgensen, Jørgen Rischel, and Oluf M. Thorsen. (The courses form a cycle of three semesters with two hours a week.)

3. Instrumental phonetics

Courses for beginners as well as courses for more advanced students were given through 1969 by Eli Fischer-Jørgensen and Børge Frøkjær-Jensen. (The courses form a cycle of three semesters with two hours a week.)

4. Phonology

The standard courses (phonological method and trends in phonological theory) were given through 1969 by Eli Fischer-Jørgensen and Jørgen Rischel. During the third semester of the cycle, Jørgen Rischel lectured on the syllable.

(In total, the courses form a cycle of three semesters with two hours a week, the subject of the third term being chosen freely.))

5. Other courses

Eli Fischer-Jørgensen lectured on diachronic phonetics through the spring semester (in continuation of her lectures on the same subject in the autumn of 1968).

Jørgen Rischel lectured through the spring semester on methods and instrumentation for generating synthetic speech.

Børge Frøkjær-Jensen lectured on Chiba and Kajiyama's book The Vowel through the autumn semester.

Børge Frøkjær-Jensen also gave a course in elementary electronics and another course in mathematics for phoneticians.

Hans Basbøll gave a course in Danish phonology.

Moreover, the students followed courses in English, French, and German phonetics at the University.

6. Seminars

The following seminars were held in 1969:

Lecturer Jørgen Rischel gave a critical survey of Peter Ladefoged, Linguistic Phonetics (1967).

Professor M. Romportl (Prag): Methode der phonischen Analyse der Sprache.

Dr. Eva Gårding (Lund): Sandhi in Swedish.

Professor Peter Ladefoged (University of California): The phonetic capabilities of Man.

Professor Gunnar Fant (Stockholm): Vowel theory (recent observations on resonators and perception).

Professor O. Fujimura (Tokyo): Recent experiments on sound production with a demonstration of a colour film of larynx.

Professor Ilse Lehiste (University of Ohio): Tones and intonation in Serbo-Croatian.

Stud.mag. Lars Brink and stud.mag. Jørn Lund: The pronunciation of Standard Copenhagen 1840-1955.

Professor James McCawley (University of Chicago): Accent in Japanese dialects.

7. Participation in congresses and lectures at other institutions by members of the staff

Eli Fischer-Jørgensen visited the phonetic institutes at Bonn and Münster and lectured at both places.

Eli Fischer-Jørgensen and Jørgen Rischel participated in the International Conference on Nordic and General Linguistics in Reykjavik. Jørgen Rischel gave a paper on "Consonant Gradation: A problem in Danish phonology and morphology".

Børge Frøkjær-Jensen participated in the XVII Northern Congress of Otolaryngology in Elsinore and gave a paper on "Comparative tests of two different types of glottographs".

Jørgen Rischel participated in the Annual Meeting of the Societas Linguistica Europaea in Vienna.

Hans Basbøll and Jørgen Rischel participated in the First Scandinavian Summer School of Linguistics in Stockholm.

AN ATTEMPT TO REGISTER LIP PRESSURE AND LIP ROUNDING BY MEANS OF THE ELECTRO-GLOTTOGRAPH[1]

Carl Ludvigsen

From a phonetic point of view a simple, reliable method for registration of lip pressure and lip rounding would be of great interest. In order to investigate whether an electrical impedance measurement is a useful tool for this purpose, some preliminary experiments have been carried out.[2]

As an attempt to measure a variation of electrical impedance related to the lip pressure, two electrodes were placed at the middle of respectively the upper and the lower lip. These electrodes will be referred to as the A-electrodes. Two other electrodes, the B-electrodes, were placed in each corner of the mouth (at each conjunction of the lips). The B-electrodes were intended to give information about the roundness of the lips. Simultaneous recording of the two impedances was obtained by using two electro-glottographs.

In order to be able to interpret the output signals of the two electro-glottographs it is necessary to know how these output signals are related to changes in the impedance of the measuring object. This relationship is generally not simple. However, when the reactive part of the impedance is time-invariant, the level of the output signal

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1) The electro-glottograph was described in the Annual Report of the Institute of Phonetics, University of Copenhagen, Vol. 3 (1969), p. 1-8.

2) Børge Frøkjær-Jensen and Jørgen Rischel have participated in various phases of the present work.

depends linearly upon the change in impedance, i.e. the change in resistance. As the impedance between two electrodes placed on the lips is approximately resistive (Ohmic) at the frequency of 3oo kcps, the output signal of the electro-glottographs is simply a measure of the resistance difference $R(t) - R_o$, where $R(t)$ is the momentary resistance between the electrodes, and R_o is the resistance corresponding to zero output level.

1. <u>The resistance between two electrodes placed in the mid-sagittal plane on respect. the upper and the lower lip</u>

The resistance between the A-electrodes depends primarily on whether the lips are separated or not. When the lips are pressed together and suddenly separated, the resistance between the electrodes changes discontinously. This feature may be of interest as it provides a method for registration of the exact moment of lip separation. However, this great change in the resistance may mask other relevant information and should therefore be avoided in registrations for other purposes. This can be done by introducing a strip of plast folio between the lips. The resistance between the electrodes is now mainly determined by the configuration of the lips. Thus, when the lips are separated, the resistance will mainly depend on the distance between the lips, and when the lips are closed, the lip pressure will be the main factor influencing the magnitude of the resistance. Furthermore, the distance between the corners of the mouth will influence the resistance slightly. This position of the electrodes seems to be useful when comparing degrees of pressure related to bilabial stops and nasals.

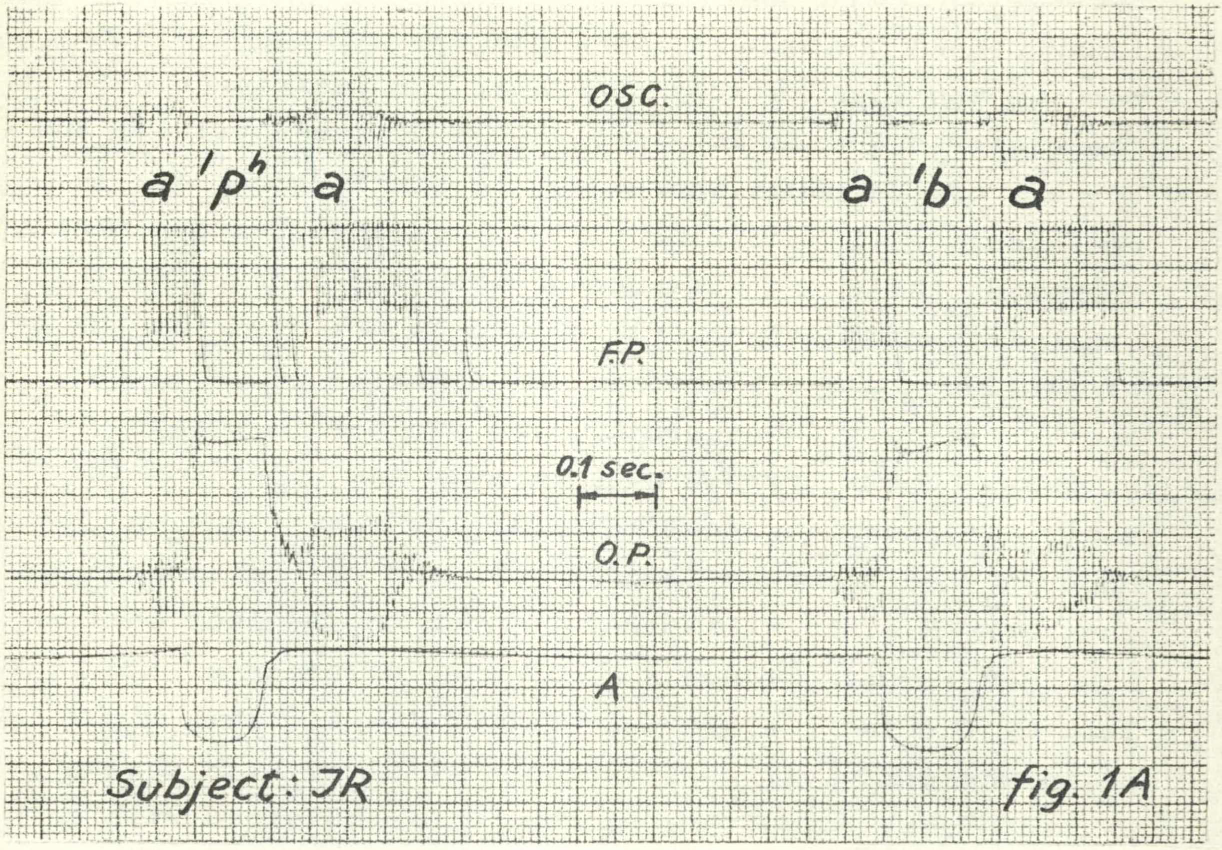
2. <u>The resistance between two electrodes placed in each corner of the mouth</u>

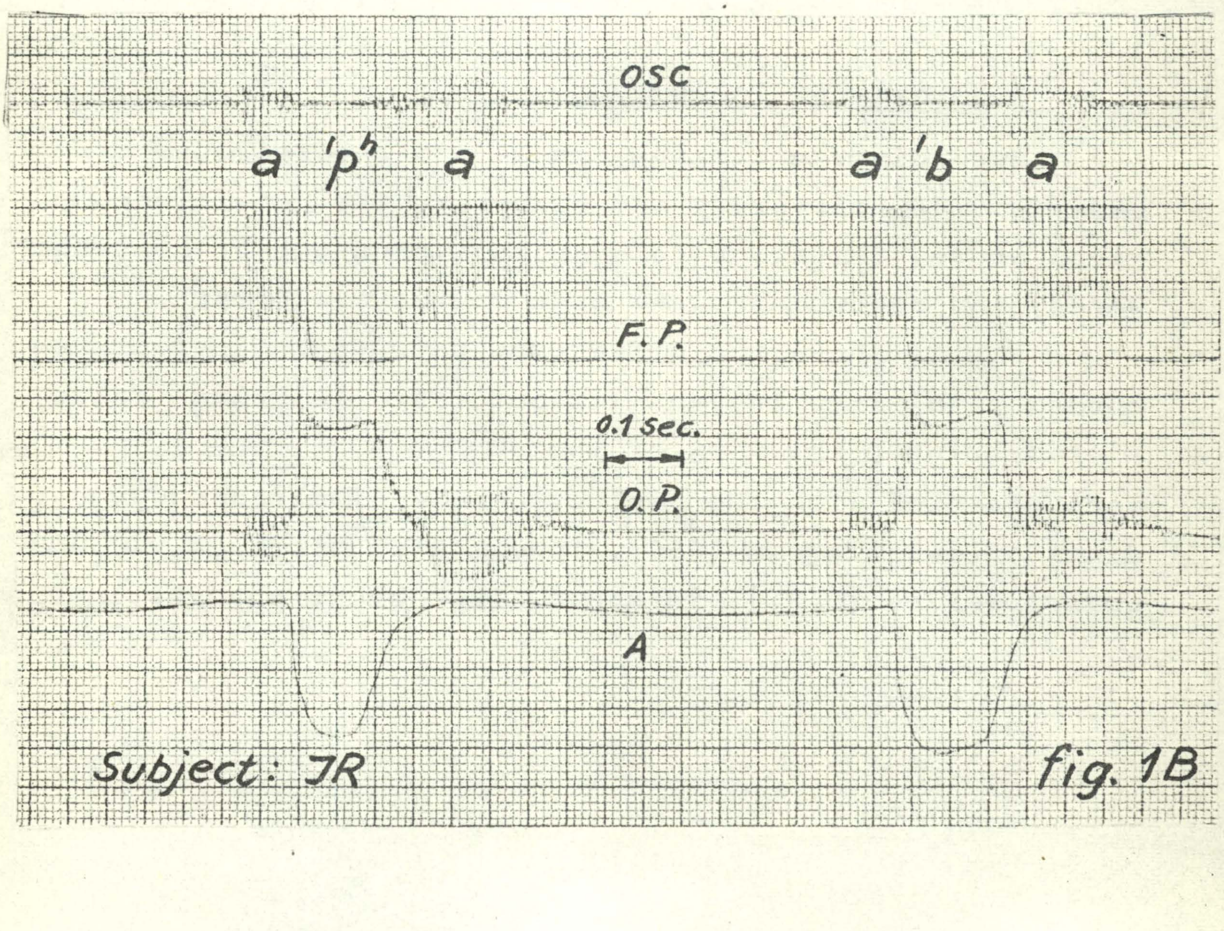
The resistance between the B-electrodes depends primarily on two parameters: 1) The distance between the corners of the mouth and 2) the distance between the lips (measured in the mid-sagittal plane). If the distance between the lips is kept constant, the resistance between the electrodes will increase as the distance between the corners of the mouth increases. A similar increase in resistance will take place if the distance between the lips increases while the distance between the corners of the mouth is kept constant. It should be noticed that the B-electrodes are not placed in the symmetry plane of the mouth orifice. Consequently, the two possible paths of current, namely through respectively the upper and the lower lip, are not identical. If the resistance in the upper path of current is called R_U and the resistance in the lower R_L, the resistance between the B-electrodes is $R_U R_L / (R_U + R_L)$. If now $R_U \neq R_L$, the influence of the smallest of the two resistances will dominate. This might explain the different registrations obtained with the A- and B-electrodes. Simultaneous recordings obtained with both A- and B-electrodes will give information about the position of the lips from which the degree of rounding of the lips may be determined.

3. Recording of labiograms

Recordings utilizing the A- and B-electrodes were made in order to verify and elaborate the considerations given above. Five subjects spoke a sequence of nonsense words, and recordings were made on the mingograph.

Fig. 1 shows the difference between labiograms recorded with (Fig. 1B) and without (Fig. 1A) plast folio placed between the lips of the subject (JR). The labiograms (A) were recorded with the A-electrodes. Simultaneous recordings of oscillogram (OSC), fundamental pitch (F.P.) and oral pressure (O.P.) are shown. The abrupt changes in the


OSC.
a 'pʰ a
a 'b a
F.P.
0.1 sec.
O.P.
A
Subject: JR
fig. 1A


OSC
a 'pʰ a
a 'b a
F.P.
0.1 sec.
O.P.
A
Subject: JR
fig. 1B

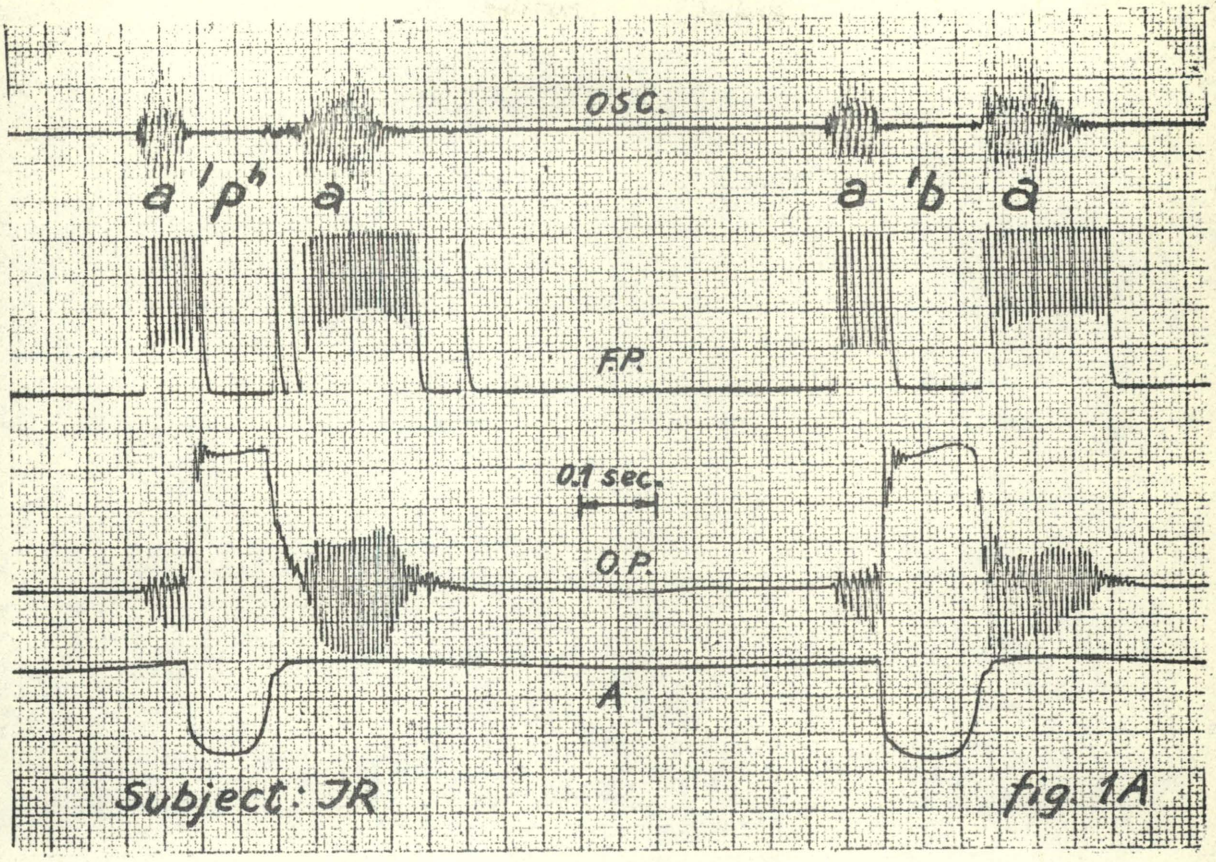

osc.
a 'pʰ a
a 'b a
F.P.
0.1 sec.
O.P.
A
Subject: JR

fig. 1A

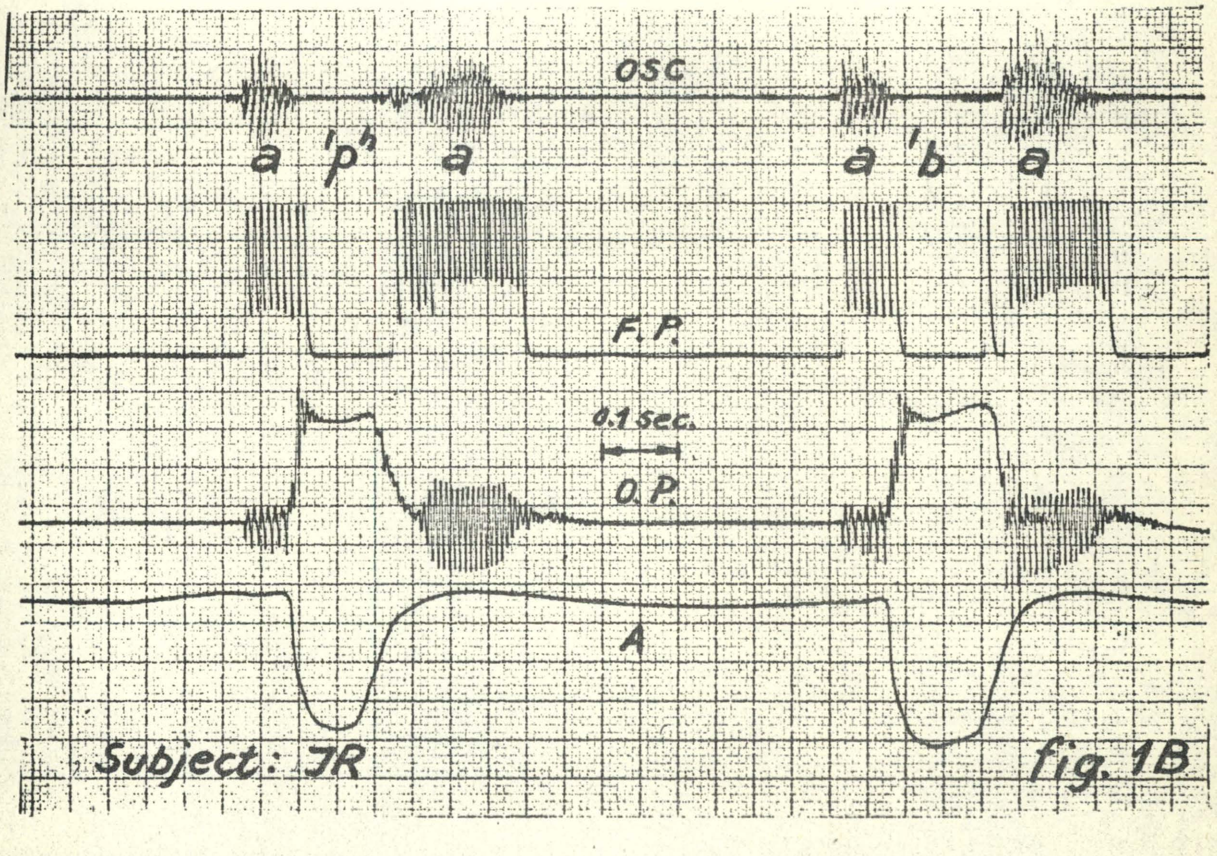

osc
a 'pʰ a
a 'b a
F.P.
0.1 sec.
O.P.
A
Subject: JR

fig. 1B

level of the labiogram Fig. 1A compared with Fig. 1B should be noticed. The moment of lip closure is well defined in Fig. 1A, while the labiogram in Fig. 1B seems to give more information about the position of the lips. Note that the labiogram scale has been changed from Fig. 1A to Fig. 1B. The labiograms shown in Fig. 2-4 were all recorded with plast folio inserted between the lips of the subject.

Fig. 2 shows A- and B-labiograms for two different subjects, (PT) and (CL). The two sets of labiograms are almost identical and indicate that the measuring method is reliable. It appears from the figures that the B-labiograms give more information about the identity of the vowels than do the A-labiograms, and that the level of the B-curve is correlated to the degree of rounding of the vowels.

Fig. 3 shows A- and B-labiograms of a bilabial stop consonant before stressed and unstressed vowels. It should be noticed that the electrical resistance related to the consonant is smaller before stressed than before unstressed vowels, indicating a greater lip pressure of the consonant before stressed than before unstressed vowels.

Fig. 4 shows labiograms of the two sequences of nonsense syllables bibybuba and titytuta. Fig. 4B shows that the influence of the position of the tongue is negligible. Thus the difference between the two labiograms is caused exclusively by the different distance between the lips. (It is supposed that the distance between the corners of the mouth varies identically in the two words.)

4. Final comments

As labiograms have to be recorded from the DC output jack of the glottograph, special attention must be paid to the possible drift of the zero-level. As one might expect, it turned out to be very difficult to fix the electrodes on the lips. Artifacts may be recorded if one or more of

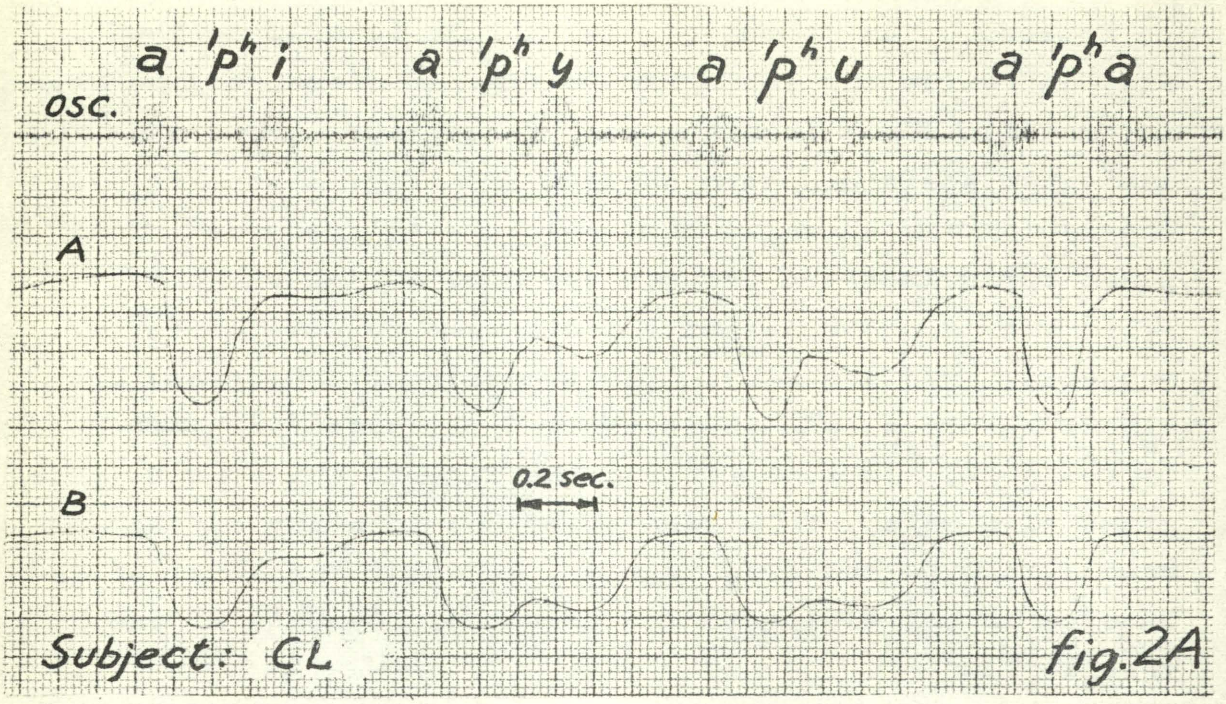

a 'pʰ i
a 'pʰ y
a 'pʰ u
a 'pʰ a
osc.
A
0.2 sec.
B
Subject: CL

fig.2A

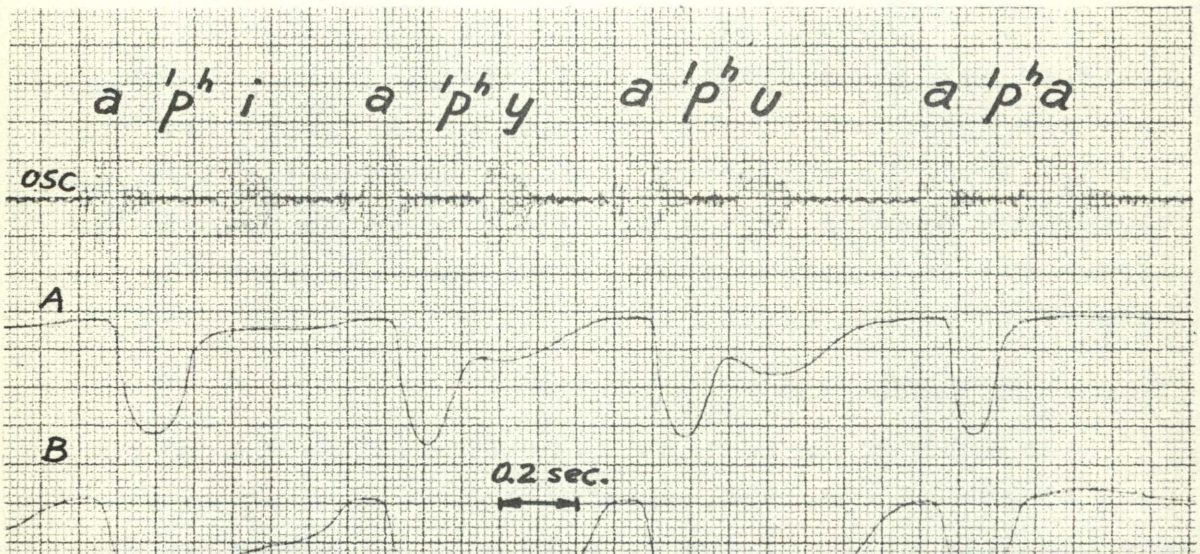

a 'pʰ i
a 'pʰ y
a 'pʰ u
a 'pʰ a
osc
A
B
0.2 sec.
Subject: PT

fig.2B

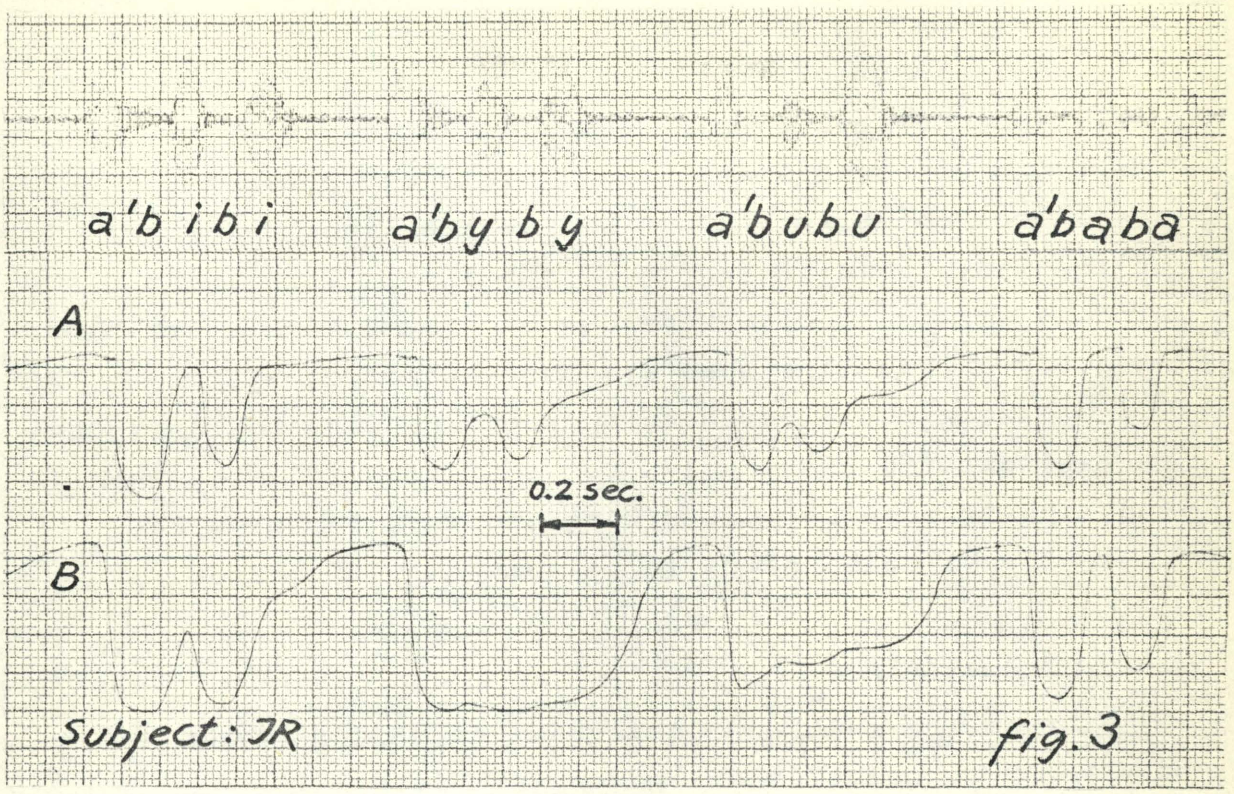


fig. 3

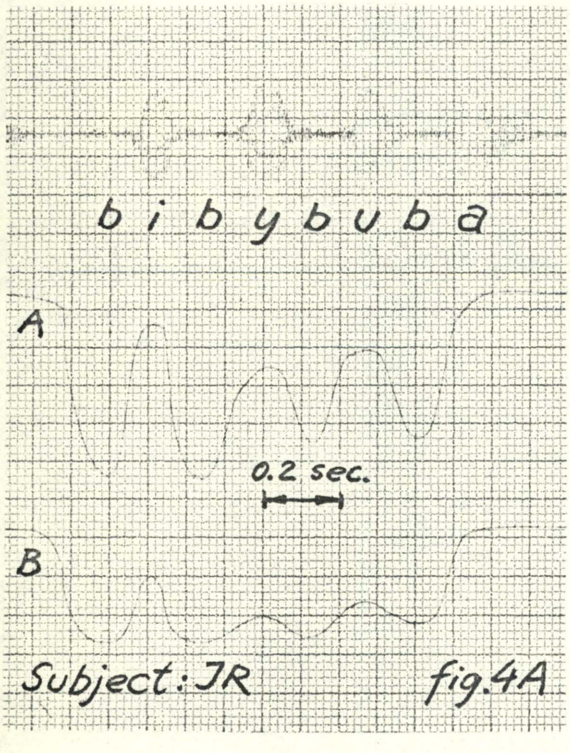


fig. 4A

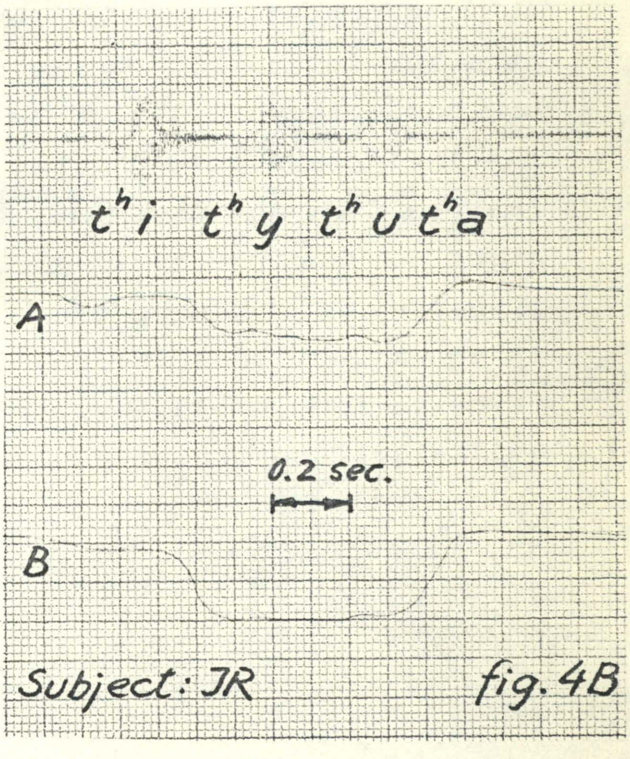


fig. 4B

the electrodes is not in proper contact with the lips. A special aspect of this problem is that the contact resistance between electrode and lip seems to depend on where the electrodes are placed. Thus the contact resistance seems to be somewhat smaller in the corners of the mouth than elsewhere on the lips. This might explain why the B-electrodes are more sensitive to the rounding of the lips than are the A-electrodes.

Fixing the electrodes on the lips does not influence the articulation seriously, but the plast folio between the lips is somewhat disturbing and may, for example, cause the bilabial stops to be somewhat affricated.

5. Conclusions

From the recorded labiograms as well as from the theoretical considerations given in this article, it is obvious that neither A- nor B-labiograms show the lip pressure or the rounding of the lips. The levels of the labiograms depend , as mentioned earlier, on several parameters; some of these may even be unknown. In order to interpret a change in level on a labiogram it is necessary that this change is caused by the variation of one parameter only, e.g. by lip pressure. However, the labiograms give a great deal of information concerning the position and movements of the lips. This information might be used to throw light on other features than lip pressure and rounding of the lips. Our main problem, then, is to extract this information from the labiograms or maybe to find a placement of the electrodes that especially emphasizes the features to examine.

The main purpose of this article is to introduce the method of measuring lip movements by means of the electro-glottograph, and the investigations should be regarded as preliminary. A more extensive series of experiments is a necessary prerequisite to a more satisfactory interpretation of the labiograms.

Acknowledgements

Special thanks are due to Børge Frøkjær-Jensen, who generously placed an additional electro-glottograph at the disposal of the laboratory.

CONSTRUCTION OF A SEGMENTATOR

Poul Thorvaldsen

Introduction

After having used our present segmentator with rather unsatisfactory results, the requirement for a segmentator with a more accurate time certainty with respect to the position of the segment arose. The development has gone on for a couple of months, and is now so advanced that it is possible to say that the principle will hold.

The principle of the segmentator

The segmentator consists of three principal components: a dual track loop-taperecorder, a programming unit and a gate.

The taperecorder is a Movic professional recorder taken over from The State Institute for Speech Defectives, Copenhagen.

The programming unit consists of an astable multivibrator connected to an electronic counter via a logical network of TTL integrated circuits from Texas Instruments. To the counter are coupled selectors by the help of which it is possible to select the position, duration, and shape of the wanted segment, just as the duration of the recorded sequence. The last mentioned selection is necessary in order not to exceed the maximum tape capacity determined by the length of the loop and the tape speed.

The mode of recording is as follows:

A push on the knob "Record" (see Fig. 1) will start the multivibrator (frequency 1 kcps), reset the flip-flops FF 1 and FF 2, reset the counter, lead the multivibrator signal to the record head of track 1, lead the input speech signal to the record head of track 2 by means of the relay and turn on the control lamp for recording. When the counter has

BLOCK DIAGRAM.

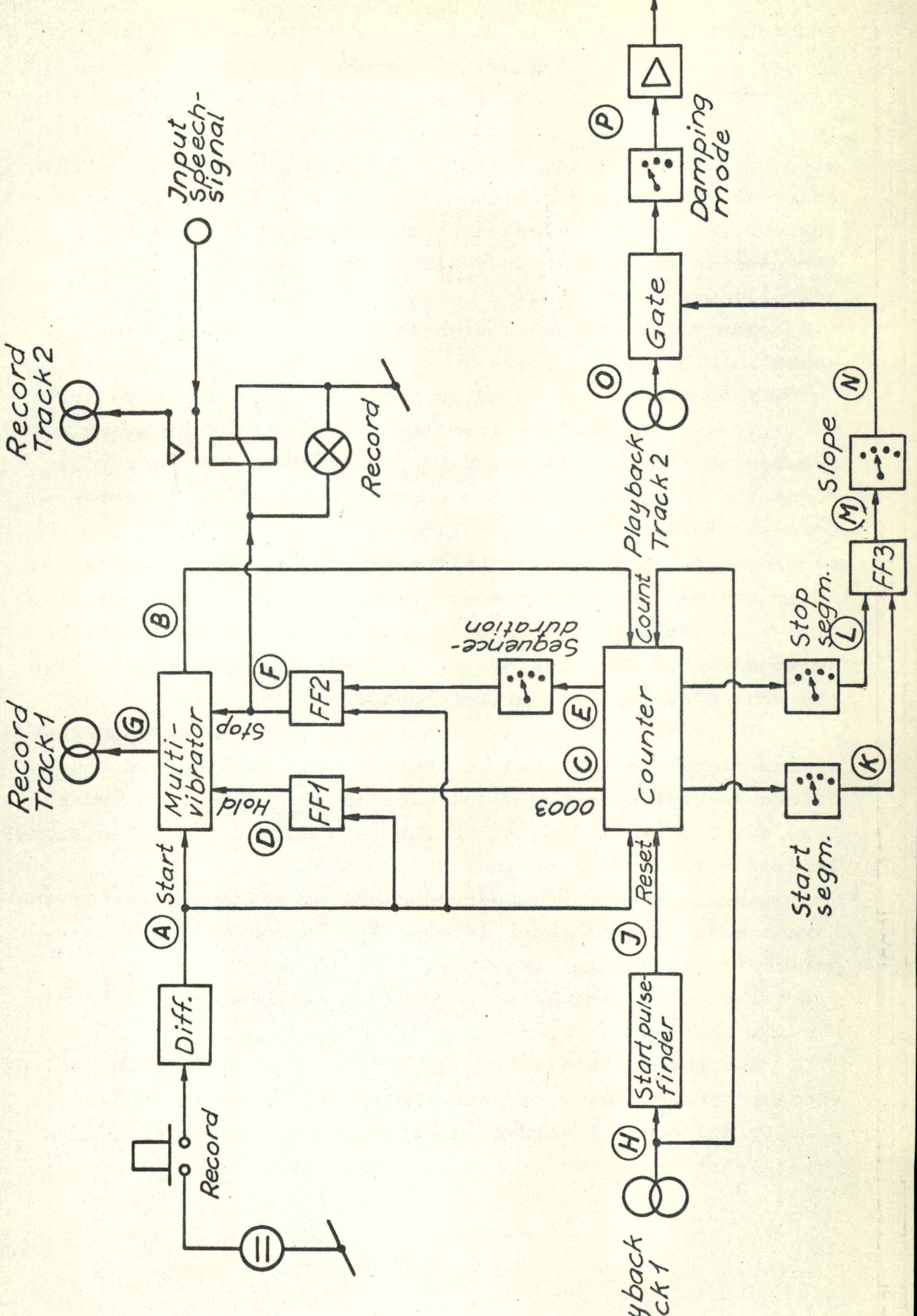


Figure 1.

counted three pulses, it will give a stop pulse to FF 1, which generates a start pulse of three msecs duration (see Fig. 2). When the counter has counted a number of pulses corresponding to the time t, selected by the sequence duration-selector, a stop pulse will be led to FF 2, which stops the multivibrator, switches off the connections to the record heads and turns off the control lamp. By means of this lamp it is possible for the user to control whether all he intended to record has actually been recorded.

The different pulse signals as a function of time are shown in Fig. 2.

The mode of operating when playing back is as follows:

When a start pulse from the playback head of track 1 reaches the start pulse-finder, a pulse from this unit will reset the counter. When the counter has counted a number of pulses corresponding to the time u, selected by the start segment-selector, a pulse will switch on the flip-flop FF 3. After having counted a number of pulses corresponding to the time v, selected by the stop segment-selector, FF 3 will be switched off. The envelope of FF 3 will be synchronous with the wanted segment of the recorded speech signal of track 2.

In order to avoid a click in the loudspeaker when the speech signal is switched on and off, the envelope is shaped before being led to the gate. The shaping circuit is of the type briefly mentioned in "Constructional Work on a Functional Generator for Speech Synthesis" in ARIPUC 3.

As the need for shaping depends on the character of the investigation, a selector is supplied which enables the experimenter to change the slope.

The pulse signals as a function of time are shown in Fig. 3.

The gate is shown in Fig. 4. It is seen that the gating element consists of a diode bridge. As the bridge needs a symmetrical control signal in order to hold the DC-level, a phase-splitter is put in front of the gate.

Pulse signals when recording.

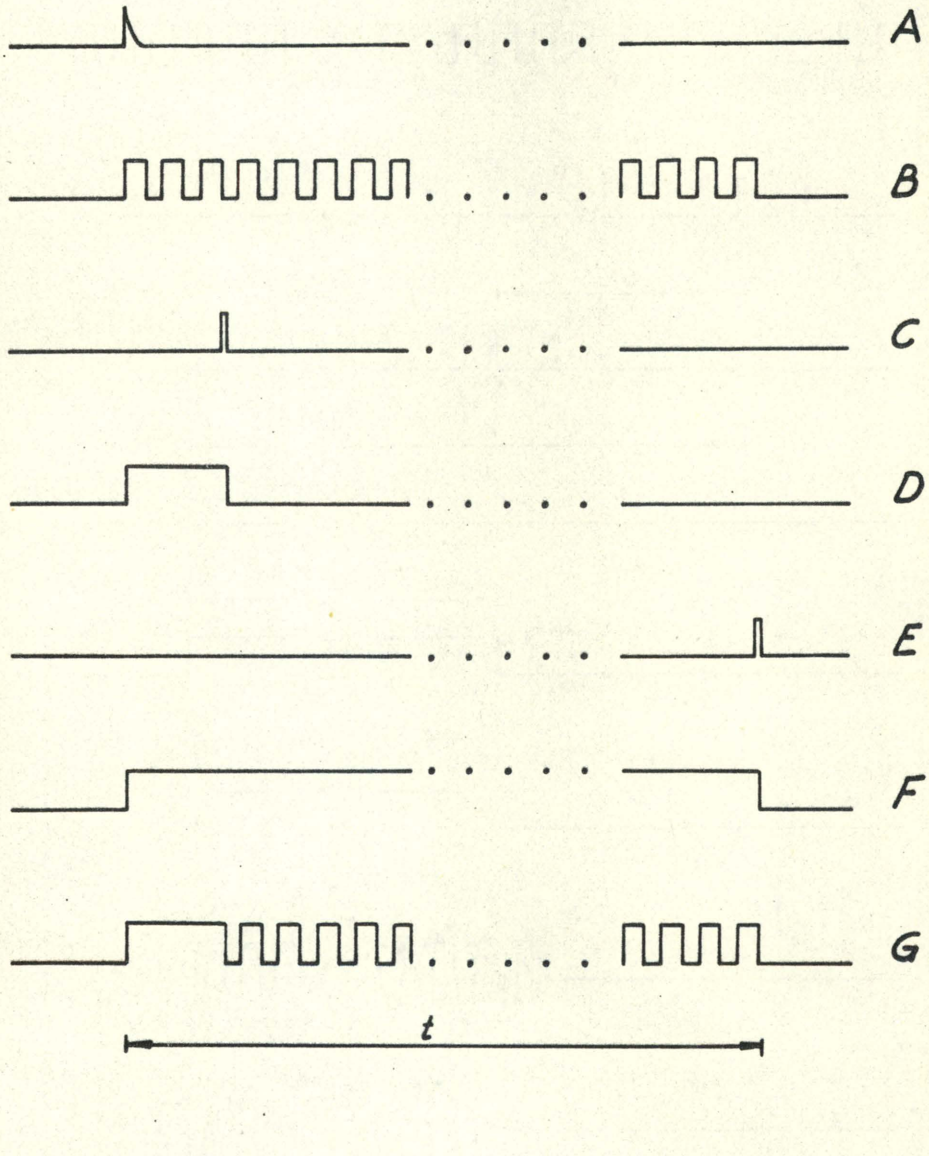


Figure 2.

Pulse signals when playing back.

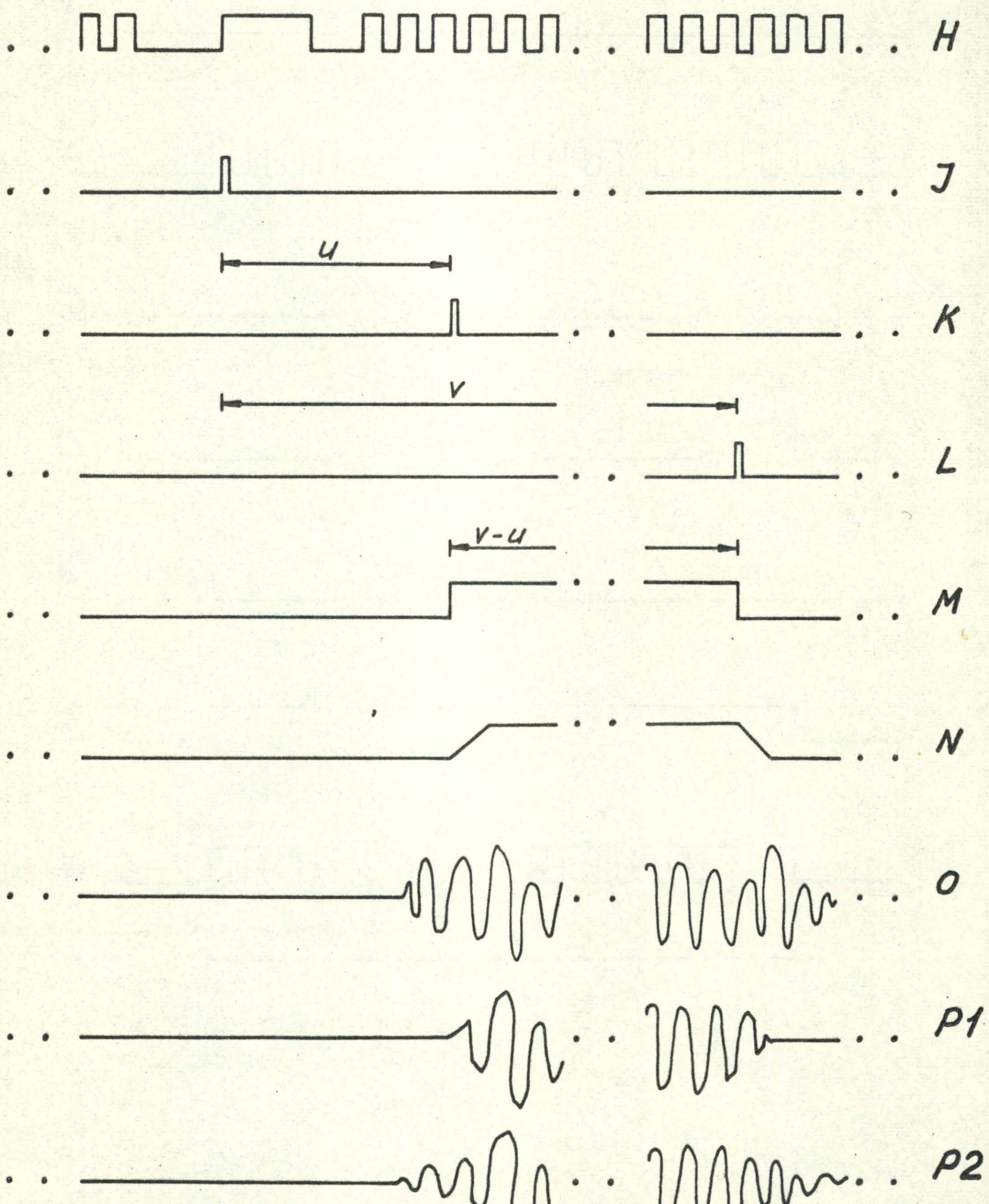


Figure 3.

GATE.

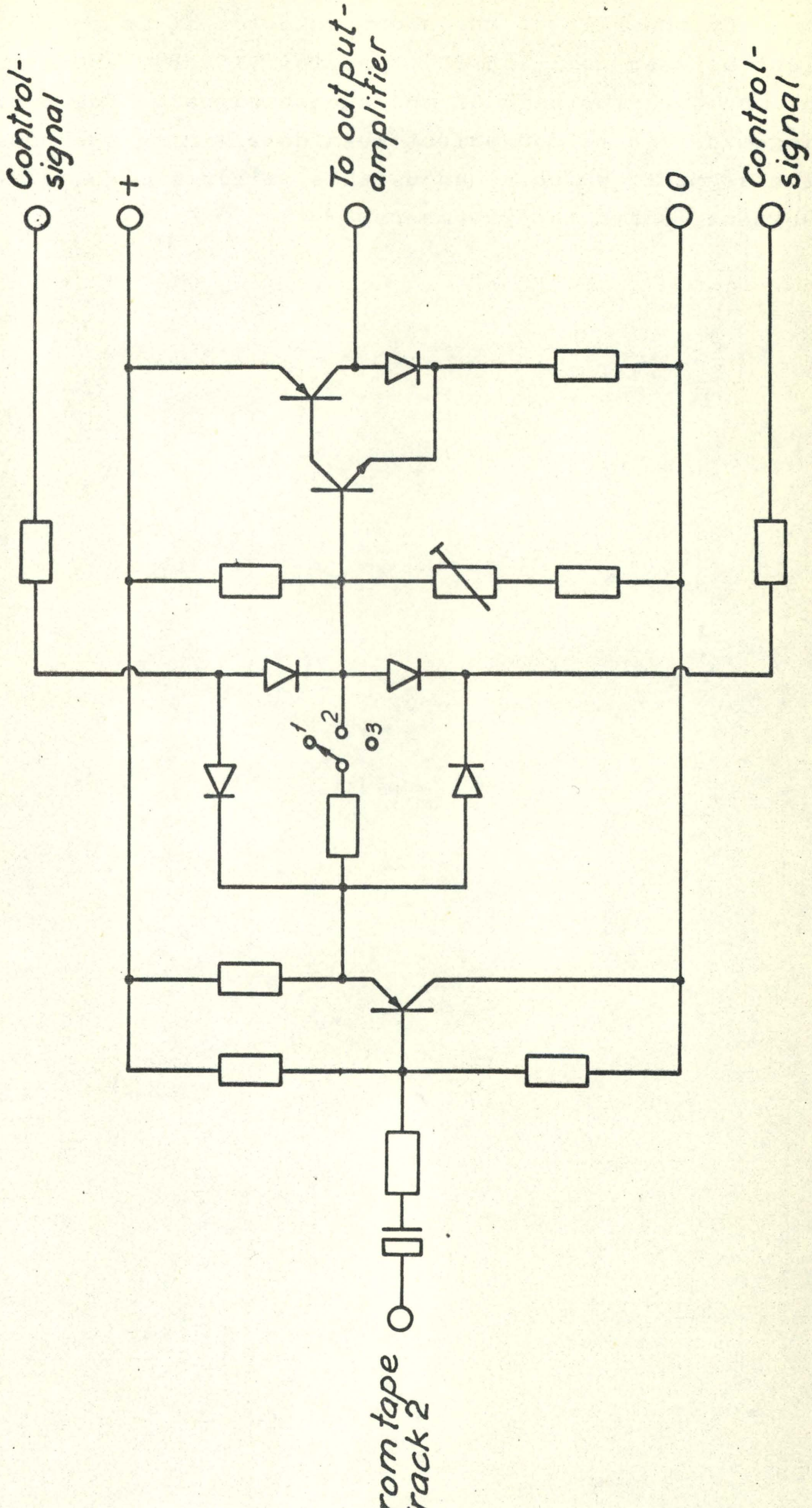


Figure 4.

By the help of the shown selector it is possible to select between full (45 dB), partial (15 dB), and no damping of the unwanted part of the speech signal. The partial damping-mode can be convenient when determining the position of the segment, which is adjustable within 1 msec. The maximum segment length is 9999 msecs.

NOTES ON THE PHONOLOGY OF DANISH IMPERATIVES WITH A DIGRESSION ON VOWEL QUANTITY[1]

Hans Basbøll

1. Introduction

The purpose of the present paper is to give a brief presentation of some facts concerning the phonology of Danish imperatives, both from a taxonomic and (mainly) from a generative point of view.

I shall be concerned with the phonological shape which the imperatives have <u>if</u> they do at all occur (the modal verbs, which never form imperatives, are, of course, left out of consideration), but not with the extent to which these imperatives are actually used or avoided in normal speech, for semantical or other reasons (cf. section 2.2.2. for some imperatives which are often avoided for phonological reasons).

In section 3.4. the vowel quantity of some related nouns and verbs is compared. The implications of this material for the imperative are discussed in section 3.3.

It should be emphasized that the present paper does not attempt to give explicit rule formulations or other definite solutions, since it is my conviction that too little is known as yet about the generative phonology of Danish (at least to the present author) to make such attempts succesful. The purpose is the more modest one of presenting some data and problems which may be relevant to later, more explicit, formulations.

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1) I am indebted to Eli Fischer-Jørgensen and Jørgen Rischel for valuable comments on a first draft of this paper.

1.1. The language under consideration

The language described here is a rather conservative variety of Standard Danish, close to the norm described by Jespersen (1o), Martinet (11), and Hjelmslev (9), generally in accordance with the pronunciations found in Ordbog over det danske Sprog. Rischel (13) often gives two or more pronunciations, and generally the more (most) conservative of these corresponds to the norm described here.

It should be noted that this "Conservative Standard Danish" (CSD) is clearly different from "Advanced Standard Copenhagen" (ASC) as described by Basbøll (1). In section 4. of the present paper a very brief survey of the imperatives in ASC will be given. (A summary of the main differences between CSD and ASC is given in the said paper (p. 34 ff).)

1.2. Phonetic transcription

I use a rather broad phonetic transcription much like the one found in Rischel (13). The reader is referred to his paper, both for a definition of the IPA symbols used in the transcription (p. 179), and for a survey of the phoneme system and the main rules of allophonic variation (p. 178 ff).

1.3. The material

The material includes all imperatives found in Sørensen (15). In some cases, other sources have been consulted, too, especially dictionaries and Hansen (6 and 8).

2. Danish imperatives from a taxonomic point of view

In most textbooks on Danish, the imperative is said to be identical to the stem of the verb, e.g. Diderichsen (5, p. 64). This is true for the orthography, and also for the pronunciation as long as the stød is kept out of consideration (cf. section 2.2. below).

The stem is found by subtracting final shwa (if there is any shwa, see below) from the infinitive, cf. the following section.

2.1. The infinitive

Danish infinitives all end in a vowel[2]: either in shwa ([ə]) or in a long or short "full" vowel (in accordance with the tradition, I consider all stød-vowels as being phonemically long; the term "full" vowel denotes all vowels except shwa).

All verbs whose stem ends in a consonant or a diphthong have infinitives ending in shwa.

Verbs whose stem ends in a vowel have infinitives identical to the stem or ending in shwa. This depends partly on the quality of the stem vowel. If it is u, the infinitive ends in shwa (exception du [du?] 'be good'). If it is i, some infinitives end in shwa (tie 'keep silent', kvie (sig) 'writhe', bie 'wait', svie 'smart', die 'suck'), others in [i?] (fri 'woo', ri 'tack', si 'strain', vi 'marry' - [gi ?]is discussed below). If it is a, the infinitives seem to end in shwa, but we have only got two marginal examples (a'e 'caress', bejae 'say yes to' - [hæ? , tæ?] are discussed below). For all other vowels, the infinitive is identical to the stem.

Thus Martinet's statement (11, 4-9) that "les infinitifs danois ne prennent pas le -e désinence caractéristique de ce mode, lorsque le thème verbal se termine par une voyelle" is not correct, but his argument (for interpreting the diphthongs as combinations of a vowel plus a consonant) holds true because stems ending in a diphthong always have infinitives with shwa.

Phonemically, there is neutralization between long and short vowel before shwa. In all cases where the stem vowel appears word-finally it has stød and thus must be considered long, and I shall therefore consider the stem vowel before shwa as being phonemically long in all cases. Examples are the

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2) The infinitives ending in a long (voiced) consonant, e.g. kalde [kal:] 'call' (only in rapid speech), are phonemically to be interpreted as consonant plus shwa (/kalə/).

adjectives ny, nye [ny?, ny(:)ə] 'new' and fri, frie [fʁi?, fʁi(:)ə] 'free' (and the sideforms of the infinitive vi/vie and di/die; the rare forms vie and di are mentioned by Hansen (6, p. 53 and 8, vol. III p. 66)). The imperatives are under discussion and should therefore not be used as an argument here.

Three verbs should be mentioned apart from the others because they have three different infintive forms: give 'give', have 'have', and tage 'take', pronounced [gi:və ,gi?, gi], [hæ:və , hæ?, ha], and [tæ:ɣə, tæ?, ta], respectively. The normal pronunciations are those with stød-vowel. [gi, ha, ta] are the only infinitives which in stressed position end in a short "full" vowel (in unstressed position all vowels may lose their lenghth and/or stød).

The verb klæde 'dress' is either pronounced [klɛ:ðə] or [klɛ?] (with the corresponding two pronunciations [klɛ:ðɒ] or [klɛ?ʁ] in the present tense). Similar sideforms are found in the verbs be(de), re(de), li(de) 'pray', 'comb', 'like'.

2.2. The imperative

The imperative of a verb is phonemically identical to the stem except for the fact that the imperative has stød whenever the stem has "phonetic stød-basis" (cf. section 3.2. below for another type of stød-basis).

Only syllables with a certain amount of stress can take the stød, but all stem syllables (which are the ones considered here) have got this amount of stress (normally primary or secondary stress), except when the word in which they occur is in unstressed position; the latter case is disregarded in the present paper.

Syllables with a long vowel always have phonetic stød-basis (if stød occurs it falls in the vowel). Syllables with a short vowel have phonetic stød-basis only if the vowel is immediately followed by a voiced consonant (which may or may not be followed by additional voiced or voiceless consonants), i.e. by [ð ɣ ʁ l m n ŋ] (if stød occurs it falls in this consonant). The i- and u-diphthongs also have phonetic stød-basis (if stød occurs it falls in its second member, cf. that they are normally interpreted as a short vowel plus /j/ or /v/; this interpretation is used in the present paper).

The above-mentioned term "voiced consonant" should be taken to denote a class of phonemes, and not as being a purely phonetic description (in the case of r, however, the following consonant must be taken into consideration, cf. section 2.2.1. below). Word-final r, l etc. in stød-less syllables are often partly or wholly devoiced (e.g. par, hul [paʁ̥, hol̥] 'pair', 'hole'), but these syllables nevertheless have phonetic stød-basis as shown by the imperatives par, hul [paʁˀ, holˀ].

As an example of the formation of the imperative, let us consider the verb give. Corresponding to the three forms of the infinitive [giːvə, giˀ, gi] we have the three imperatives [giˀv, giˀ, gi].

Two verbs are exceptions to the rule that all imperatives with phonetic stød-basis (in the sense defined here) have stød, viz. kom, gør [kɒm, gœʁ] 'come', 'do'[3]. (According to the general scheme these imperatives should be *[kɒmˀ, gœˀʁ], cf. the infinitives [kɒmə, gœːʁə].) Probably no purely synchronical explanation of these exceptions can be given, but Rischel (12) has pointed to the fact that these forms are often used in unstressed position, and in this position stød and vowel length are normally lost.

2.2.1. Verbs with stem-final r + consonant

The verbs with stem-final r + consonant pose special problems. I shall only give a very rough sketch of what I hope to be the main facts (in accordance with Hansen (7, p. 75 ff)); the practice of Ordbog over det danske Sprog is, however, extremely complicated - and probably inconsistent - on this point, cf. Diderichsen's detailed discussion (4, p. 62 ff).

In the norm described here, r after a short vowel is unvoiced before f, s, and written p, t, k. Such syllables do not

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3) Before the enclitic variants [ən, əð] of den, det [dɛnˀ, de] 'it', monosyllables with phonetic stød-basis always have stød, e.g. ['gœʁˀəð] (or ['gœʁdə]) 'do it (imperative or present)', but this phenomenon has nothing to do with specific grammatical forms, e.g. the imperative, see Hansen (6, p. 115 ff).

have phonetic *stød*-basis, cf. the absence of *stød* in imperatives like *styrt*, *verf* [sdyʁ̥d , vɛʁ̥f] 'overthrow', 'throw'. On the other hand, *r* before other consonants, including written *b*, *d*, *g*, is voiced, and such syllables have phonetic *stød*-basis, cf. the *stød* in imperatives like *myrd*, *hverv* [myʁˀd , vɛʁˀv] 'murder', 'recruit'.

There are commutation pairs like *værten*, *verden* [vɛʁ̥dən, vɛʁdən] 'the host', 'world'. Phonemically, this may be a difference between /rt/ and /rd/ (after [ʁ̥] also [t] is heard, but never after [ʁ]), or between /r̥/ and /r/.

The first solution, which is in fact the common one, is in disagreement with the well-known statement (first mentioned by Uldall (16, p. 56 f), and discussed in detail by Martinet (11, 3-5 ff)) that there is neutralization [p/b] , [t/d] , and [k/g] before shwa. This argument is decisive for Martinet because he considers /ð/ and /ɣ/ (which generally are in opposition to [t/d] and [k/g], respectively, before shwa) as being separate phonemes, and he concludes that if the opposition *verden* : *værten* were general in Danish (what he refutes) it must be a distinction between a voiced and an unvoiced *r*-phoneme (11,3-3o).

This distinction between two *r*-phonemes would permit us to state the needed addition to the rule for phonetic *stød*-basis of section 2.2. above in a simple way: /r/ belongs to the class of phonemes that constitute *stød*-basis together with a preceding short vowel, whereas /r̥/ does not. [ʁ̥] before *f* and *s*, where there is no opposition to [ʁ] , is then of course to be identified with /r̥/, whereas word-final *r* (which may have anything between voicelessness and full voicing) is identified with /r/. (In ASC these words behave differently, cf. section 4. below.)

If, on the other hand, [t-] and [-d(-)] are reduced to one phoneme /t/, and [d-] and [-ð(-)] to /d/ (and similarly for [k-] and [-g(-)], and for [g-] and [-ɣ(-)]) - as they have normally been in Danish phonemics - Martinet's argument is no longer valid since there is then opposition between /t/ and /d/, and between /k/ and /g/, in the position between a vowel and shwa. Thus it seems to be the simplest solution not to introduce a new phoneme (/r̥/), but to let the distinction between <u>værten</u> and <u>verden</u> be one between /rt/ and /rd/ where /d/ is manifested by a stop (and not by a fricative as when occurring between a vowel and shwa). It should be added that /g/ is manifested by a fricative in the cluster /rg/, and that the distinction between /p/ and /b/ after /r/ is similar to that between /t/ and /d/ (e.g. <u>torpen</u>, <u>Torben</u> [t ɒʁ̥ b ə n , t ɒʁ b ə n] 'the thorp', '(a boy's name))[4].

If the above-mentioned reduction is accepted, the formulation of phonetic <u>stød</u>-basis of section 2.2. above must be modified like this: (1) Syllables with a long vowel have phonetic <u>stød</u>-basis; (2) syllables with a short vowel immediately followed by one of the phonemes /d, g, l, m, n, ŋ , j, v/ have phonetic <u>stød</u>-basis; (3) syllables with a short vowel immediately followed by /r/ have phonetic <u>stød</u>-basis unless the /r/ is immediately followed by one of the phonemes /p, t, k, f, s/.

2.2.2. Final consonant clusters

It is well known that Danish imperatives often have final consonant clusters which do not otherwise occur word-finally but only word-medially in Danish (between a "full" vowel and shwa). This is the reason why imperatives are generally excluded from the material when the permissible final consonant combinations are set up, e.g. by Martinet (11), Uldall (16), and Vestergaard (17). I quote Uldall on this point (p. 56): "imperatives have been left out, because in these forms groups occur which are not otherwise permissible in the language (e.g. in <u>slobr</u>, <u>klatr</u>, <u>vekl</u>). The conclusion is that the imperative is normally formed by substraction."

Jespersen (1o, p. 172 ff) does not exclude the imperatives explicitly, but he only mentions imperatives in three cases, all in parentheses ([ðn] in <u>vidn</u> 'witness', [ðm] in <u>rødm</u> 'redden', and [ln] in <u>skeln</u> 'distinguish'). Diderichsen (3) includes imperatives in the material.

I shall not try to make any systematic (not to say exhaustive) classification of these clusters (and they will not even

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4) Eli Fischer-Jørgensen has suggested this point.

be enumerated), but I wish to make a few tentative remarks concerning the more important types.

(1) Some final clusters do not constitute any difficulties for Danish speakers, although they are not found word-finally in native words outside the imperatives (some foreign words pose similar phonotactic problems as the imperatives). This is true for e.g. [ð n] , [ð m] , and [ln] (cf. vidn [við ʔn], rødm [ʁøð ʔm], and skeln [sgɛ lʔn] ,the three imperatives mentioned by Jespersen); these imperatives are always pronounced as true monosyllables (otherwise Vestergaard (17, p. 6o)). The reason probably is that they are in agreement with the order relations for final consonants, according to which voiced fricatives appear before nasals (Vestergaard 17, p. 56)), and liquids appear before nasals, too (Vestergaard does not state this latter rule, but it can be deduced from his diagram (ib.)).

(2) The clusters which conflict with the above-mentioned order relations for final consonants fall into two groups according to (a) their agreement with or (b) their violation of the basic order relation that voiced consonants appear before voiceless ones (initially the relation is, of course, the reverse). Vestergaard (17) states this as an order rule among many others, but it seems to be of a more fundamental nature (cf. the treatment of the imperatives below; the postvocalic voiced consonants are crucial to formulations of the appearence of stød; and Danish speakers react much more violently to conflicts with this rule than to conflicts with the other order rules).

(a) Final clusters that conflict with at least one order relation, but not with the 'voicing rule'. Such clusters are e.g. [mʁ], [ml], [nl] , as in the imperatives tømr [tœmʔʁ] 'carpenter', vriml [vʁ em ʔ l] 'swarm', and handl [han ʔ l] 'trade'. These are either pronounced as true monosyllables, or as dissyllables, thus coalescing with the nouns tømmer [tœmʔɒ] 'timber', vrimmel [vʁem ʔ l̩] 'swarm', and handel [han ʔ l̩] 'trade'. Similarly, the imperative logr [lɒɣʔʁ] 'wag' may be pronounced either as a monosyllable or as a dissyllable rhyming with kogger [kɒɣʔɒ] 'quiver'. (Hjelmslev (9) interprets those nouns as being "ideally" (i.e. - with a gross approximation -

morphophonemically or in their underlying form) monosyllables because of the stød.)

The cluster [ð ʁ], as in hædr [h ɛð ʔ ʁ] 'honour!' probably belongs here. It conflicts with Vestergaard's rule that liquids appear before fricatives (17, p. 56), but this rule is somewhat dubious because of the important "exceptions" [ɣl] and [u̯l] which are much more stable than the reverse clusters [lɣ] and [lv]. It may be more correct to say that [ð ʁ] does not conflict with any order rule but that it does conflict with the principle that two members of the same "order class" do not combine, [ð] and [ʁ] being otherwise vowel adjacent (it is hard to say whether [ð ʁ] or [ʁ ð] is the more "unnatural" combination).

(b) Final clusters that violate the 'voicing rule'. Examples are [tʁ], [kl], [sn], as in the imperatives klatr 'climb', pukl 'swot', and visn 'wither' (notice that the three imperatives mentioned by Uldall (16, the quotation above) as an argument in favour of excluding all imperatives from the distributional material, all belong to this group). These are normally pronounced as dissyllables, thus coalescing with the nouns klatter [kladɒ] 'blots', pukkel [pogl̩] 'hump', and the adjective vissen [vesn̩] 'withered'. If, however, they are pronounced as monosyllables, the last consonant is devoiced, thus obeying the 'voicing rule': [kladʁ̥], [pogl̥], [vesn̥] (these pronunciations are quoted by Rischel (12)).

3. Danish imperatives from a generative point of view

3.1. The problem

A basic problem concerning the Danish imperatives from a generative point of view has been formulated by Rischel (13, p. 202), who also suggests where to look for a solution:

"A paradigm like [bað] 'bath' - plural [bæ:ðə] can be described as a case of vowel lengthening in "open syllable" under the conditions summarized above [i.e. "typically before a voiced approximant [5] that is followed by a vowel, cp. [hɑu̯] 'sea' - plural [hæːvə], [glað] 'glad' - plural [glæːðə] " (13, p. 2o1).]. The verb [bæːðə] 'bathe' with its preterite and past participle forms [bæːð(ə)ðə] , [bæːð (ə)t] can apparently be explained in the same way, as derived from underlying forms with short vowel. However, the imperative of this verb is [bæʔð], which rather points to underlying long vowel in the verb. Thus it may seem that vowel length is generated by a simple rule in plural forms like [bæːðə] but is due to a stem formation feature of length in infinitive forms like [bæːðə] .

There is, however, some evidence that the behaviour of the imperative is due to special formation features and thus should not be taken as decisive in assessing the underlying quantity. It is necessary here to point to the fact that stød, too, functions (on the surface) to distinguish imperative forms from otherwise phonetically similar noun forms, cp. the noun [sbel] 'play' (definite form [sbelʔəð]) versus the imperative [sbelʔ] 'play' (infinitive [sbelə])."

Rischel's two proposals for the formation of the imperative will be discussed below in section 3.3., but this discussion presupposes a conception of the stød from a generative point of view which will be stated briefly in the following section.

3.2. Phonological stød-basis

In addition to the phonetic stød-basis discussed in section 2.2. above, one may define a "phonological stød-basis". In general, the problems concerning stød (and quantity, cf. section 3.4. below) are much too complicated to be taken care of in this paper, and I shall only roughly sketch what I understand by the term "phonological stød-basis".

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5) On this point Rischel disagrees with Hjelmslev (9) who postulates a vowel lengthening before all single consonants followed by shwa (cf. section 3.4.1. below).

It was mentioned in section 2.2. that some syllables do not have stød when they occur as stressed monosyllabic words, although they have phonetic stød-basis, e.g. hul, par, ven, ham [6], bad, hav, tøj, fog [hol, pɑʁ, vɛn, ham, bað , hɑu̯, tɒi̯, foɣ] 'hole', 'pair', 'friend', 'him', 'bath', 'sea', 'cloth', 'blizzard'. In foreign (French) words also word-final [ŋ] occurs in stød-less syllables, e.g. in bon [bɒŋ] 'voucher'. These stød-less monosyllables with phonetic stød-basis all have short vowel plus a single "systematically" [7] voiced consonant.

When the final consonant in question is followed by other consonants, the syllable has stød. (Two stød-less words which normally end in [l] may, however, end in [lv] in very formal or perhaps somewhat artificial speech: sølv, gulv [søl(v), gol(v)] 'silver', 'floor'; note, however, that lv in these words is normally retained before shwa: gulve, forsølve [golvə, fɒʁˈsølˀvə] 'floors', 'silver-plate (verb)'). The domain of this stød-basis rule does not exceed morpheme boundaries, cf. tals [tals] ,genitive of tal [tal] 'number' as against hals [halˀs] 'neck' (this difference may be explained by some sort of juncture in the former case).

A final consonant with stød which is not followed by other consonants can sometimes, as shown by Hjelmslev (9), be considered a manifestation of an underlying consonant cluster, e.g. in mand, skyld [manˀ, sgylˀ] 'man', 'guilt', cf. the derivatives mandig, skyldig [mandi, sgyldi] 'manly', 'guilty' (the derivative is -ig and not -dig, cf. søvnig [sœu̯ni] 'sleepy', derived from søvn [sœu̯ˀn] 'sleep'). This is never the case for final l, n etc. in stød-less monosyllables.

These facts may be generalized so that stød occurs automatically in stressed monosyllables with underlying short vowel plus a consonant cluster (including geminates) whose first member is one of the voiced consonants mentioned above, i.e. l,

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6) Final [m] occurs in stød-less monosyllables only in pronouns and the imperative kom [kɒm] .

7) By this term I mean that the consonant in question is [+voiced] in the completely filled (i.e. redundant) matrix which is input to the phonological rules (i.e. after the redundancy rules have applied).

n, *m*, *ð*, *ɣ*, *j*, *v*, *r* (if *r̥* is not taken to be a segment distinct from *r* (cf. section 2.2.1. above), the clusters *rp*, *rt*, *rk*, *rf*, *rs* are exceptions to the rule). Furthermore, the *stød* occurs automatically in stressed monosyllables with an underlying long vowel. In the following, these two types of syllables are said to have phonological *stød*-basis. (An interpretation very much along these lines was first proposed by Hjelmslev (9).)

It is clear that the *stød* must be assigned at an early stage of the derivation since it is dependent on the morphological structure (which may be expressed by means of junctures) and latent consonants.

Although I do not *a priori* exclude the possibility that the *stød* may be introduced at various stages of the derivation, I shall in the following presuppose that the *stød* is predictable from the underlying form, i.e. only syllables with phonological *stød*-basis have *stød*. This *stød* occurs in all syllables with phonological *stød*-basis with certain exceptions, notably when they occur in unstressed position, before shwa, and as first part of compounds and certain derivatives (e.g. *måle*, *målmand*, *søvnig* [mɔ:lə, 'mɔ:lˌmanʔ, sœu̯ni] 'measure (verb)', 'goal-keeper', 'sleepy', cf. *mål*, *søvn* [mɔʔl, sœu̯ʔn] 'measure (noun), goal', 'sleep').

Some proposals which modify the concept of phonological *stød*-basis stated above are mentioned in the following section.

3.3. The imperative

The nouns *bad*, *spil* [bað, sbel] 'bath', 'play' are obviously related to the verbs *bade*, *spille* [bæ:ðə, sbelə] 'bathe', 'play', imperatives [bæʔð, sbelʔ]. There seem to be several possible ways to explain the relation between these forms.

(1) As proposed by Rischel (section 3.1. above) the noun and the verb stem may have the same underlying form, viz. ending in a short vowel plus a single consonant, and the vowel length of the plural [bæ:ðə] of the noun and in the forms of the verb [bæ:ðə] except the imperative are explained by means of a vowel lengthening rule in open syllable. According to this proposal the imperatives [bæʔð, sbelʔ] are formed by a

special stem formation rule which in some verbs (e.g. bade) geminates the vowel, in others (e.g. spille) geminates the final consonant (I use the terms "lengthening" and "gemination" synonymously).

(2) Another possibility, briefly suggested by Rischel (section 3.1. above), is that the vowel length in the verb [bæ:ðə] is due to a stem formation feature of length. Thus the imperative [bæˀð] is identical to the verb stem in the underlying representation, and we may conclude that also the imperative [sbelˀ] is identical to the stem of [sbelə], i.e. spille is derived from the noun [sbel] by means of a stem formation feature which geminates the final consonant.

The fact that the vowel quantity of the infinitive and the imperative is always the same (on the surface) (except gøre, gør) speaks against assumption (1). On the other hand, in all cases where a verb and a plural ending in shwa are both formed from the same (stød-less) noun with an underlying short vowel plus a single final (systematically) voiced consonant (without any vowel shift), the vowel quantity of the verb and the plural is the same. This suggests that the vowel length of e.g. the plural and the infinitive [bæ:ðə] is in fact the same phenomenon (as it is according to hypothesis (1)). This might lead to a third hypothesis.

(3) There is one phonological rule which - under certain conditions and in certain words, see below - lengthens vowels (a) in open syllables and (b) in imperative forms; or which lengthens the vowels in question in open syllables, after which the final shwa (of the infinitive) is deleted in imperative forms. This is, however, in disagreement with my presupposition on the stød (section 3.2. above: the stød is predictable from the underlying form) since according to hypothesis (3) the stød-rule would have to apply after the mentioned vowel lengthening rule (it may of course be the presupposition which is wrong). Furthermore, a rule would be required to lengthen the consonant in e.g. the imperative [sbelˀ] before the stød-rule applies.

(I shall not discuss whether the stød-rule could be an 'over-all rule' applying whenever certain conditions are fulfilled. Another possibility, which is also in disagreement with the claim of section 3.2. above that only syllables with phonological *stød*-basis have *stød*, is the following: *stød* is assigned to all syllables which should have *stød* according to the morphological structure of the word in which they occur (e.g. to the root syllable of a complex verb (*afspille*, *udgøre* etc.), to the imperative, and to a monosyllabic noun before the definite article). The *stød* could be removed from syllables without phonetic *stød*-basis by some sort of output-constraint. According to this proposal, the concept of phonological *stød*-basis defined in section 3.2. above would be relevant only to certain word-types, notably the (stressed) monosyllables.)

Under the mentioned assumption about the *stød* (of section 3.2. above) I have found one argument which strongly speaks against proposal (1) and in favour of (2). Verbs like *spille*, *smøre* [sbelə, smœːʁə] 'play', 'butter (the bread)' should according to (1) have underlying short vowel plus a single (systematically) voiced consonant, i.e. no phonological *stød*-basis, cf. the nouns *spil*, *smør* [sbel, smœʁ] 'play', 'butter'. However, as the second part of complex verbs they always have *stød*, e.g. *afspille*, *besmøre* ['ɑu̯ˌsbelˀə, be'smœˀʁə] 'play back', 'smear'.

The same is true of the two verbs whose imperatives have no *stød* although they have phonetic *stød*-basis, viz. *komme*, *gøre* [kɒmə, gœːʁə] (imperatives [kɒm, gœʁ]), cf. *bekomme*, *udgøre* [be'kɒmˀə, 'uðˌgœˀʁə] 'get', 'consist of'. These *stød*-forms suggest, together with the fact that all other forms of these verbs (except the present *gør* [gœʁ]) seem to have *stød* under the same conditions as other verbs (cf. the preterite *kom* [kɒmˀ] 'came' and the past participle *gjort* [gjoˀʁd] 'done'), that the verbs *komme* and *gøre* have underlying forms with phonological *stød*-basis, and that the imperative *kom* and the imperative and present *gør* are marked as exceptions in the lexicon. But this argument is only valid if my assumption about the *stød* is valid (section 3.2. above), and I shall leave the question open here.

Another argument which seems to speak in favour of (2) is the first vowel of the noun badning which may be long and always has the quality of the long vowel: [bæ(:)ð neŋ]'bathing'. (Rischel has, however, mentioned the possibility of deriving it from bade+ning, i.e. with lengthening in open syllable and shwa-deletion (oral communication).)

I shall not make any definitive choice between the hypotheses in question, but I think there are better arguments in favour of (2) than of (1).

One might ask why the verb is formed from the noun by a stem formation feature of length, and not the noun from the verb by a shortening "stem rule". The reason is that we can - in the cases under consideration here - give certain rules for the derivation from noun to verb but not the other way round: e.g. the verbs corresponding to the noun spil [sbel] (with underlying single l) and the noun spild [sbilˀ] 'waste' (with underlying geminated l) both have (surface and underlying) short vowel and, according to hypothesis (2), underlying geminated l ([sbelə] and [sbilə] 'waste', respectively, which have exactly the same stød-possibilities in all forms); and similarly the verbs corresponding to the noun bad [bað] (with underlying short vowel) and the noun rod [ʁoˀð] 'mess' (with underlying long vowel) both have (surface and, according to hypothesis (2), underlying) long vowel ([bæ:ðə] and [ʁo: ðə] , respectively).

According to hypothesis (1), the following section 3.4. on vowel and consonant lengthening is directly relevant to the formation of the imperatives; according to (2), the relevance is only indirect, viz. for the stem formation of the verbs and not specifically for the imperative forms. I shall use the vague terms "vowel and consonant lengthening (or gemination)" which may be taken to be a phonological rule or a stem formation rule according to the hypothesis in question on the formation of the imperative.

Since alle imperatives with phonetic stød-basis have stød (except kom and gør, cf. the discussion above), either one or the other lengthening rule will apply to all verbs derived from words with underlying short vowel plus a single voiced consonant, e.g. [bæ?ð] has vowel lengthening and [sbel?] has consonant lengthening.

If the underlying vowel of the related noun is long (<u>håne</u> [hɔːnə] 'mock', derived from <u>hån</u> [hɔ?n] 'scorn'), or if the postvocalic voiced consonant (of the verb) is followed by a consonant (<u>hilse</u> [hilsə] 'greet'), neither of the lengthening rules need apply (the imperatives are [hɔ?n] and [hil?s]). (If it turns out to give a simpler description, one may let the vowel lengthening rule apply in the first case and the consonant lengthening rule in the second case since they will then apply vacuously, in the second case without any complications at all.)

Infinitives with (surface) long vowel plus an unvoiced consonant are never derived from words with a short vowel, and thus they probably all have underlying long vowels (they are often derived from monosyllables with long vowels, e.g. <u>mase</u> [mæːsə] 'toil' from <u>mas</u> [mæ?s] 'bother (noun)'). Thus neither of the lengthening rules need apply to verbs whose (first) postvocalic consonant is unvoiced (but they might apply vacuously, cf. above).

<u>3.4. Vowel and consonant lengthening</u>

The following problem remains: to which verbs derived from monosyllables with underlying short vowel plus a single voiced consonant does vowel lengthening apply, and to which verbs does consonant lengthening apply? This question is intimately connected with a more general one: before which consonants does vowel lengthening occur at all? It goes without saying that this general question can by no means be answered definitively in this paper, but I shall give a brief survey of some material which must be taken into account.

Our focus of interest will be the relation between the (surface) vowel quantity of the infinitive (imperative) and of the word (generally a noun) it is derived from (or related to).

A summary of the vowel lengthening tendencies is given in section 3.4.1.6. below.

3.4.1. Vowel lengthening

Before we examine the material, a few preliminary remarks will be necessary.

Firstly, our material is limited to stød-less monosyllables ending in a voiced consosonant (including [i̯] and [u̯]). Thus an example like spøg [sb ɒ i̯ ʔ] 'joke', cf. the verb spøge [sbø:ɣə] 'joke' [8], is not taken into account, because it involves not only vowel lengthening, but also consonant shortening (if our concept of phonological stød -basis (section 3.2.) is accepted), and a "consonant shift".

Secondly, forms whose vowel quality differs (phonemically) from that of the infinitive will not be taken as decisive evidence for vowel lengthening of the infinitive; e.g. neither the noun skud [sguð] 'shot' nor the participle skudt [sgud] 'shot', nor the preterite skød [sgøʔð] 'shot' will be taken as decisive for whether the vowel of skyde [sgy:ðə] 'shoot' has been lengthened or not. As shown by these and many other examples (which often seem to give contradictory results), the inclusion of such material would presuppose a general examination of ablaut and umlaut in Danish which has not been undertaken so far.

Thirdly, special problems arise in the noun declension. The noun fred [f ʁ eð] 'peace' has the definite form freden [f ʁ eʔðə n] , whereas bred [b ʁ eð] 'brink' has the definite form bredden [b ʁ eðʔə n]. It is not possible to explain this difference by a distinction between underlying long and short vowel, since there are also nouns with surface length in the indefinite form, like ed [eʔð] 'oath' (definite eden [eʔðən]), and these obviously have underlying long vowel. How this problem should be handled in a generative grammar of Danish is an open question which will not be discussed in the present paper.

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8) The pronunciations [sbø ʔɣ] and [sb ɒ i̯ ə] also occur, but more rarely in the norm described here.

Before m, l, and j, there are no examples of vowel lengthening. The case before the remaining voiced consonants, i.e. n, r, v, ð, and ɣ, will be descussed separately (the question whether ð and ɣ are primary segments or derived from d and g, is discussed in Rischel (14)).

3.4.1.1. Vowel lengthening before n

Generally, there is no vowel lengthening before n (cf. ven, venner [vɛn, vɛnɒ] 'friend', 'friends'; søn, sønner [sœn, sœnɒ] 'son', 'sons'; tin, fortinne [ten, fɒʁ'tenˀə] 'tin (noun)', 'tin (verb)'; tran, trannet [tʁɑn, tʁɑnəð] '(whale) oil', 'oily').

In some cases, long and short vowels are found in both mono- and dissyllabic forms; but this should not, of course, be taken as a proof of vowel lengthening (cf. gran [gʁɑn, gʁɑʔn, gʁɑnʔ] 'spruce', plural [gʁɑʔnɒ, gʁɑnˀɒ]; spån [sbɒn, sbɔʔn] 'chip', plural [sbɒnɒ, sbɔːnɒ]).

Two words might be taken as evidence of vowel lengthening before n (Hjelmslev's example (9, p. 2o): han, hane [han, hæːnə] 'he', 'cock' should be disregarded - there is absolutely no need to consider these two words related). One valid example is vane [væːnə] 'habit', obviously related to van [van] which is only found in the locution pleje van 'use to' (the related verb vænne [vɛnə] 'habituate' has a short vowel in all forms). The other is the somewhat old-fashioned verb trine [tʁiːnə] 'stalk', obviously related to the noun trin [tʁin] 'step' (the rare pronunciation [tʁiʔn] is also found, cf. that the definite form is either [tʁinˀəð] or [tʁiʔnəð]).

This is the only example where a verb seems to be formed by vowel lengthening before n, but the example is not at all convincing, partly because the rare form [tʁiʔn] also exists. (Rischel has suggested that the difference in vowel length between the noun [tʁin] and the verb [tʁiːnə] may be explained as a case of ablaut like the one between the noun bud [buð] and the verb byde [byːðə], both meaning 'command'.)

As stated above, vowels are generally not lengthened before n, and the verb fortinne [fɒʁ'tenˀə] is formed by consonant lengthening.

3.4.1.2. Vowel lengthening before r

In some cases, vowel lengthening seems to occur, maybe (partly?) depending on the vowel in question, but the material is too limited for safe conclusions to be drawn from it.

ɔ and œ seem to be lengthened before r (vor, vore [vɒʁ, vɒːʁə] 'our'; for, fore- [fɒʁ, fɒːʁə], e.g. in tage sig for = foretage sig 'undertake'; smør, smøre [smœʁ, smœːʁə] 'butter (noun)', 'butter (verb)'; gør, gøre [gœʁ, gœːʁə] 'does', '(to) do', but gør is an exception, cf. section 3.3. above). (Note, however, that the definite form of hør [hœʁ] 'flax' is [hœʁˀən] without lengthening, like smør, smørret [smœʁ, smœʁˀəð] 'butter', 'the butter'.)

i, y, a, and ɛ do not seem to be lengthened before r[9] (ir, irre [iʁ, iʁə] 'verdigris', 'become coated with verdigris'; fyr, fyrre- (træ etc.) [fyʁ, fyʁə(tʁɛ?)] 'fir', 'fir (tree etc.)'[10] (definite form fyrren [fyʁˀən]); par, parre [pɑʁ, pɑʁə] 'pair (noun)', 'pair (verb)' (definite form parret [pɑʁˀəð]; cf. kar, karret [kɑʁ, kɑʁˀəð] 'vessel', 'the vessel'); jer, jeres [jɛʁ, jɛʁəs] 'your' (cf. bær, bærret [bɛʁ, bɛʁˀəð] 'berry', 'the berry' and herr (short form of herre), herren [hɛʁ, (hɛʁə,) hɛʁən] 'sir', 'the gentleman')).

Thus smøre [smœːʁə] is the only verb whose infinitive seems to be formed by vowel lengthening before r (still disregarding være). The verbs irre, parre [iʁə, pɑʁə] are formed by consonant lengthening.

A special problem concerning the imperative tør [tœʁˀ] 'dry' of the verb tørre [tœʁə] should be mentioned here.

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9) The verb forms er, var, være [ɛʁ, vɑʁ, vɛːʁə] 'is', 'was', 'be' are not taken into account.

10) This example should not be taken as decisive, however, since fyrre only occurs as first part of compounds where there is a general tendency toward vowel shortening.

This verb is derived from the adjective tør [tœ ʔ ʁ] which seems to have an underlying short vowel (and a geminated r to explain the stød), since its definite and plural forms both are tørre [t œ ʁ ə] (like the infinitive of the verb). Likewise, the adverb før [f œ ʔ ʁ] 'before' (comparative) may have an underlying short vowel, cf. the superlative første [f œ ʁ̥ sd] 'at first'. The r of [f œ ʔ ʁ] would then be an underlying geminate (to explain the stød); thus før (comparative) would have the stem "f œ r" plus the comparative flexive "r".

This would, however, presuppose a rule which lengthens the vowel, probably applying only to these two words. And since the adjective and the imperative tør are distinguished on the surface (as [t œ ʔ ʁ] versus [t œ ʁ ʔ]), the mentioned rule should apply only in the context [÷ verb] or the like. Since this is a very artificial kind of rule it may be the simplest solution to account for these alternations in the lexicon, but I shall leave the question open here.

3.4.1.3. Vowel lengthening before v

The words in question are those with the final stød-less diphthongs [ɑu̯] and [ɒu̯].

Three of these seem to have vowel lengthening (hav, have [h ɑ u̯, hæ:v ə] 'sea', 'seas'; trav, trave [t ʁ ɑ u̯, t ʁ ɑ :v ə] 'trot (noun)', 'trot (verb)'; lov, love [l ɒ u̯, l ɔ:v ə] 'law, praise (noun)', 'laws, praise (verb)'). (Since the definite forms are havet, travet, loven [hæ ʔ v ə ð , t ʁ ɑ u̯ ʔ ə ð , l ɔ ʔ v ə n], respectively, it might be questioned whether the basic form of hav and lov has underlying short or long vowel; but as mentioned in section 3.4.1. above, we disregard the definite form.)

One word, however, has definitely no vowel lengthening, viz. tov, tove [t ɒ u̯, t ɒ u̯ ə] 'rope', 'ropes' (definite form tovet [t ɒ u̯ ʔ ə ð]).

The remaining ones have short vowel in the definite form, and they do not form plurals different from the singular forms (lav, nav, rav, rov, behov [l ɑ u̯, n ɑ u̯ (ʔ), ʁ ɑ u̯ , ʁ ɒ u̯ , be'h ɒ u̯] 'lichen', 'hub', 'amber', 'rapine', 'need (noun)';

the last example shows that the rule that stressed syllables with the prefix be- have stød if they have phonetic stød-basis, is confined to verbs and deverbatives (e.g. participles used as adjectives, cf. behåret [be'hɒ ʔʁ ə ð] 'hairy' and håret [hɒ : ʁ ə ð] 'hairy')).

The two verbs in this material are thus formed by vowel lengthening (imperatives trav, lov [t ʁ ɑ ʔ v, l ɔ ʔ v] 'trot', 'promise').

The word bogstav [bogsdæu̯] [11] 'letter (of the alphabet)', plural bogstaver ['bog,sdæ ʔ v ɒ] , should be mentioned. Its second syllable probably has an underlying long vowel since its phonetic quality throughout the paradigm is that of the long vowel, cf. hav, have [h ɑ u̯, hæ:v ə]. The reason why this syllable has no stød in the indefinite singular form should then be that it has no stress; a similar shift between unstressed and stressed syllable (in indefinite singular versus all other forms) seems to be found in words of the type madding, maddinger [ma ð eŋ , ma ð eŋ ʔ ɒ] 'bait', 'baits', where the absence of stød in the first case can only be explained by the absence of stress (the stød in the second case might, however, be explained as an automatic phenomenon occurring in all derivatives in -ing).

3.4.1.4. Vowel lengthening before ð

There is a rather large number of stød-less monosyllables ending in ð. Whether vowel lengthening before ð occurs (in open syllable) seems to be highly dependent on the vowel segment in question.

It might be pointed out here, too (cf. Rischel (14)), that there is only one adjective in the material - glad, glade [gla ð , glæ: ð ə] 'happy' (all other adjectives with final ð have a long vowel) - and a couple of adverbs and other "small words" (ad, hvad, ved, med, hid, gid [a ð , va ð , ve ð , m ɛ ð, hi ð , gi ð]), all the remaining words being nouns with a de-

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11) A sideform ['bog,sdæ ʔ v] also occurs.

finite majority for the neuter gender (most of the nouns with facultative *stød* are of the common gender, viz. *bred*, *brod*, *od*, *glød*, *nød* [bʁeð(ʔ), bʁɒð(ʔ), ɒð(ʔ), glø(ʔ)ð, nø(ʔ)ð] 'brink', 'sting', 'point', 'ember', 'nut' (notice, however, that *stød* [sdø(ʔ)ð] is neuter)).

When the vowel is *ɔ*, definitely no lengthening occurs (*lod*, *lodder* [lɒð, lɒðɒ] 'weight', 'weights'; *skod*, *skodde* [sgɒð, sgɒðə] 'stump', 'top (a cigarette)'; *brod*, *brodder* [bʁɒð(ʔ), bʁɒðɒ] 'sting', 'stings'; *od*, *odder* [ɒð(ʔ), ɒðɒ] 'point', 'points'; all the mentioned nouns plus *flåd*, *tråd* [flɒð, tʁɒð] 'float', 'foot lever' have short vowel in their definite form (the latter two are related to the verbs *flyde*, *træde* [fly:ðə, tʁɛ:ðə] 'float', 'step', respectively, but as mentioned above we shall not use forms with (phonemically) different vowels as decisive evidence for the underlying quantity of each other)).

All the words with *a* which also occur in open syllable[12] have vowel lengthening (e.g. *had*, *hade* [hað, hæ:ðə] 'hatred', 'hate'; *fad*, *fade* [fað, fæ:ðə] 'dish', 'dishes'), also in their definite forms.

The words with *e*, *ɛ*, *u*, *y*, and *ø* have vowel lengthening when the vowels occur in open syllable (their definite forms have sometimes long, sometimes short vowels, e.g. *bud*, *budet*, *bude* [buð, buʔðəd, bu:ðə] 'messenger', 'the messenger', 'messengers', versus *bud*, *buddet* [buð, buðʔəd] 'command(s) (noun)', 'the command'). Vowel lengthening in open syllable also applies to words with *i*, except *spid*, *spidde* [sbið, sbiðə] 'spit(noun)', 'spike (verb)'.

Thus it seems that verbs derived from nouns with underlying short vowel and single *ð* are formed by consonant lengthening if the vowel is *ɔ* (imperative *skod* [sgɒðʔ] 'top (a

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12) I.e. before a single consonant followed by shwa; there is evidence, however, that definite forms of monosyllables (e.g. *øllen* [ølʔən] 'the beer'), and plurals whose stem has *stød* in that form (e.g. *øller* [ølʔɒ] 'beers'), should be interpreted as being (systematically) monosyllables, cf. Hjelmslev (9).

cigarette)') and in the case of the verb spidde (imperative spid [sbið ?] 'spike'). If the vowel of the noun is short a, e, ɛ, ø, or i, the verbs are formed by vowel lengthening (except spidde) (e.g. the imperatives mad, smed, tilsted, stød, bid [mæ?ð , sme?ð , 'tel̩sdɛ?ð , sdø?ð , bi?ð] 'feed', 'forge', 'allow', 'push', 'bite'; cf. the nouns mad, smed, sted, stød, bid [mað , smeð , sdɛð , sdø(?)ð , bið] 'food', 'smith', 'place', 'push', 'bite'). There are no examples of verbs with u or y, but such forms, too, would probably have vowel lengthening if they did occur (cf. above).

3.4.1.5. Vowel lengthening before ɣ

There are very few stød-less monosyllables in ɣ. Some of those have vowel lengthening in their definite forms (e.g. rug, rugen [ʁu(?)ɣ , ʁu?ɣən] 'rye', 'the rye'), others have not (e.g. skrog, skroget [sgʁɒɣ , sgʁɒɣ?əð] 'hull', 'the hull').

I have only found one valid example (albeit a rather marginal one) of vowel lengthening in open syllable, viz. fjog, fjoget [fjɒɣ [13], fjɔːɣəð] 'fool', 'foolish'; but skrog, skroget 'poor thing', 'miserable' has no lengthening ([sgʁɒɣ, sgʁɒɣəð]).

The only verb relevant to our discussion is fjoge [fjɔːɣə] (e.g. in fjoge rundt 'make a fool of oneself'), imperative [fjɔ·?ɣ] , which seems to be formed by vowel lengthening. The same may be true of the verb tage [tæːɣə , tæ?, ta] 'take' (imperative tag [tæ?ɣ , tæ?, ta]), related to the noun tag [tæ?ɣ, tɑɣ] 'grasp'.

3.4.1.6. Summary of the vowel lengthening tendencies

Before we drown in details, let me briefly summarize the vowel lengthening tendencies stated above.

It should be kept in mind that we have only examined the dissyllables with a single intervocalic consonant derived from

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13) This is the pronunciation given by Ordbog over det danske Sprog, but also [fjoɣ] and [fjɔɣ] are heard.

stød-less monosyllabic words with final voiced consonant (because it is certain that these monosyllables have underlying short vowel and a single final consonant, if our concept of phonological *stød*-basis is accepted at all). Furthermore, all cases where the vowels in question are of (phonemically) different quality have been disregarded. For a general discussion of quantity, other kinds of material should, of course, be taken into consideration, too.

With these reservations, it seems as if the verbs derived from monosyllables with underlying short vowel plus a single *v* or *ɣ* always have vowel lengthening (there was only one marginal example with *ɣ* (imperative *fjog* [fjɔ?ɣ]), but since word-final *ɣ* never has *stød*, we can be sure that *ɣ* belongs to this group).

If the single consonant is *r* or *ð*, vowel lengthening sometimes occurs. The open rounded vowels, i.e. *ɔ* and *œ*, seem to be lengthened before *r*. *ɔ* is the only vowel which is not lengthened before *ð*. It seems surprising that the tendencies for a given vowel to be lengthened or not before *r* or *ð* look exactly reversed. Eli Fischer-Jørgensen has suggested that the lengthening of *ɔ* before *r* may be due to the fact that their place of articulation is practically the same (phonetically, syllable-final *r* is often pronounced [ɒ̯]). And since *œ* does not occur before *ð* at all, the discrepancy between the lengthening tendencies before *r* and *ð* is maybe only apparent. (It may be questioned whether *ø* and *œ* are phonemically distinct (a survey of the relevant material and a discussion may be found in Basbøll (2)); if they are not, *ø* is lengthened both before *r* (*smør*, *smøre* [smœʁ, smœːʁə] 'butter (noun)', 'butter (verb)') and *ð* (*stød*, *støde* [sdø(?)ð, sdøːðə] 'push (noun)', 'push (verb)').)

On the other hand, the material is so limited that some of the tendencies we have found toward a dependency between the vowel quality and the ability of lengthening in open syllable may be rather accidental, being due to lack of sufficient data.

3.4.2. Consonant lengthening

Verbs derived from monosyllables with an underlying short vowel plus a single (systematically) voiced consonant are formed by consonant lengthening if they are not formed by vowel lengthening (cf. the preceding section). Consonant lengthening thus applies if the consonant is l, j, m, or n (on the verb trine, cf. section 3.4.1.1. above), and sometimes when it is ð or r (see above).

4. Appendix. Imperatives in Advanced Standard Copenhagen

One difference between Advanced Standard Copenhagen (ASC; cf. the references given in section 1.1. above) and the Conservative Standard Danish described in the present paper (CSD) is that the postvocalic r is pronounced [ɒ̯] or deleted (viz. after [ɑ] and [ɒ]) in ASC. This is probably a reason why many imperatives, which in CSD end in [ʁ̥] plus an unvoiced consonant and thus have no stød-basis, have stød in ASC (the voicing of the r is at least a necessary condition for it to have stød). Examples are spark 'kick' (CSD [sbɑʁ̥g] , ASC [sbɑʔg]), styrt 'overthrow' (CSD [sdyʁ̥d], ASC [sdyɒ̯ʔd]), skærp 'sharpen' (CSD [sgɛʁ̥b], ASC [sgæɒ̯ʔb]), and mors 'morse' (CSD [mɒʁ̥s], ASC [mɒʔs]). This tendency is not, however, completely carried through in ASC (e.g. mærk 'remark', CSD [mɛʁ̥g], is [mæɒ̯g], less often [mæɒ̯ʔg], in ASC).

If this tendency is carried through, the result will be that r then belongs to the class of phonemes which always have phonetic stød-basis together with a preceding short vowel, and phonological stød-basis together with a preceding short vowel and a following consonant, i.e. the rules for stød-basis become considerably simpler (both because the stød-basis may be formulated without regard to vowel-remote consonants (cf. the clusters /rp, rt, rk, rf, rs/ in CSD), and because the class of phonemes constituting stød-basis together with a preceding short vowel will simply be those which are [+voiced]).

But the main difference between ASC and CSD is - at least as far as the imperatives are concerned - that in ASC all stød-syllables with final [ɒ̯, u̯, i̯, ð] (corresponding to

CSD r, v or ɣ, j or ɣ, and ð) have a short vowel and stød in the following segment. This makes the description of the imperatives more complicated from a taxonomic point of view (cf. bad, bade [bæðʔ], [bæ:ðə] 'bathe (imperative)', 'bathe (infinitive)' with different vowel quantity).

From a generative point of view, there seems to be at least two possible ways of describing this phenomenon:

(1) All imperatives of verbs derived from monosyllables with underlying short vowel plus a single (systematically) voiced consonant except nasals and l are formed by means of a stem formation feature of consonant lengthening.

(2) Imperatives are formed in the same way as in CSD, and there is a later rule (that will be needed anyhow) which moves the stød from the vowel to the following consonant if the latter is [+voiced, -nasal, -lateral].

It should be noted that alternative (1) does not remove the difficulty of explaining what vowels are lengthened before what consonants in what position; e.g. the difference between slid, slide [slið , sli:ðə] 'bother (noun)', 'toil (verb)' and spid, spidde [sbið , sbiðə] 'spit (noun)', 'spike (verb)' is still to be explained.

I shall leave the choice between the alternatives open, but only emphasize that the grammars of ASC and CSD cannot, of course, be looked upon as independent of each other.

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CLOSE AND LOOSE CONTACT ("ANSCHLUSS") WITH SPECIAL REFERENCE TO NORTH GERMAN [1]

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1. Introduction

North German is generally assumed to have a difference in contact (Anschluss, Silbenschnitt), short stressed vowels being described as having close contact (festen Anschluss, scharf geschnittenen Akzent), long and unstressed vowels as having loose contact (losen Anschluss, weich geschnittenen Akzent). [2]

E. Sievers (26, p. 222 ff) was the first to give a detailed description of the difference: "Hier wird der Sonant bei den kurzvocaligen Wörtern (voll, kamm, fass, hat, sollt etc.) durch den folgenden Consonanten in einem Moment abgelöst, wo er noch voll und kräftig ertönt (unmittelbar hinter dem Silbengipfel), der jähe Absturz der Exspiration fällt in den oder die silbenschliessenden Consonanten, die daher kräftig beginnen, aber mehr oder weniger abrupt endigen; bei den lang-

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1) This report is a summary (with various additions and modifications) of two papers: Eli Fischer-Jørgensen, "Untersuchungen zum sogenannten festen und losen Anschluss", and Hans Peter Jørgensen, "Der Intensitätsverlauf beim sogenannten losen und festen Anschluss im Deutschen", both of which were published in 1969 (references 7 and 18). A more detailed account of speakers and material is found in these papers. The acoustic investigations have been carried out by HPJ, the investigations of physiological factors and of duration by EFJ. We are grateful to various staff members and students of the Institute for help. Some of the modifications have arisen from a discussion in the Institute of Communication Research and Phonetics in Bonn.

2) The terminology "checked vowels" versus "unchecked vowels" is more often applied to the distributional difference (presupposing a following consonant versus not presupposing a following consonant).

vocaligen (wōl, kām, lās, rāt, hōlt etc.) erfolgt die Umstellung der Organe für den Consonanten, nachdem der Sonant bereits deutlich geschwächt ist (also eine merkbare Zeit nachdem der Silbengipfel passirt ist); der Consonant setzt daher auch mit nur mässiger Stärke ein, kann aber bei dem langsamen Decrescendo der Silbe deutlich und bequem ausklingen." In dissyllables there is also a difference of syllabic boundary (Sievers 26, p. 225).

Jespersen, who has taken over the distinction from Sievers, gives the following description (15, p. 2o2 ff): "Kommt er [der Konsonant] schnell und bricht den Vokal in dem Augenblick ab, wo dieser am kräftigsten gesprochen wird, so haben wir festen Anschluss ..... Wenn er dagegen erst eine Zeit nach der kräftigsten Aussprache des Vokals kommt, wenn der Vokal also vor Eintritt des Konsonanten etwas geschwächt ist, so haben wir losen Anschluss." Thus Jespersen leaves out the description of the particular initial force of the consonant after close contact, and considers the dynamic movement of the vowel as decisive. If the peak of the vowel is followed by a decrease before the arrival of the consonant, the contact is loose, otherwise close.

Sievers' description is at the same time physiological and auditory ("der jähe Absturz der Exspiration" .... "voll und kräftig ertönt"), Jespersen's purely physiological ("kräftig gesprochen").

According to Jespersen the difference between close and loose contact is found not only in German, but in all Germanic languages, whereas Slavonic and Romance languages have loose contact in all types of syllables. Many phoneticians have accepted Jespersen's description, e.g. Broch and Selmer (1, p. 1o9 ff), L. L. Hammerich (11, p. 58 ff), and, particularly for German, the editors of Siebs, Deutsche Hochsprache, 16. ed. (25, p. 27 ff) (whereas Siebs did not mention this distinction himself). Martens, in his phonetic textbook for German (21, p. 1o5), follows Sievers and Jespersen in considering the short vowel to have a stronger tendency to close contact than the long vowel, but he finds that the type of following consonant is more important, the contact being close before voiceless consonants, loose before voiced consonants.

On the whole, Jespersen's description seems to be widely accepted for North German, Dutch and Norwegian. In Danish the close contact is at least weaker than in German, and it is hardly found in modern Copenhagen pronunciation. Phoneticians have hesitated to accept the difference between close and loose contact for English. Jones does not mention the phenomenon, whereas Heffner uses the terminology "close and loose nexus" (12, p. 183). He identifies his close nexus both with Jespersen's "festen Anschluss" and with Stetson's consonant arrested syllables; but these identifications are not very convincing. As already mentioned, Jespersen considers close contact to be conditioned by short vowels. Heffner, on the other hand, considers it to be conditioned by a following voiceless consonant. Finally, according to Stetson, a consonant can be arresting in all types of closed syllables (cf. e.g. 27, p. 7).

The disagreement is probably due to the fact that the auditory difference is rather subtle. On the other hand, it cannot simply be considered as a convention taken over from one phonetic textbook into the other. The tests carried out by the present authors, as also the tests carried out by Fliflet (8), seem to indicate that phoneticians who have learnt the distinction, react in a meaningful way to test items. There seems to be a subjective auditory dimension which people can be trained to perceive in the same way as e.g. volume for pure tones, and which may perhaps best be described as a feeling of the consonant being more or less intimately connected with the vowel.

A closer examination of syllabic contact is of particular interest for two reasons:

(1) It has been maintained by Trubetzkoy (28, p. 176 ff and p. 196 ff) that the difference of contact should be distinctive in German, whereas the difference of vowel length should be redundant. His main arguments are (a) that by this interpretation it is possible to remove some of the counterexamples to the general law that a language cannot at the same time have distinctive length and dynamic accent, (b) that in final position, where both length and contact are neutralized, and where

the unmarked member of the opposition should be expected to occur, German has only long vowels, evidently without close contact. As 'short' and 'not cut off by the consonant' must be the naturally unmarked members of the oppositions, it must be an opposition of contact. (c) In unstressed syllables we have short vowels with loose contact. (The first of these arguments is not convincing, since it seems to be a tendency rather than a law.) Roman Jakobson (13, p. 24) also sets up a contact feature: "in the case of the so-called c l o s e contact (scharf geschnittener Akzent), the vowel is abridged in favour of the following arresting consonant, whereas at the o p e n contact (schwach geschnittener Akzent), the vowel displays its full extent before the consonant starts". Languages where both stress and length are distinctive are said to be quite exceptional.

(2) The presence or absence of close contact after short vowels seems to be connected with a number of other characteristic features of the languages in question, particularly features of syllabic structure. Languages which are considered to have close contact after short vowels, are generally characterized by a strong dynamic accent, by the lack of a clear syllabic boundary after short vowels, by a relatively high frequency of closed syllables and by a predominance of final consonant clusters. Moreover their short vowels are normally lax, and their voiceless stops in most cases aspirated (with Dutch as an exception). These relations have been treated in more detail by EFJ (3) and by Fliflet (1o).

On this background it may be of interest to ask the following questions:

(a) What are the articulatory and acoustic correlates of the auditory impression, and, in particular, can the phonetic description given by Sievers and Jespersen be confirmed?

(b) Is it possible to set up a separate and independent articulatory or acoustic dimension, or is the auditory impression conditioned by a combination of already known acoustic dimensions (as it is the case with the auditory dimensions volume and brightness)?

(c) What are the most important acoustic cues for the perception of close and open contact?

We have no definitive answers to these questions, but we have tried to give some contributions to a solution, and some suggestions for further investigations.

For this purpose it seems most practical to concentrate on a language in which the difference between close and loose contact seems obvious to many phoneticians, e.g. German.

2. The acoustic and physiological correlates of syllabic contact

2.1. The dynamic movement of the vowel

2.1.1. A physiological examination of the dynamic movement of the vowel might be undertaken by means of electromyography, preferably of the expiratory muscles. We have not had occasion to do this, but it is evidently a desideratum.

A recording of the air flow might also be expected to show a difference, but numerous curves, taken for this purpose and for other purposes, show that the air flow of the vowel is so strongly influenced by the air flow required by the surrounding consonants that e.g. the vowels of both [ta:l] [tɔl] and [ta'lɛnt] will have decreasing air flow, whereas the vowels of e.g. [li:t] [lɪt] and [litur'gi:] will have increasing air flow (we will return to the air flow in the section on the force of the consonant).

2.1.2. As for the acoustic correlate of the loudness movement of the vowel, it is natural to look for it in the intensity movement. It might perhaps also be due to the movement of frequency, but in the material used in this investigation no difference could be detected in the frequency movement of the vowels. Thus the intensity movement remains.

In the paper by EFJ from 1941 (3), the results of a preliminary investigation of the intensity movement of German vowels were given (p. 57 ff). The material consisted of the vowels of two German records. Although at least one of the speakers had a rather pronounced close contact, no difference in the placement of the intensity peak could be detected for either of the speakers. Both in short and long vowels the peak could be found anywhere in the vowel from the beginning to the end with an average around 50%. Also measurements of the absolute distance between peak and end showed complete overlapping.

Later von Essen (2) has examined 16 pairs of words spoken by a German subject. He found a constant difference, but not quite of the sort one should expect according to Sievers. The peak was never found at the very end of the vowel, but the fall after the peak was more abrupt in short than in long vowels, the angle between the base line and a line drawn through the point of the peak and the end point of the vowel being double so large in short vowels as in long vowels. This result is, however, based on a very restricted material, and, moreover, the measurement was made on the oscillogram of the oscillomink, which means that only frequencies below 800 cps are included, that phase differences influence the result, and that the angle changes with the overall intensity of the signal. This investigation does therefore not prove very much.

The present investigation, undertaken by HPJ, is based on a much larger material, and more measurements have been made. The texts consisted of word series of the type piepe, Lippe, tapern, tappe, liebe, lebe, Ebbe, lieb, lob, Grab, Tipp, Topp, ab etc., containing combinations of different vowels followed by the consonants p t k b d g f s m n l. Some of the lists contained also examples of unstressed vowels, but they were not measured. Some of the lists were spoken several times with different word order. A restricted number of examples were also spoken in sentences. There were six speakers, four North Germans (KV, HT, NB and HP) and two coming from the Northern part of the Rheinland (HL and WS). From an auditory point of view they all had close contact after short vowels, although not all of them to quite the same degree, the extremes being KV, who had a pronounced close contact, and HP, who had a relatively weak contact, perhaps due to a long stay in Denmark. The total material consisted of 2066 words with stressed vowels.

The word series and sentences were spoken on tape, and a mingographic recording containing a duplex oscillogram, a fundamental frequency curve and two intensity curves (one without filtering, and one with highpass filtering at 500 cps) was made (see Fig. 1).

The following measurements were carried out: (1) the absolute distance (in cs) from the intensity peak to the end of the vowel, (2) the relative distance from the peak to the end, i.e. the distance in percentage of the total duration of the vowel, (3) the intensity fall (in dB) from the peak to the end of the vowel. The measurement was made on the unfiltered curve, but a measurement of the filtered curve would not have changed the general result.

In some cases the location of the peak was problematic. Fig. 2 shows, in schematic form, the different types of curves and the point chosen as the peak. Type c, with increasing intensity to the very end of the vowel, was found relatively often, both in long and short vowels. In type g it would probably have been more correct to consider the peak as being quite at the end (as in c), because also in this case the vowel has kept its full intensity at the implosion of the consonant (this latter point was chosen in the previous investigation (3)). But the distance from the point chosen (the cross in Fig. 2) to the end of the vowel is generally short in type g, and a different method of measurement would not have given a better distinction of the two types of vowels.

The averages of the different measurements are given in table I. This table also contains a measurement of the steepness of the curve calculated as the fall in dB divided by the distance in cs. This calculation is based on averages only.

It appears from the table that the short vowels do not have their peak quite at the end, but at a distance of 3.5 cs on the average (or 37% of the total duration of the vowel). However, all speakers have a longer distance from the intensity peak to the end in long vowels than in short vowels, the average difference being 4.0 cs. For KV the difference (5.8 cs) is evidently significant, but not for HP (1.7 cs), cf. also the histograms in Figs. 8 and 9.

The relative distance is also longer in long vowels than in short vowels (except for HP where the opposite is the case)

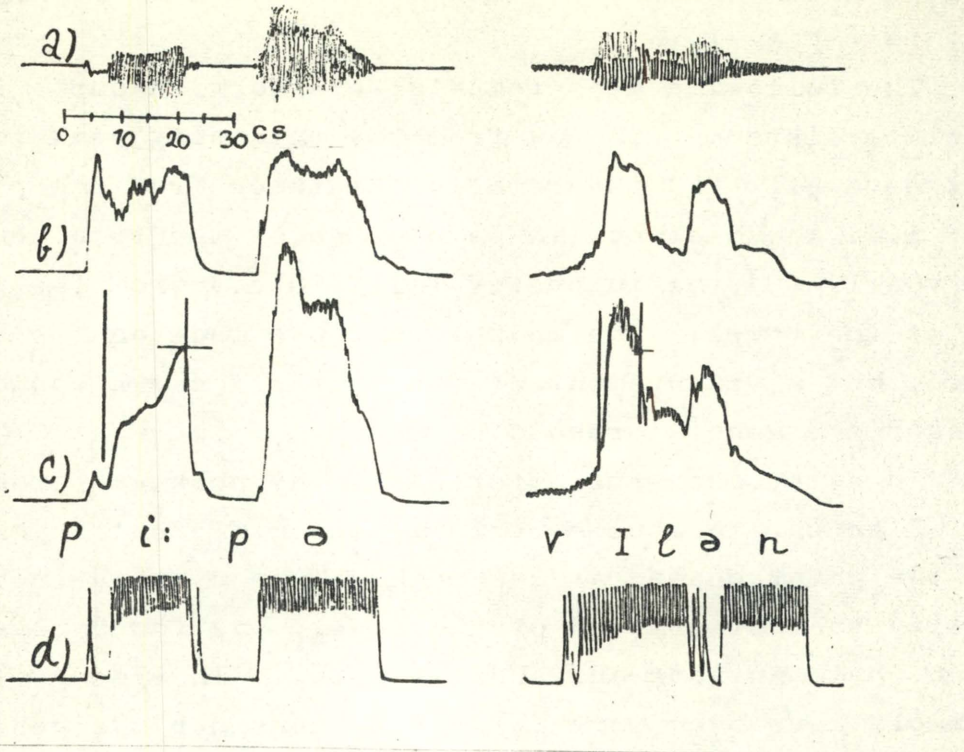

Fig. 1.

a) duplex oscillogram,

b) logarithmic intensity curve, highpass filtered at 500 cps,

c) linear intensity curve without filtering,

d) fundamental frequency curve.

Speaker KV.

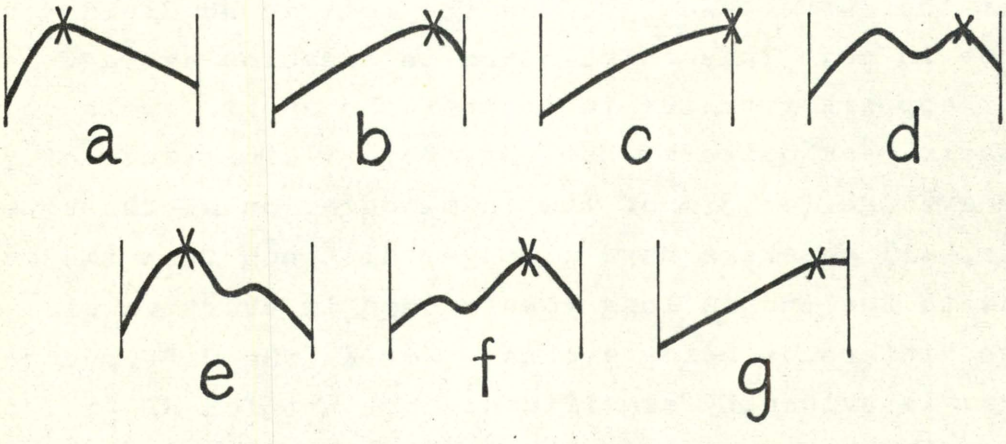

Fig. 2.

Schematic drawing of different types of intensity curves. The point chosen as peak is indicated by a cross.

TABLE I

Placement of intensity peak and fall of intensity in long and short vowels in German

Sp.	N	dist. cs	dist. %	fall dB	steepness dB/cs
LONG VOWELS					
KV	(265)	9.o	5o.4	3.4	o.38
HT	(318)	6.6	36.4	2.2	o.33
HP	(266)	6.o	28.8	2.3	o.38
WS	(142)	8.8	41.4	2.3	o.26
NB	(54)	8.8	49.6	4.2	o.48
HL	(54)	6.o	37.o	3.o	o.5o
General average		7.5	4o.6	2.9	o.39
SHORT VOWELS					
KV	(224)	3.2	37.4	1.9	o.59
HT	(273)	2.8	21.8	1.2	o.43
HP	(238)	4.3	42.o	2.3	o.53
WS	(137)	3.4	31.7	1.7	o.5o
NB	(48)	4.3	44.o	2.7	o.63
HL	(48)	3.1	34.5	2.5	o.81
General average		3.5	36.8	2.1	o.58

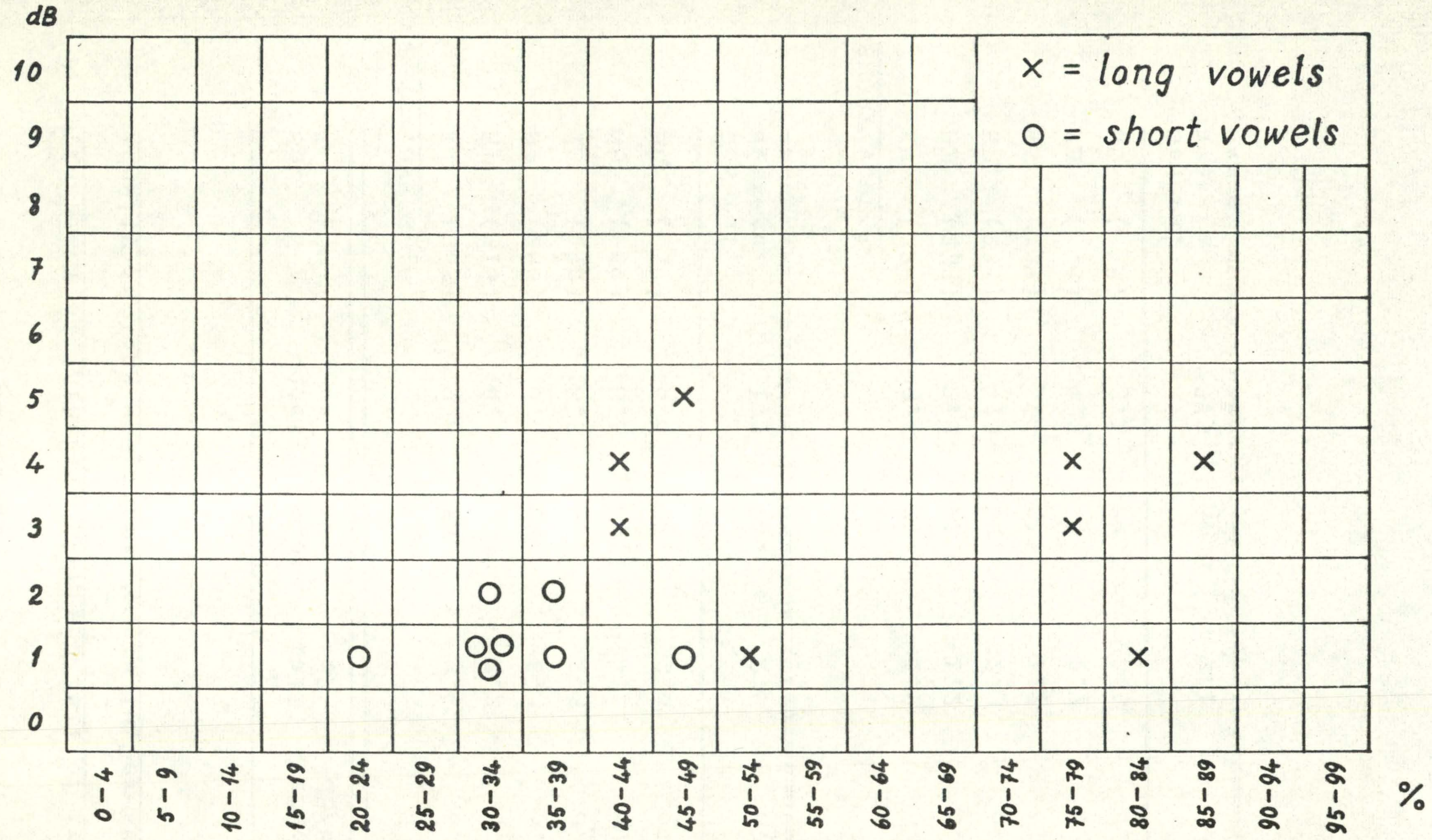

Fig. 3.

Relative distance from the intensity peak to the end of the vowel (horizontally) and fall in dB (vertically). Speaker WS: i:/ɪ + s

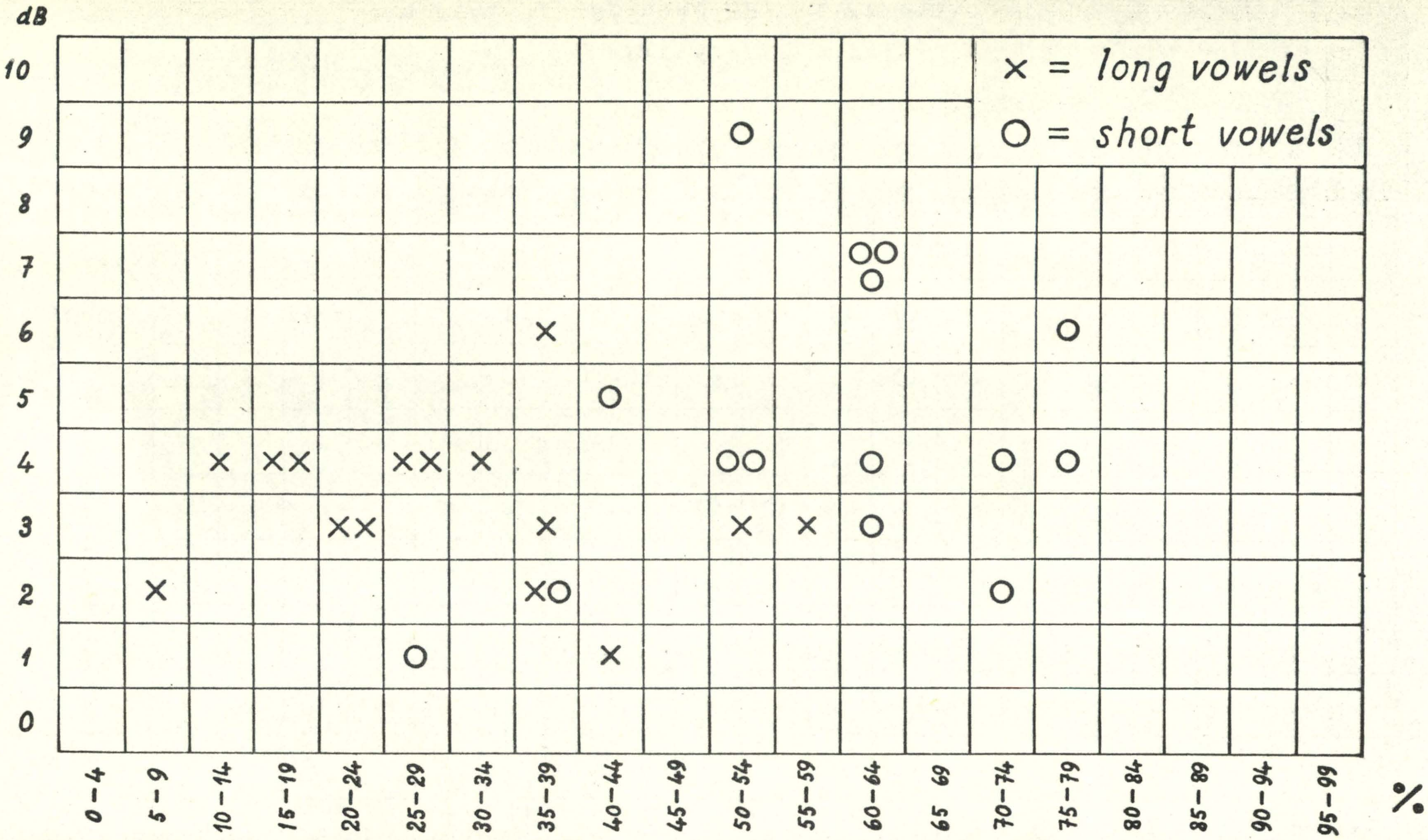

Fig. 4.

As Fig. 3. Speaker HP: a:/a + s

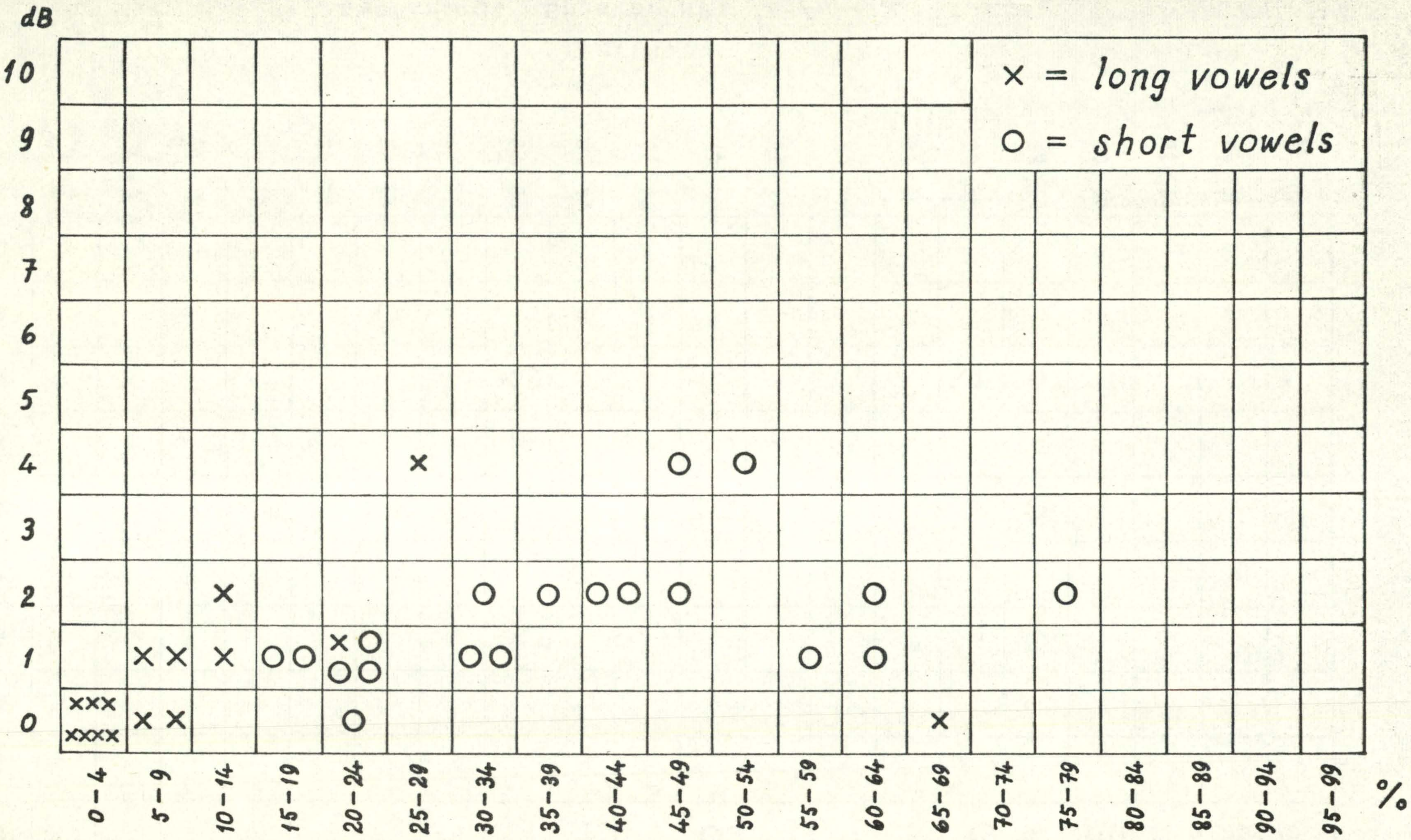

Fig. 5.

As Fig. 3. Speaker HP: i:/ɪ + l

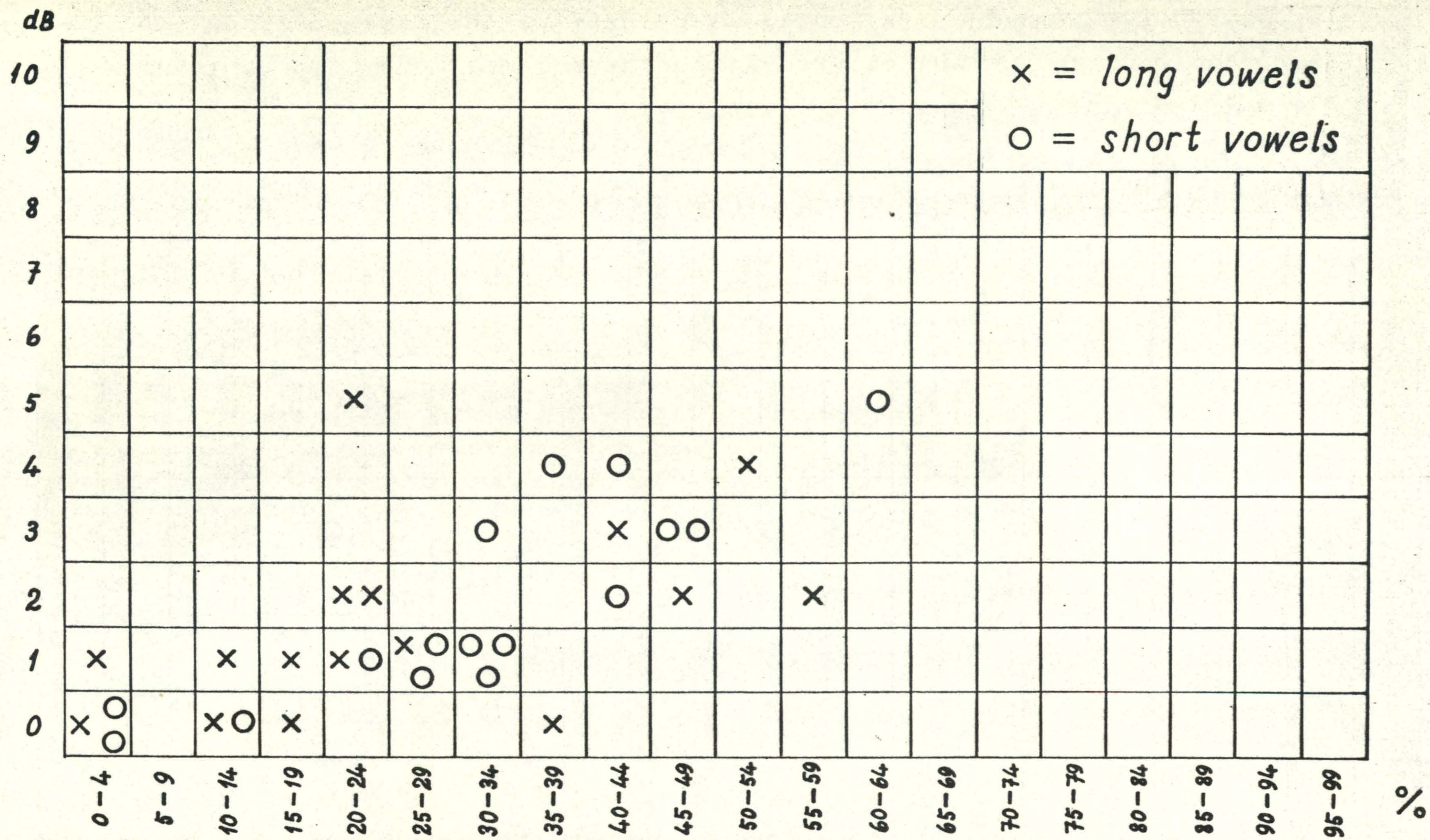

Fig. 6.

As Fig. 3. Speaker KV: a:/a + 1

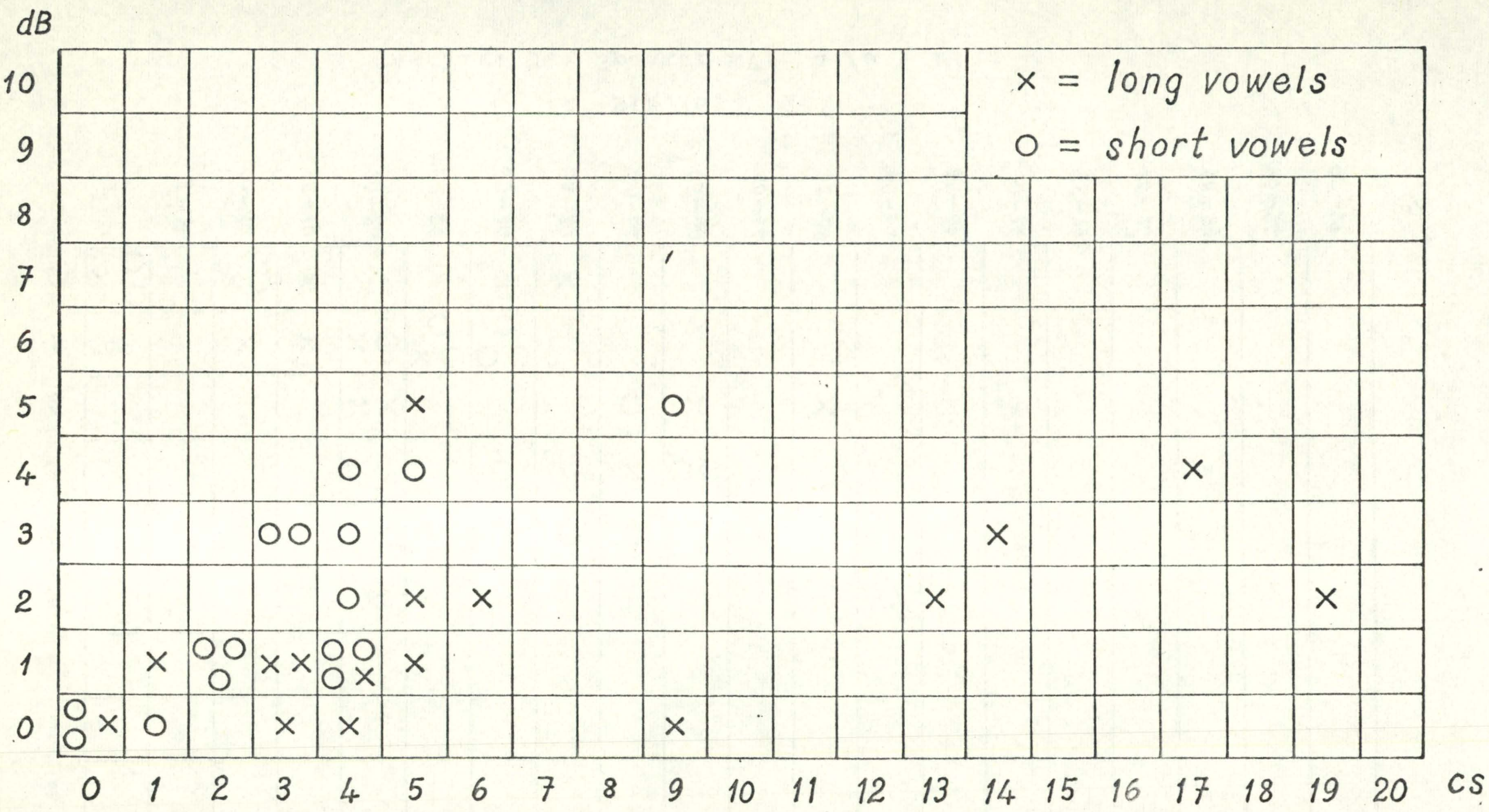

Fig. 7.

Absolute distance from the intensity peak to the end of the vowel in cs (horizontally) and fall in dB (vertically). Speaker KV: a:/a + 1

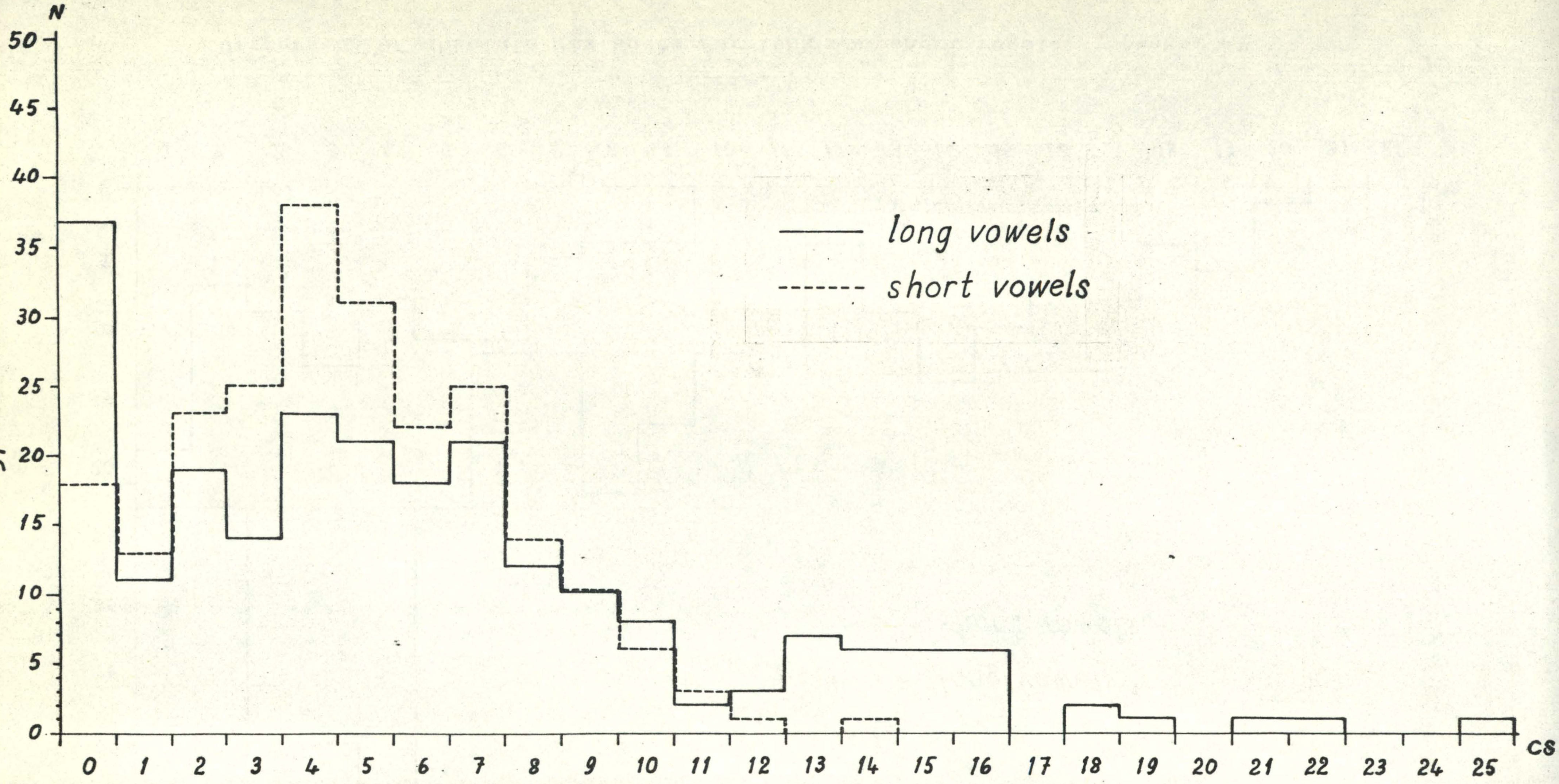

Fig. 8.

Dispersion of absolute distances for long and short vowels. Speaker HP.

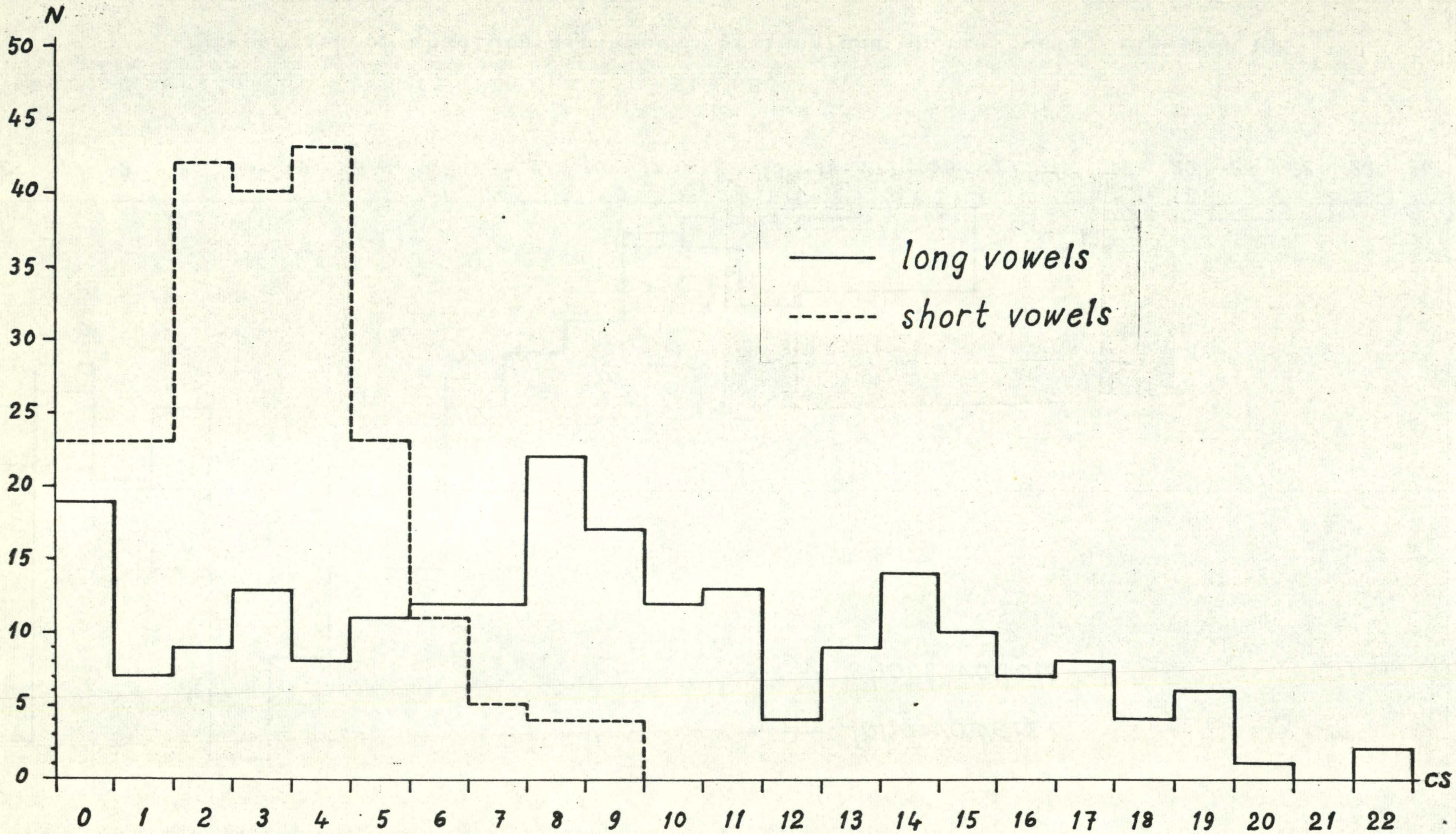

Fig. 9.

Dispersion of absolute distances for long and short vowels. Speaker KV.

the general averages being 4o.6% and 36.9% respectively. However the differences are very small, except for KV, and there is much overlapping between speakers, some of them having a longer distance in short vowels than others have in long vowels.

The fall in dB is greater in long vowels (except for HP, where it is the same), but also in this case the differences are small, the average difference being o.8 dB.

As for the steepness, all speakers have a steeper fall in short vowels than in long vowels, as they should have according to von Essen, but the difference is smaller as that found by von Essen, and it depends solely on the difference in absolute distance (the fall being more extensive in long vowels).

These are, however, average differences. The overlapping of individual examples is large in all cases, even in the case of KV's absolute distance, the most evident of all the average differences (see Fig. 9).

The absolute distance constitutes the most obvious difference between the two types of vowels. But this distance is not independent of the duration of the vowels. In the case of KV, for instance, 4o% of the values for the long vowels exceed the average duration of the short vowels (9.6 cs), which means that in a good many cases the limited duration of the short vowels prevents them from having the same distance from the peak to the end as the long vowels, and only if they were falling from the very beginning, could they have the same average distance as the long vowels. It is also evident that even if long and short vowels had the same relative distance, the absolute distance would be longer in long vowels; this might therefore also be expected to be the case in languages without close contact. For these reasons the relative distance has been examined in more detail than the absolute distance.

For all speakers long and short vowels have been placed in a coordinate system with the relative distance horizontally and the intensity fall in dB vertically (Figs. 3-6). According to Sievers' description the short vowels should be found at the zero point or at any rate close to the zero point, whereas the long vowels (having a long and extensive fall) should be found in the upper right part of the quadrangle. According to von Essen's theory the short vowels should be found above a line from the zero point through the center of the group of long vowels, and if the difference in steepness were very pronounced and due to both distance and fall, the short vowels should be found in the upper left part and the long vowels in the lower right part of the quadrangle.

When all vowels of a speaker is placed in such a diagram, the result is general confusion, both long and short vowels being dispersed over the whole space. Since this might be due to differences in vowel duration caused by the degree of opening of the vowel and the type of the following consonant, individual diagrams were made for each pair of vowels (e.g. i:/I, u:/U) before each consonant (e.g. i/I + t). 190 diagrams of this type were made. They give a very varied picture of the dispersion.

In 68 cases (approximately one third) a positive tendency to a distinction in agreement with Sievers' description can be seen, but only in 27 cases is this distinction clear in both dimensions (Fig. 3 is an example of this type). 19 cases show a directly opposite picture (Fig. 4); it may even be so that the long vowels are found close to the zero point (Fig. 5). In the majority of cases, however, long and short vowels are found all over the space without any clear tendency (Fig. 6). A consistent difference according to vowel quality and following consonant cannot be seen. A distribution in accordance with Sievers' theory is relatively frequent for y+t, e+k and ø+l, but it often happens that vowel + l shows the opposite tendency. Separate diagrams for monosyllables and dissyllables do not give a better distinction either.

There are some differences between the speakers, as can be seen from table II. ("Positive tendency" means agreement with Sievers' theory.)

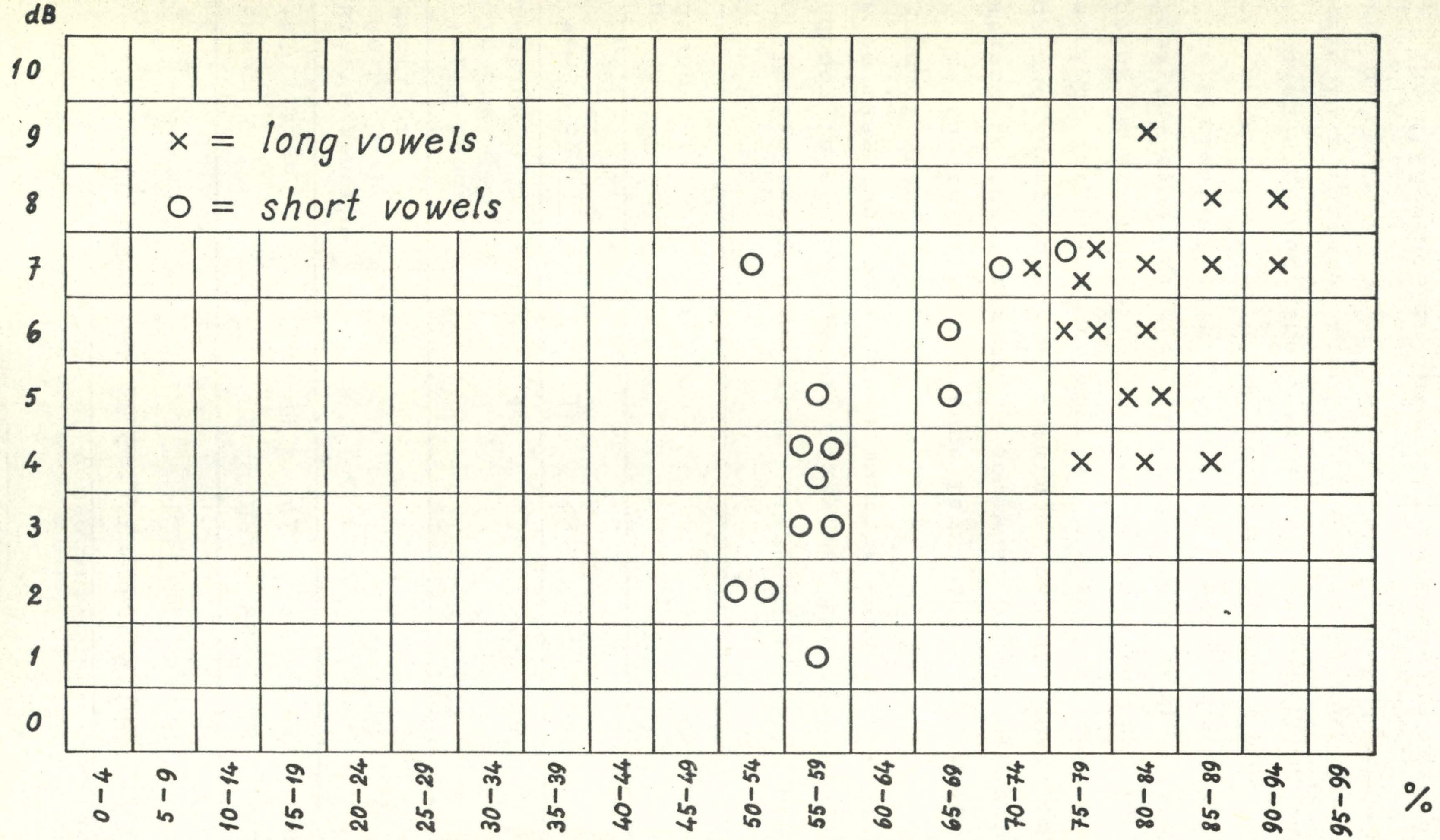

Fig. 10.

Relative distance from the peak to the end of the vowel (horizontally) and intensity fall in dB (vertically). Speaker ML (Czech): a:/a + s

TABLE II

Number of diagrams of consonant-vowel combinations showing agreement or disagreement with Sievers' theory

Speaker	KV	HT	HP	WS	NB	HL	Total
Total number	41	41	41	37	15	15	19o
positive tendency in both directions	8	9	1	5	2	2	27
positive tendency in one direction	12	1o	3	8	4	4	41
no tendency	21	19	3o	22	7	6	1o5
opposite tendency	o	3	7	2	2	5	19

This clearly shows that, although there is a certain tendency in accordance with Sievers, the counter-examples are so many that these cues must be said to have a very low degree of stability.

If the relative distance is replaced by the absolute distance in the diagrams, a somewhat better separation between long and short vowels is obtained, because there is a limit to the right for the short vowels, but even in this case the overlapping is extensive. This can be seen in Fig. 7, which comprises the same examples as Fig. 6, but with absolute distance as the horizontal axis. (This figure, by the way, shows a certain agreement with von Essen's theory.) When all vowels are taken together, the overlapping between long and short vowels in respect of absolute distance is very great (see Figs. 8 and 9).

The difference in intensity movement between short and long stressed vowels in German is thus not consistent, but it may still be true that German vowels have their intensity peak closer to the end than vowels in Romance and Slavonic languages. This requires further investigations, but the comparisons we have made with a restricted material does not show any consistent difference. 45 word pairs spoken by a Czech subject were measured according to the same method as the German words. The speaker has in all cases a relatively long distance from the peak to the end of the vowel (50% or more), so that in this sense she has loose contact in both long and short vowels, but the contact is looser (according to Sievers) in long than in short vowels, and there is a clear distinction between the two groups in both directions. (See Fig. 10.)

One French speaker also had a greater distance from the peak to the end of the vowel than the German speakers, but a preliminary examination of a more extensive French material showed for several speakers a clear tendency to rising intensity in close vowels. Finally a Danish subject with Copenhagen pronunciation and a contact which was very loose from the auditory point of view, had two intensity peaks in most vowels (combined with a falling-rising tone), and both in short and long vowels sometimes the first peak and sometimes the last peak was the stronger of the two.

One might also expect a difference in formant transitions to be associated with close and loose contact, but an extensive material of spectrograms used for formant measurements of German long and short vowels (HPJ 17), did not show any consistent difference. Fliflet (9), on the other hand, has found longer transitions in short vowels than in long vowels in German. The question needs further investigation.

2.2. The force of the consonant

2.2.1. Physiological measurements

Also for the examination of the force of the following consonant electromyographic measurements would be of great interest. It has, however, not been possible to use this method in the present investigation. Instead we have measured the organic pressure at the point of articulation by means of a small rubber bulb connected with an electrical manometer. The material consists of a restricted number of word pairs (113 in all) with short and long vowel followed by a labial consonant. They were spoken by two different speakers, HP and CH, both from Northern Germany.

For f the results are not very reliable because of the relatively weak labiodental constriction. The stops p, b and m, however, show for both speakers a higher pressure after short vowel than after long vowel, both in medial and in final position. The variation is relatively great, which is normal in the case of lip pressure, but when the words are compared in pairs, the difference is found to be statistically significant at the 1% level for CH and at the o.1% level for HP, and in most cases it exceeds the motoric difference limen found by Malécot (19).

Besides the organic pressure the duration of the consonant seems to give a good indication of the force of articulation (EFJ 6, pp. 73, 8o and 1o5). The present investigation shows that both speakers have a longer consonant after short vowels than after long vowels. Moreover there is an evident correlation between duration and organic pressure in the sense that a particularly great difference in organic pressure corresponds to a great difference in duration. This can be seen in table III which shows the percentual increase of organic pressure and duration after short vowels compared to long vowels.

TABLE III

Percentual increase of lip pressure and duration of the consonant after short vowels compared to the values found in the position after long vowels

cs	-p-	-p	-b-	-m-	-m	-f-	-f
CH							
number	(8)	(12)	(6)	(15)	(6)	(13)	(1o)
lip pressure	1o%	12%	52%	2%	4o%	(-4%)	(27%)
duration	12%	11%	27%	2o%	44%	58%	22%
HP							
number	(8)	(12)	(8)	(12)	(8)	(8)	(7)
lip pressure	55%	7%	84%	92%	12%	(11%)	(47%)
duration	42%	7%	71%	58%	1o%	33%	21%

The same correlation is seen by a comparison between the two phenomena medially and finally for p and m, both speakers having higher lip pressure and longer duration in final m than in medial m, and lower lip pressure and duration in final p than in medial p (with the exception that CH has higher lip pressure (and also longer duration) in final p than in medial p after short vowel). There is no difference in the rate of increase of the organic pressure after short and long vowels.

The relative prolongation of the consonant after short vowel is confirmed by a larger material comprising 1142 word pairs spoken by ten different subjects, the seven speakers mentioned above and three others, two North Germans (WL and GR) and one from the Rheinland (GJ). All ten speakers have longer consonants after short vowels than after long vowels, the general average being a prolongation of 27% and the individual averages ranging from 10 to 74%.

The long vowel is for all subjects approximately twice as long as the short vowel. This means that the relation C/V (the relative duration of the consonant compared to the vowel) would give a still greater difference between the two word types than the simple duration of the consonant. This relation is, however, very variable due to the specific durations of different types of vowels and consonants and to the influence of the consonant on the duration of the vowel. For most speakers the relation is, e.g., higher for long vowel + fs than for short vowel + l.

As a third indication of force of articulation, one might think of the air flow. The air flow at the moment of transition from vowel to consonant has been measured by means of the aerometer in 292 word pairs with following ptk bdg and fs, spoken by four subjects (KV, HT, HP and WS). All speakers have stronger air flow after short vowels than after long vowels, and the difference is significant at the 0.1% level, except for HT's stops. The percentage of word pairs showing a stronger air flow after short vowels is for the four speakers 93, 67, 83 and 80 respectively. The relative increase of air flow after short vowels can be seen in table IV.

TABLE IV

Relative increase of air flow after short vowel compared to the air flow after long vowel (number of examples in parentheses)

Speaker	KV		HT		WS		HP	
	N	%	N	%	N	%	N	%
ptk	(24)	31	(26)	5	(46)	22	(42)	21
bdg	(6)	43	(6)	8	(2o)	13	(1o)	11
fs	(3o)	61	(41)	26	(16)	12	(25)	32

A further difference can be seen in f and s. The air flow curve for these consonants has generally two peaks, one just at the start and one at the end of the consonant. After short vowels the first is relatively higher, after long vowels the second. This is true not only of dissyllables, as giessen, bissen, but also of monosyllables of the type misst, giesst (but not finally).

The intra-oral air pressure of the consonant has been measured in 138 pairs with stops and fricatives for two speakers (HP and CH). It was found to be higher after short vowels, and the difference is significant (except for HP's fs, which showed the opposite tendency), but the differences are relatively small (5% for pt and 21% for bd for both speakers, 22% for CH's fs and -5% for HP's fs), and for most consonants they are below the motoric difference limen found by Malécot (2o). There was no constant difference in the rise of the air pressure.

2.2.2. Physical intensity of the consonant

Corresponding to the differences found in the physiological curves, one should expect to find a difference in physical intensity. It has, however, not been possible to find any difference in the case of stops and fricatives. As for the stops, they have normally a very weak implosion, which is hardly measurable, and no difference could be detected on the mingograms neither in the implosion nor in the explosion. As for the fricatives, there was no difficulty of measurement, but no difference of intensity could be seen, although the difference of air flow and duration was clear. Now, the relation between force of articulation and physical intensity is rather complicated in the case of fricatives, since the constriction of a fortis consonant may be narrowed beyond the point where the relation between air flow and constriction is optimal for the production of noise. It is possible that the difference of duration is sufficient to give an impression of stronger intensity, although the difference amounts to only some 1o-2o%. As far as the stops are concerned, one cannot exclude the possibility that oscillograms taken at high speed might show some differences in the implosion.

In the nasals and l, however, a tendency to stronger intensity after short vowels is apparent, although for these consonants no difference of air flow was visible, only a difference of duration and (in m) of lip pressure.

The average intensity of the first 5 cs of m, n and l was measured and compared with the last 5 cs of the preceding vowel for the speakers KV, HT, HP and WS. The tendency to stronger consonant after short vowel than after long vowel is particularly evident for HT, and in some combinations the consonant is stronger than a preceding short vowel, but weaker than a preceding long vowel. For the speakers KV, HP and WS the tendency is, however, not so clear, and when all words with the same sound combination (e.g. y:/Y + t) are taken together, the tendency is only evident for e:/ɛ and ø:/œ. However, if the words are compared in pairs (Höhle/Hölle etc.), the tendency is evident for HT, KV and WS, but not for HP. This can be seen from table V.

TABLE V

Percentage of pairs in which the consonants l, m, and n have stronger (a) or weaker (c) intensity after short vowel than after long vowel, or the same intensity after long and short vowels (b)

	Number of pairs	a stronger	b same	c weaker
HT	1o2	76%	19%	5%
KV	9o	78%	11%	11%
WS	48	67%	1o%	23%
HP	89	38%	2o%	42%

3. Is there an independent acoustic or physiological dimension corresponding to the impression of contact?

If the curves had shown an evident and stable difference in the intensity movement of the two types of vowels, it would have been possible to consider this as a separate acoustic dimension. But, as shown above, the overlapping is so extensive that this is not possible.

On the physiological plane one might think of the air flow at the implosion as a specific correlate to syllabic contact, although no difference could be seen for l (the nasals must be left out of consideration, since only the air flow from the mouth was recorded). E. A. Meyer (23) considered this as the decisive factor, languages with close contact being characterized by a more open position of the glottis, and consequently by aspirated consonants, lax vowels with relatively strong air flow, and audible noise at the implosion. This sounds very plausible (although, as mentioned above, Dutch constitutes an exception as it has unaspirated stops, but short lax vowels), and it may be the best explanation of the differences found between Germanic languages on one hand

and Romance and Slavonic languages on the other (this has also been emphasized by A. Thelin in an unpublished thesis), but it can hardly be set up as an independent dimension in German, at any rate if we look for a phenomenon which should be characteristic of the transition from vowel to consonant, for the stronger air flow in words with short vowels is not restricted to the implosion, it is found throughout the preceding vowel, and even in the initial consonant (in 74% of 114 comparable pairs with initial ptkbgvfh). It might therefore be more correct to consider it as a characteristic of short syllables without direct correlation to the contact phenomenon. Very restricted material from Danish, French and Swiss German shows a similar, although weaker, difference between syllables with long and short vowels. In German the difference may be enhanced by the laxness of the short vowels.

The remaining factors are differences of duration and of consonant intensity. The correlation to vowel duration in stressed syllables (but not in unstressed syllables) is evident, but this is not a separate contact dimension. The differences of consonant duration and intensity are less stable, but evidently not accidental. Fliflet is probably right, when he states (10) that a syllable with a short and lax vowel + a long strong consonant will be perceived as having close contact, whereas a syllable with a long and tense vowel + a short and weak consonant will be perceived as having loose contact. But, as he demonstrates, this is not only valid for Germanic languages; there is a widespread tendency in various languages to combine vowel and consonant types in this way, although this tendency is not universal. (In Danish, for instance, consonants are not usually longer after short vowels than after long vowels, see EFJ (4), p. 46, and (5), p. 188). Anyhow, this is not a simple and independent physiological or acoustic cue for the perception of contact.

We seem to be faced with a perceptual phenomenon, which has complex correspondences both acoustically and physiologically. In this case it is important to investigate the relative importance of the cues. On the basis of our material we can only do this for the acoustic cues.

4. The relative importance of the acoustic cues

4.1. Comparison of speakers

Some very preliminary conclusions might be drawn from the fact that, according to the subjective impression, some speakers have a closer contact than others, the extremes being KV (with a very close contact after short vowels) and HP (with a relatively loose contact). The measurements show that KV's short vowels have a shorter absolute and relative distance from the peak to the end of the vowel, and a less pronounced intensity fall than HP's short vowels, whereas the difference in steepness is negligible. On the other hand NB has almost the same averages as HP, and his contact sounds almost as close as that of KV. HP has more overlapping between the two types than KV, but this is above all due to the fact that his long vowels have a shorter distance from the peak to the end of the vowel than the long vowels of the other speakers (in many cases the peak is quite at the end of the vowel) and that the intensity fall of his long vowels is relatively small, whereas KV's long vowels have a particularly long distance to the peak and an extensive fall. Thus the contact of HP's long vowels should sound relatively close, but this was not obvious. As for the physical intensity of lmn, HP has no difference after long and short vowels, and KV has a clear difference. On the other hand, HP's difference of lip pressure and duration is larger than that of CH, whose short vowels sound quite typical. Out of ten speakers HP has even the next highest prolongation of consonants after short vowels (47%), and one of the highest C/V relations. The absolute duration of his vowels is, however, longer than those of KV, HT or CH.

According to these observations the peak placement should be more important than the relation between vowel and consonant, but the conclusions are not very safe.

4.2. Test

4.2.1. In order to get a better measure we made a test consisting of 84 German words taken from the tapes used for the acoustic measurements and (for comparison) two Czech, two

French and two Danish words, thus 9o words in all, of which 67 should have close contact, and 23 have loose contact, according to the traditional description. The words were chosen in such a way that there were two or more examples of the same or similar words differing in respect of duration or of the dynamic movement of the vowel. These similar examples were placed close to each other on the test tape, and the listeners were allowed to go back and forth on the tape and repeat the words. The listeners were eight Danish phoneticians and dialectologists, who were familiar with the concept of close and loose contact. They were asked to judge each word in respect of close and loose contact on the basis of a seven point scale comprising the steps (1) very close, (2) close, (3) close rather than loose, (4) questionable, (5) loose rather than close, (6) loose, (7) very loose.

The listeners found the test meaningful, and the answers do not seem to be accidental. All steps in the scale were utilized, the percentage of utilization being (1) 19%, (2) 3o%, (3) 19%, (4) 5%, (5) 8%, (6) 12%, (7) 7%. It is worthy of note that No. 4 (questionable) comprises only 5% of the answers, that the extreme judgments (1) and (7) are never found together for the same word, and that (1) and (6) were only combined in 6 words, and similarly with (2) and (7). This may, however, to some extent be due to theoretical knowledge about the "right" answers. Most of the German words were immediately recognizable as German, and, with exception of the word "lieb", all German words with long vowels were heard as loose, and all German words with short vowel as close by the majority of the listeners. But none of the 8 listeners distributed their answers mechanically in this way. They all heard some short vowels as loose and (with one exception) some long vowels as close, and the three degrees in each group were fully utilized. The two Czech words (bas and basu) were heard by the majority as close, and the two French words (basse and dix) as loose, whereas the two Danish words in Copenhagen pronunciation (kasse, bisse) were almost evenly distributed on loose and close.

There was little evidence for the assumption that voiceless consonants should have closer contact than voiced consonants (cf. Martens and Heffner). The average answers were:

<u>short vowel:</u> +<u>sf</u> 2.3 +<u>lmn</u> 2.5 +<u>ptk</u> 2.7 +<u>d</u> 3.o

<u>long vowel :</u> +<u>s</u> 6.o +<u>ptk</u> 6.1 +<u>l</u> 6.9

(there were no examples of long vowel + <u>d</u>, <u>m</u>, <u>n</u>).

In view of the restricted number of examples, the only thing that can be said is that long vowel + <u>l</u> sounds definitely loose.

A consideration of the number of "loose" answers for short vowels, and "close" for long vowels gives a similar result:

<u>answer "loose" for short vowels:</u>	+<u>ptk</u> 11%	+<u>sf</u> 3%
	+<u>lmn</u> 3%	+<u>d</u> 0%
<u>answer "close" for long vowels :</u>	+<u>ptk</u> 19%	+<u>sf</u> 13%
	+<u>l</u> 0%	

<u>4.2.2.</u> The question of the <u>relative importance of the acoustic cues</u> was examined in different ways.

First the words were divided into five large groups: A, heard as close by all listeners, B, heard as close by the majority, C, heard as loose and close by equal numbers of listeners, D, heard as loose by the majority, E, heard as loose by all listeners. For each of these five groups separate averages were calculated for (1) vowel duration, (2) consonant duration, (3) consonant/vowel relation, (4) absolute distance from intensity peak to the end of the vowel, (5) relative distance, (6) fall in dB. The results are given in Fig. 11. There is an evident correlation between vowel duration and the five groups of answers from close to loose, and a certain correlation with the C/V relation, but as the consonant duration does not show anything, the agreement with the C/V relation must simply be dependent on the correlation with vowel duration. A certain correlation can also be seen for absolute distance, but, as mentioned above, this is partly dependent on the duration of the vowel. The other acoustic factors do not seem to have any influence on the answers. Steepness has been left out because it could only be calculated for part of the examples (not for those with zero fall), but it did not show any consistency either.

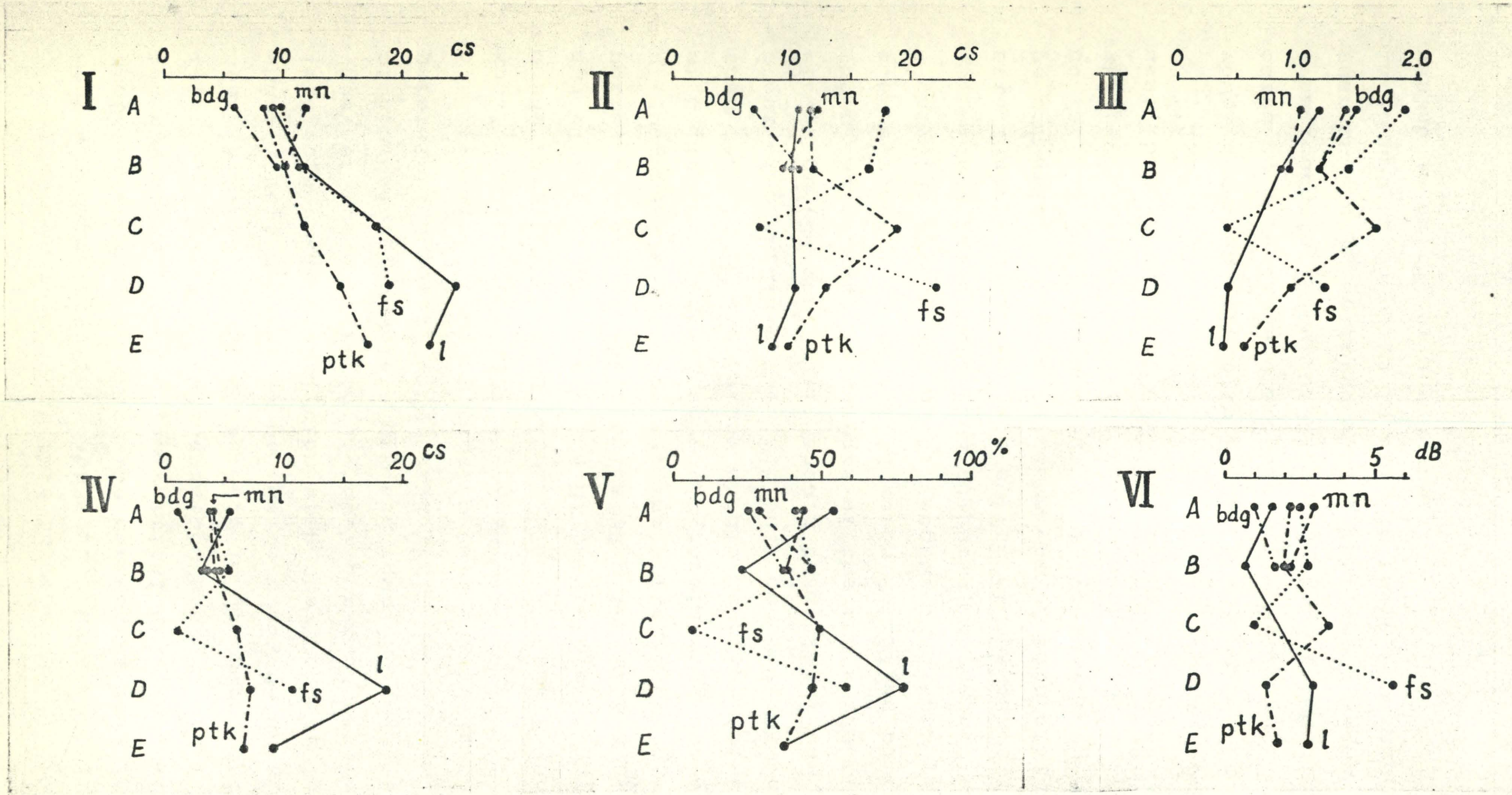

Fig. 11. Graphical presentation of the answers to the listening test divided into five groups (A. all judgments: close, B. majority of judgments: close, C. equal number of judgments: close and loose, D. majority of judgments: loose, E. all judgments: loose) and compared to the average values of I. vowel duration, II. consonant duration, III. cons./vowel, IV. absolute distance, V. relative distance, VI. intensity fall for ptk, bdg, fs, mn, l.

In order to examine this in more detail the average judgement was calculated for each word, and a number of scatter plots were made, in which the horizontal axis indicates the average judgements and the vertical axis the different acoustic factors. Only for vowel duration could a clear correlation be seen (Fig. 12). The difference in judgement between long and short vowels may partly be due to previous knowledge, but there is also a clear correlation with the group of long vowels. (Because of the difference of vowel duration before different types of consonants, vowels + ptk and vowels + fslmn were plotted separately and vowels + bdg were left out.)

Finally, in order to eliminate the influence of theoretical knowledge entirely, the judgements of identical or very similar words were compared in pairs, e.g. KV Güte I and II, HP Latte and HT Latte, HT hassen and HT passen etc. There were 65 such pairs, and out of these pairs 32 pairs with a clear difference of judgement were selected, the criterion being that (1) 5 out of 8 listeners should agree in considering one as more close than the other, and nobody should have the opposite view (or 6 out of 8 should agree, and only one have the opposite view etc.), or (2) that there should be at least one full step between the average judgements of the two words (e.g. 5.6 versus 6.6 or more). 23 of the 32 words fulfilled both conditions, 4 only the first, and 5 the second.

These pairs were then compared in respect of the 7 acoustic factors mentioned above (for steepness only 16 pairs could be compared, since in 14 cases one or both of the members had no fall). The result is given in table VI, where + indicates shorter distance, smaller fall, shorter vowel, longer consonant, higher value of C/V and greater steepness.

The result is that there is an evident correlation with vowel duration, since in 29 out of 32 pairs the member indicated as more close has a shorter vowel. This correlation is even found in 19 out of 24 pairs where the majority is smaller than in the 32 selected pairs, i.e. the agreement is found in 48 out of 56 pairs in all (in the 8 remaining pairs there was no majority for any answer).

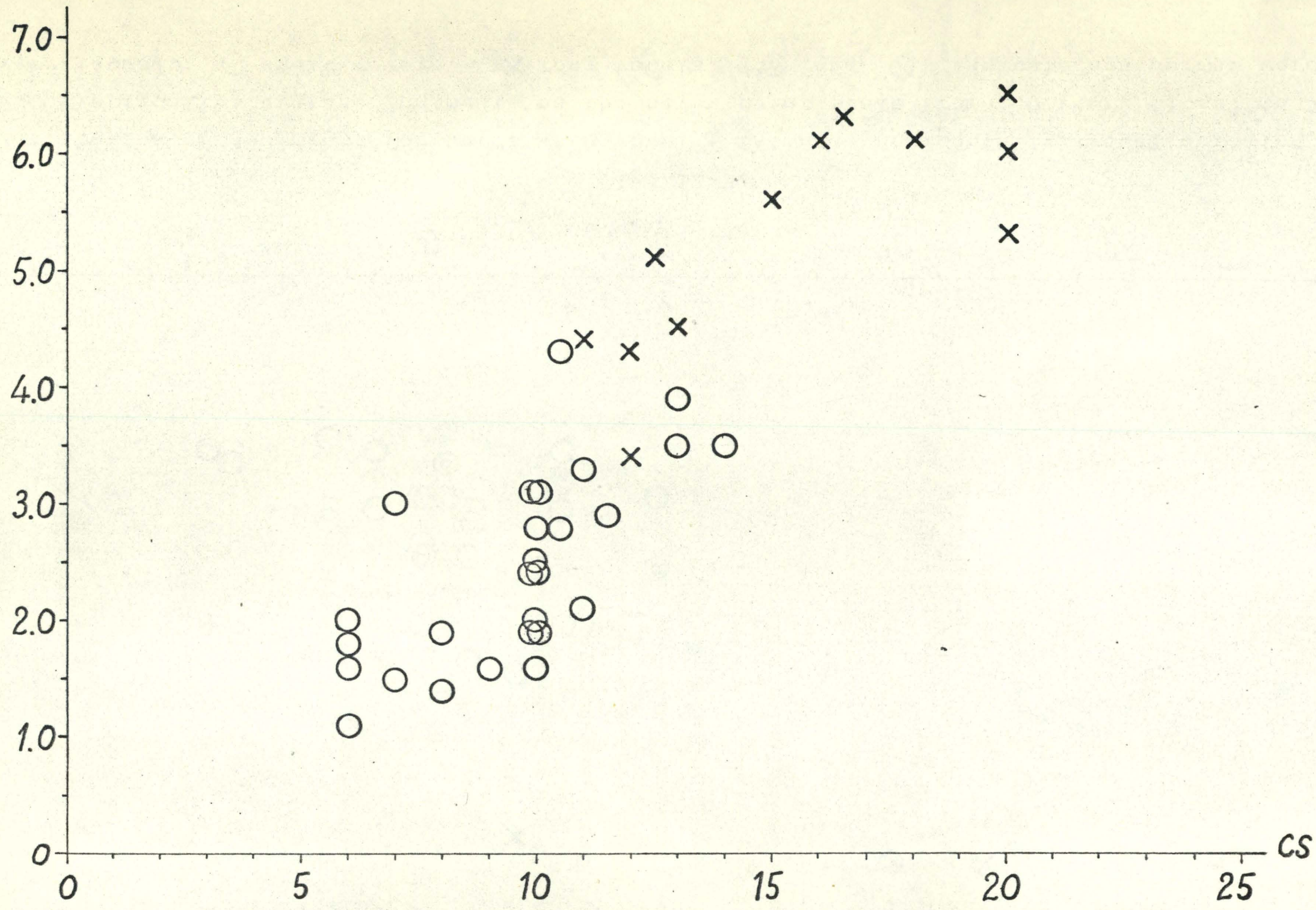

Fig. 12-A.

Distribution of judgments for words with vowel + ptk. Horizontally: vowel duration in cs. Vertically: average judgments on the seven point scale from 1.0 (very close) to 7.0

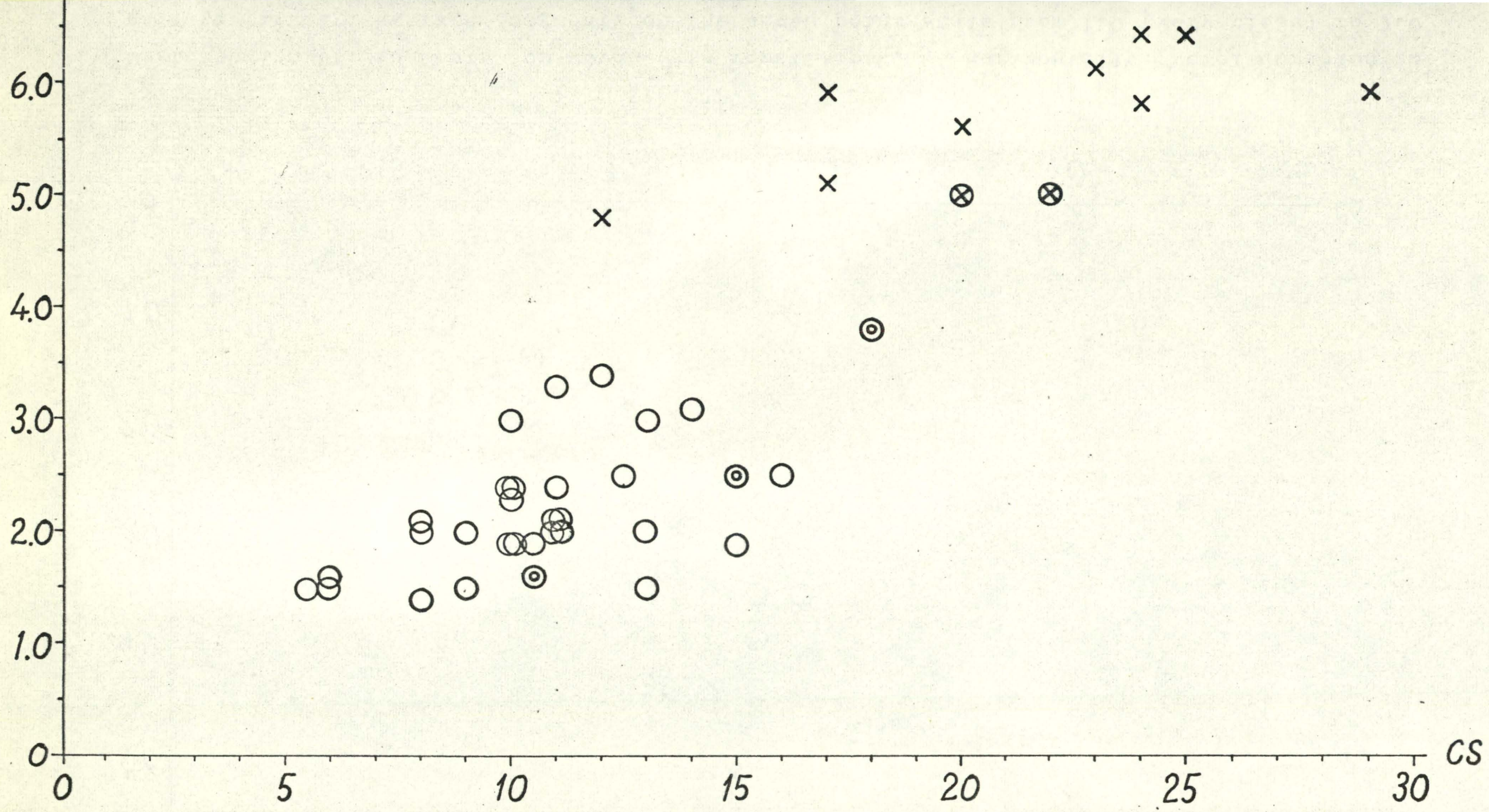

Fig. 12-B.

Distribution of judgments for words with vowel + fslmn. Horizontally: vowel duration in cs. Vertically: average judgments on the seven point scale from 1.0 (very close) to 7.0 (very loose). ○ short vowels, × long vowels. ⊚ and ⊗ indicate non German words.

TABLE VI

Acoustic factors connected with the impression of closer contact in pairs of similar words

	Duration			Intensity			
	V	C	C/V	abs. dist.	% dist.	fall	steepness
+	29	15	22	18	17	14	1o
0	2	1	5	4	3	5	1
-	1	16	5	1o	12	11	5

There is also a correlation with the C/V value, but in 15 out of 22 positive cases it is vowel duration that is the exclusive or dominating factor, not consonant duration. The absolute distance and the steepness may have some influence, but in all cases where the distance or the steepness are positive, the influence can also be ascribed to the vowel duration, whereas on the other hand there are many cases with long distance or weak slope which are nevertheless heard as close. The only thing which is proved is thus the influence of the duration of the vowel.

This is in good agreement with a test carried out by A. L. Fliflet, containing a great number of words from many languages, and of which he has given a brief report in (8). He used tape cutting and splicing, cutting the vowel from the start or the mid part of the consonant, and thus leaving the transition from vowel to consonant untouched. Fliflet found that a shortening of the vowel might change the perceptual impression of contact and syllabic structure completely, so that a word with pronounced loose contact before the cutting was heard with pronounced close contact after the cutting. However, he also found that the duration and perceptual loudness of the following consonant was of importance (but the loudness of the consonant was found to depend partly on its duration). This does not appear from our test, except that the duration of <u>s</u> seems to have some influence on the judgement. The acoustic intensity could only be compared for 14 pairs, of which 7 belong to the group with a clear majority, and here no correlation could be found. But the number of examples is too small. This problem needs further investigation.

According to the present investigation the impression of syllabic contact seems to be influenced predominantly by the duration of the vowel, and, according to Fliflet also, but not quite to the same extent, by the duration (and loudness) of the following consonant. This again shows that there is no independent acoustic (or physiological) dimension corresponding to the perceptual dimension of contact. It is based on a complex of already known acoustic dimensions.

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FALLING WORD TONES IN SERBO-CROATIAN

Per Jacobsen

In an earlier paper (ARIPUC No. 2/1967) I examined the Serbo-Croatian word tones. It turned out that the long falling and short falling word tones differ markedly in the tone contour of the accented syllable. The long falling word tone (^) has a marked rising-falling tone with a difference of up to one octave between the peak, which is in the first third of the vowel (syllable), and the final tone level of the vowel. The short falling tone (ˮ), on the other hand, is not characterized by any particular tone movement but may be slightly rising, slightly falling, or slightly rising-falling with a peak in the middle or in the second half of the vowel (syllable). In polysyllables with ˮ the tone level of the second syllable (^ as well as ˮ can occur only on the first syllable) is lower than the final tone of the first syllable. Moreover, the second syllable of polysyllables with ^ or ˮ has less intensity than the first syllable.

The falling word tones ^ and ˮ are opposed to short and long rising word tones, which are characterized by higher tone and more intensity on the syllable after the ictus than on the ictus syllable.

The present paper deals with the two falling word tones, the purpose being to examine whether these differ first and foremost in length, or whether the very different tone contours are in themselves sufficient to establish a distinction between the tones.

The best way to answer this question would be to produce minimal word pairs by means of speech synthesis, the parameter of tone being kept constant whilst the parameter of duration was varied, and vice versa. Since this was not possible, I had a native Serbo-Croatian, Mira Adum, M.A., who teaches Serbo-Croatian at the University of Copenhagen, speak some minimal pairs of words:

a) kȉm [kìm] 'caraway'

b) kîm [kì:m], instr. sing. of ko 'who'

c) dȕga ['dùgɑ] , nom. sing. fem. 'long'

d) dûga ['dù:gɑ] , gen. sing. 'debt'

These words were recorded on tape, using the sound treated room of the Institute of Phonetics. They were spoken in two ways: in normal pronunciation (examples of set I) and with deviating duration, the words with a short falling tone (kȉm, dȕga) being drawn out while the tone in the accented syllable was kept as constant as possible (level tone contour), whereas the words with a long falling tone (kîm, dûga) were spoken with a shorter duration but with preservation of the characteristic rising-falling tone contour (see Fig. 1 - 4).

Among a great number of "pseudo-synthetic" words produced in this way I chose a set of examples (II) in which the words of each contrasting pair (kȉm-kîm and dȕga-dûga) had physically equally long (accented) vowels but exhibited a difference of the kind described above between short falling and long falling tone contour. Similarly, I chose a set of examples (III) in which the vowels with rising-falling tone contour (characteristic of ⌒) had the same physical duration as the vowels in the corresponding words with ‟ in normal pronunciation, and in which the vowels with a level tone contour had the same physical duration as vowels in the corresponding words with ⌒ in normal pronunciation (i.e., the examples of III were selected in such a way that the durations were opposite to what would be expected). The tone movements and durations measured in these examples (Fig. 1 - 4) are given in Tables 1 and 2 below.

The examples were recorded on tape in a quasi-random order and played back to a number of native speakers, who

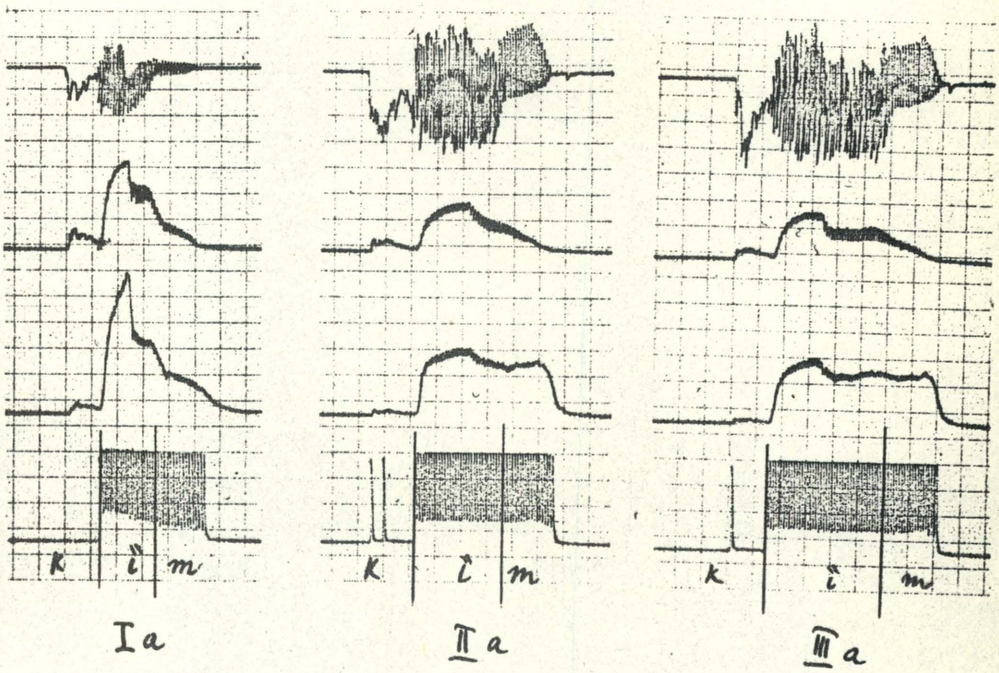


Fig. 1

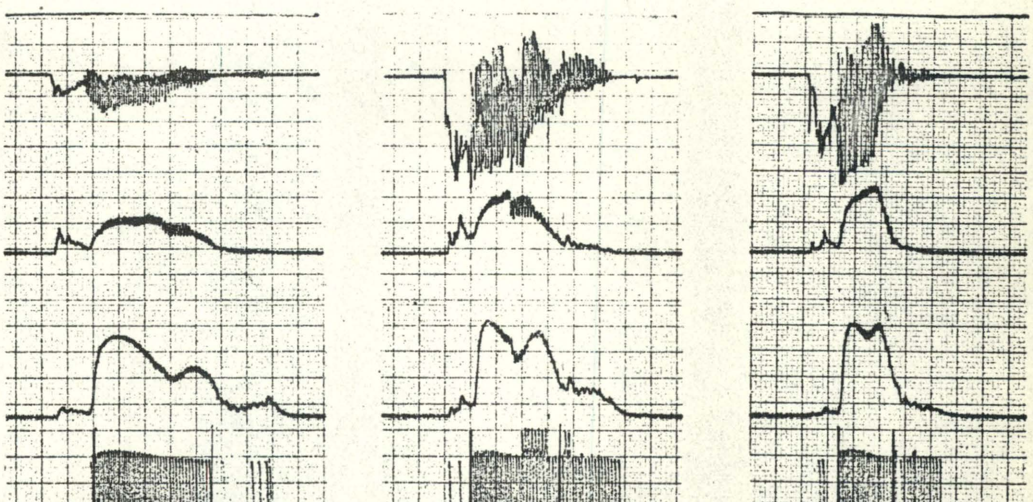


Fig. 2

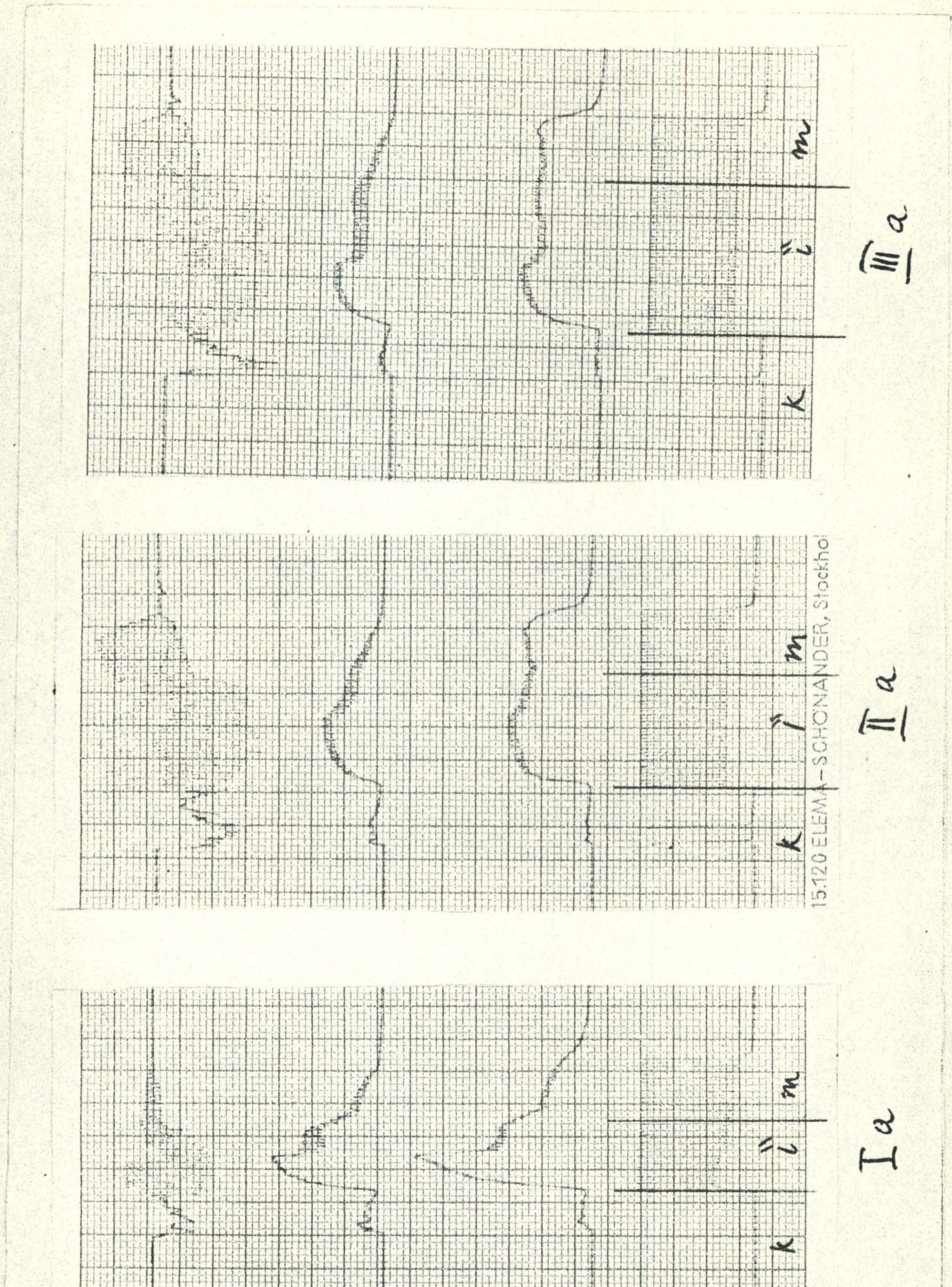


Fig. 1

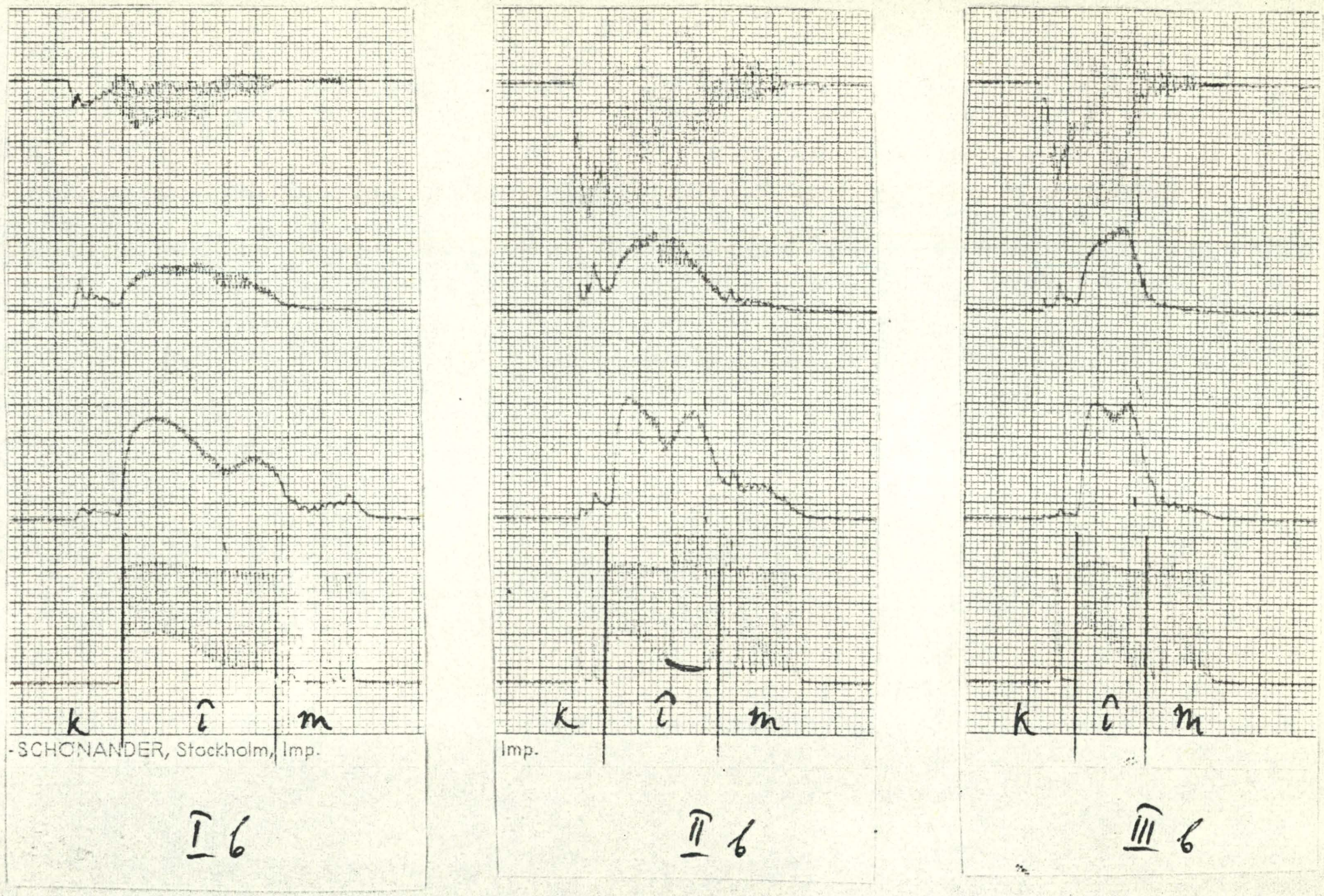
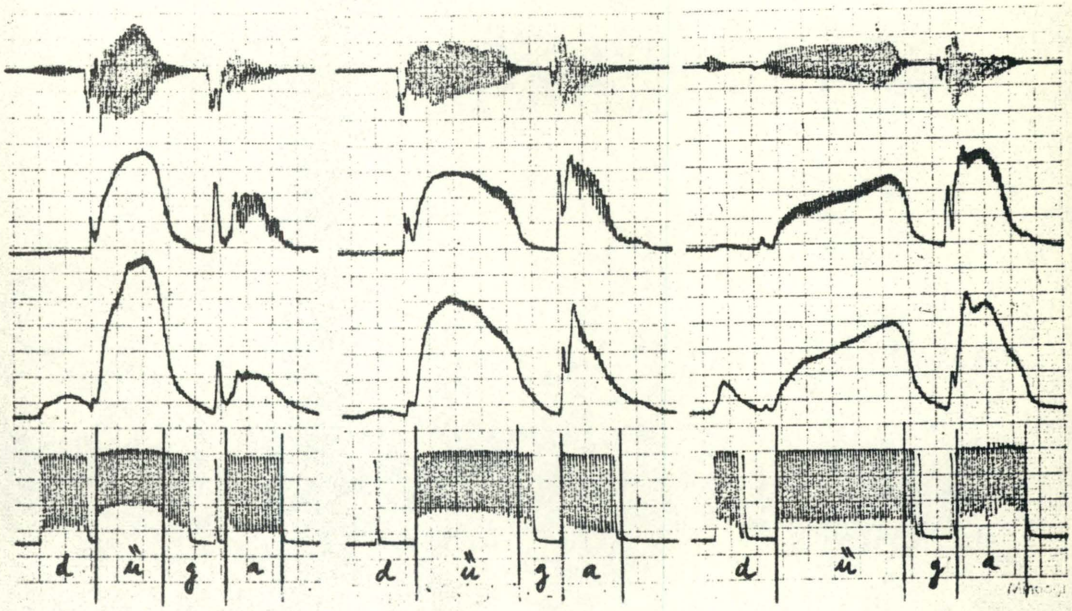
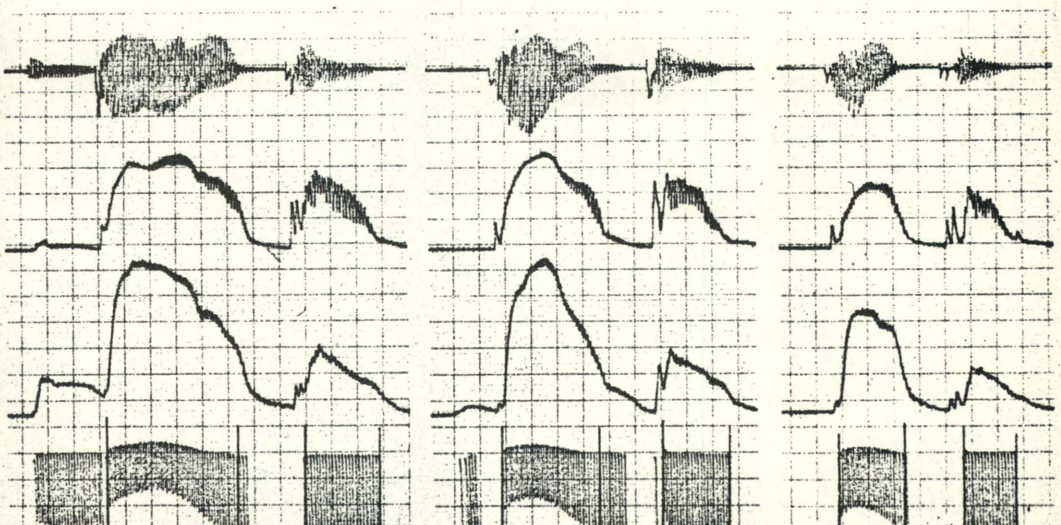


Fig. 2



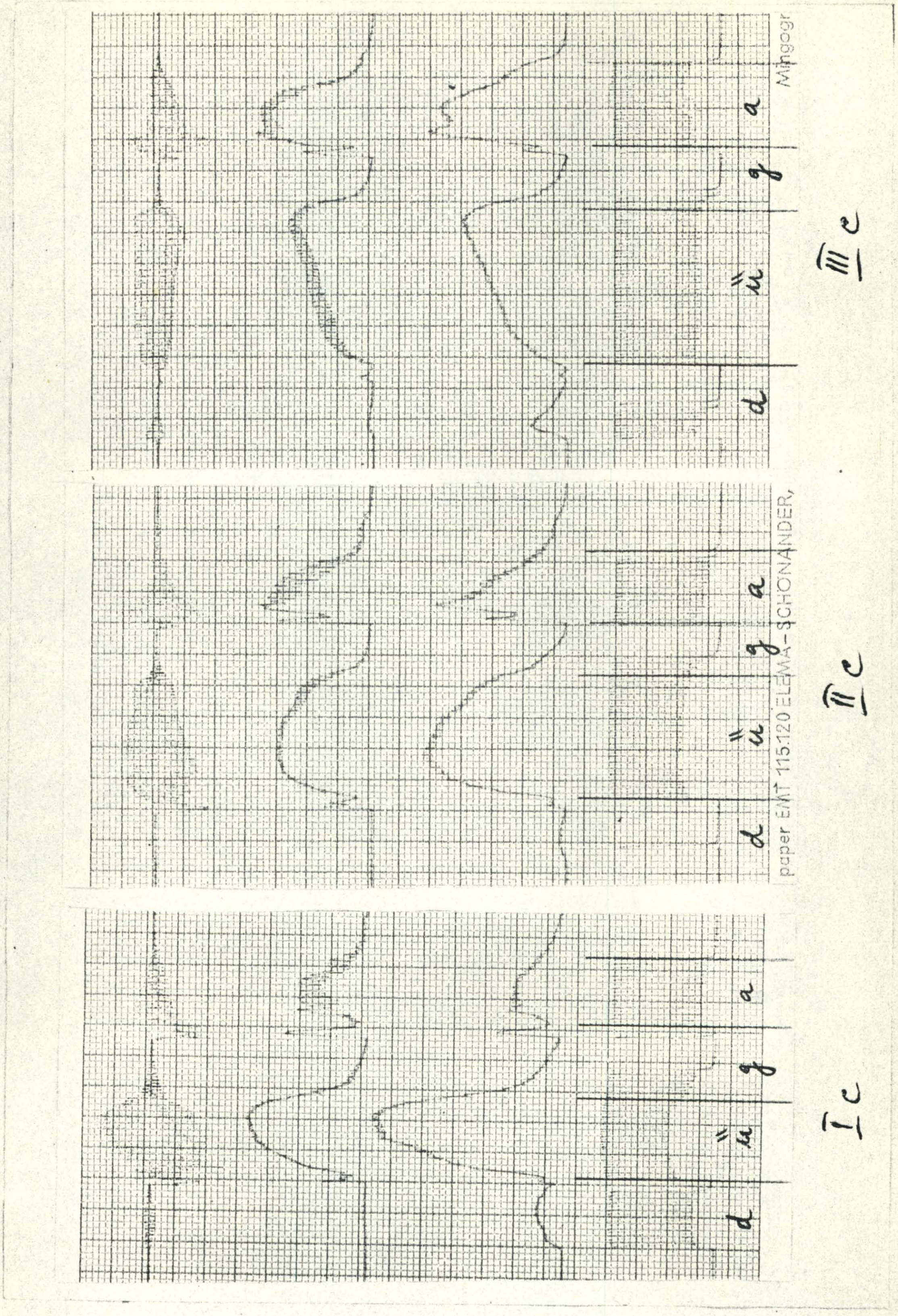
Ic IIc IIIc

Fig. 3



Id IId IIId

Fig. 4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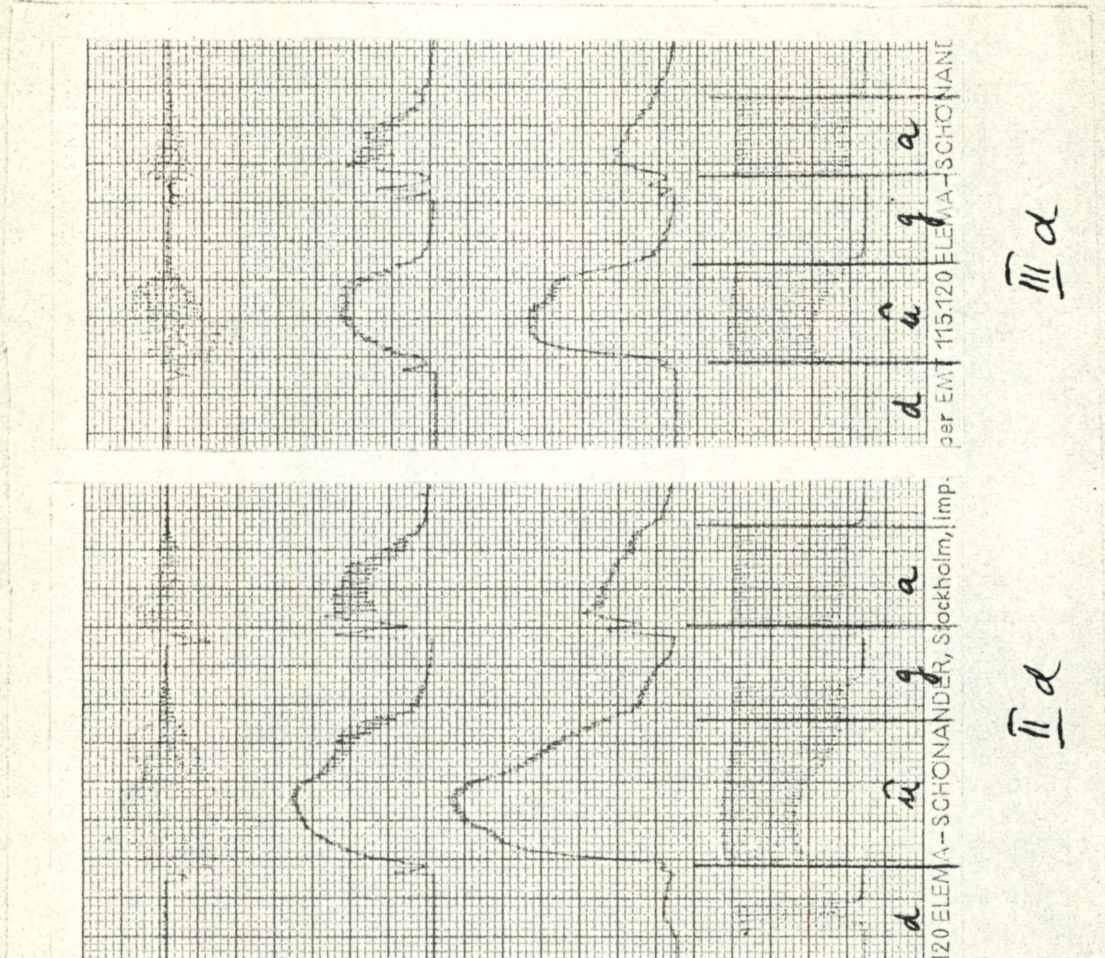
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Fig. 4

TABLE 1. TONE MOVEMENT IN CPS

		1st syllable				2nd syllable	
		beg.	peak	end	peak in per cent	beg.	end
a	kȉm I	2oo		18o			
	kȉm II	19o		19o			
	kȉm III	19o		19o			
b	kȋm I	2oo	225	14o	2o		
	kȋm II	19o	225	14o	17		
	kȋm III	225	238	14o	2o		
c	dȕga I	2oo	225	2oo	5o	18o	14o
	dȕga II	19o	213	19o	5o	17o	14o
	dȕga III	18o		18o		18o	2oo
d	dȗga I	225	263	16o	33	16o	16o
	dȗga II	225	25o	16o	33	16o	16o
	dȗga III	2oo	225	14o	33	16o	14o

TABLE 2. DURATIONS IN CS

		1st syllable	2nd syllable
a	kȉm I	11	
	kȉm II	17	
	kȉm III	23	
b	kȋm I	23	
	kȋm II	17	
	kȋm III	11	
c	dȕga I	13	11
	dȕga II	20	12
	dȕga III	25	13
d	dȗga I	25	14
	dȗga II	19	13
	dȗga III	13	10

were to decide on the meaning of each test item. They were requested to place each word presented to them in one of 5 sentence contexts, which clearly defined the meaning of the word. It was also permitted to answer: 'I don't know'.

As for k̏im-kîm there is no third way of interpreting these two words, but in the case of dȕga-dûga there is a third possibility: dúga ['dúg:ɑ] 'rainbow'.

All listeners distinguished clearly between Ia and Ib, but there was much uncertainty about IIa and IIb. Thirty per cent of the listeners thought that IIa meant k̏im, sixty per cent thought it meant kîm, and ten per cent answered: 'Don't know'. Forty per cent thought that IIb meant k̏im, forty per cent thought it meant kîm, and twenty per cent answered: 'Don't know'. Ten per cent thought that IIIa meant k̏im, and ninety per cent thought it meant kîm. All listeners thought that IIIb meant k̏im.

In the case of the examples duga there were four possibilities: dȕga, dûga, dúga, and 'Don't know'.

All listeners distinguished between dȕga and dûga (Ic-Id). Thirty per cent thought IIc meant dȕga, whereas seventy per cent thought it meant dúga. Twenty per cent thought that IId meant dȕga, sixty per cent thought it meant dûga, and twenty per cent answered 'Don't know'. All listeners thought that IIIc meant dúga. Ninety per cent thought that IIId meant dȕga, whereas ten per cent thought it meant dûga.

The conclusion to be drawn from these data must be that duration and not tone movement is the distinctive feature of the falling word tones in Serbo-Croatian. This conclusion is clearly substantiated by the uncertainty in the identification of the examples of the second set, and by the universal agreement in the identification of the examples of the third set.

Admittedly, the intensity contours of the examples in IIc and IIIc differ from those of Ic. With the material available and with the somewhat primitive method used here it has not been possible to eliminate this difference of intensity, which may have influenced the result. However, this difference affects mainly the relationship between falling and rising word tones; it is not so relevant to the relationship between short and long falling word tones. Experiments with synthetic speech will, of course, make it possible to arrive at a definitive conclusion on this point, and also to check the results of the present investigation.

MEASUREMENTS OF THE LENGTH OF SOME JAPANESE VOWELS WITH SPECIAL REFERENCE TO THEIR DEVOICING

Hideo Mase

o.1. Introduction

It is known that in Japanese unaccented i and u[1] are devoiced when they occur between voiceless consonants.[2] At the same time, it is generally admitted that the length of a syllable[3] - a mora - is fairly constant in Japanese.

In my previous experiment (5) I found the following tendency in ka-syllables: the vowel is shorter in a low-pitched syllable than in a high-pitched one, while the length of the 'open interval (= the distance from the explosion to the beginning of the vowel) + vowel' is almost the same in both high- and low-pitched syllables. (See Fig. 1 in Mase (5), p. 154.)

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1) "Accented" and "unaccented" means "phonologically accented" and "phonologically unaccented". An accented vowel is phonetically a high(er)-pitched vowel before word border or immediately followed by a syllable with a low(er)-pitched vowel, the latter being an unaccented vowel. An unaccented vowel is any vowel which does not fulfill the above condition of the accented vowel. An unaccented vowel is low(er)-pitched if it occurs in the initial syllable or in the syllable after the syllable whose vowel is accented; it is high(er)-pitched if it occurs in a non-initial syllable before the syllable whose vowel is accented.
The present investigation is confined to vowels which occur in the initial syllable, so that high- and low-pitched vowels are phonetic manifestations of phonologically accented and unaccented vowels, respectively.

2) Besides, unaccented u after a voiceless consonant and in phrase- or utterance-final position is often devoiced.
Details about conditions on devoicing are found in M.Han (2), p. 17-34. A summary of her description is found in my previous report(5), p. 146-47.

3) A phonological syllable consists of one or two morae and of one phonetic syllable. (Cf. Hattori (3) and (4), p. 751.) When a phonological syllable consists of two morae, the second mora is always a bound mora, since it cannot take accent, and since it always occurs after a free mora. For the experiment reported here only syllables consisting of one mora were chosen, so that a phonological syllable accords with a phonetic syllable and a 'free' mora. I sometimes use 'syllable', sometimes 'mora' - a unit of length - depending upon the situation.

This lengthening of the open interval in low-pitched syllables is presumably partly due to the devoicing of the following vowel. It is not possible to distinguish such a devoiced phase from the aspiration on the mingograms, and hardly on the spectrograms either. Therefore, the devoiced beginning of the vowel will be taken to belong to the preceding consonant, or rather to the open interval of the preceding consonant. This is also true of the devoiced beginning of the vowel after the spirant ʃ: it is not possible to distinguish the devoiced part from ʃ. It is therefore interesting to investigate whether there is a vowel-shortening in low-pitched position, which corresponds to a lengthening of ʃ and of the open interval of a stop consonant, or whether there is also a lengthening of the closure period, i.e. lengthening of the whole consonant. In m + V-syllables, for example, there is no devoicing of the vowel, and the syllable length is fairly constant. Accordingly, a lengthening of ʃ and of the open interval of stop consonants and a shortening of the vowel can be considered as a compensation between the consonant and the vowel, though the principle of compensation must be applied with care, because there may be various heterogenous factors involved[4].

The present experiment was undertaken to investigate the influence of initial voiceless consonants on the devoicing of vowels. Completely devoiced vowels will, however, not be considered.

o.2. Material and informant

The stop consonant k and the spirant ʃ (hereafter written S) are chosen here as initial consonants in a CV-syllable. The disadvantage in choosing k is clear, because the consonant is accompanied by much aspiration and affrication, especially when it is combined with high vowels, viz. i and u. But at

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4) Cf. Eli Fischer-Jørgensen (1, p. 2oo ff).

the same time, since the open interval is longer in k than in t and p (cf. 1.o.), the difference in length of open intervals is easiest to observe in k. The choice is also due to a phonological restriction. The phoneme (in the traditional sense) /t/ is phonetically manifested as [t] when it occurs before /a/, but as [tʃ] before /i/ and as [ts] before /u/. Word-initial /p/ ([p]) occurs only in loan words. S was chosen because it is found before i, a and u ([s] does not occur before i). Some other consonants have also been used as initial consonant. t is taken up in 1.o. and others in 1.2.

The vowels a, i and u have been used. The reason why a was chosen is that the vowel is the longest of the 5 Japanese vowels (cf. Han (2), p. 16), and is least influenced by surrounding consonants. i and u were used for comparison with a in the same consonantal environment.

The investigated high- and low-pitched syllables are followed by another CV-syllable where C- is t, d, k, s or m. These CVCV-syllables make up a phrase. In the text the phrase is preceded by a frame 'Sorewa' ("It (is) ...") - a frame which does not destroy the pitch contrast in the first syllable of the following phrase. Test words were arranged rather in random, but were ordered in such a way as to prevent unnatural lengthening or shortening of syllables or words. Two words, kù-t and kù-d[5], have no low-pitched counterparts, since I could not find any suitable examples.

Two standard-dialect speakers were chosen as informants. One is a male speaker (MM) (post-graduate student) and the other is a female speaker (NF) (born in the 193oies). In MM's speech devoicing is so conspicuous that i and u between voiceless consonants are almost completely devoiced both in high- and low-pitched environments. (But devoicing of an accented vowel in this consonantal environment does not on the whole seem to be rare in Japanese. My previous investigation (5) was

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5) The symbol ` denotes accent.

about this very phenomenon observed in three male speakers other than MM.) NF has a flapped r, and MM's /r/ is either r-like or l-like. MM has an intervocalic g where NF has ŋ. u may be slightly rounded in the speech of both persons. (Japanese u is unrounded and tense, but is not so back and high as Cardinal No. 16.)

o.3. Recording and registration

Each test word was spoken lo times by each person. The recording was made in the recording studio of the Phonetics Institute of the University of Copenhagen.

An 8-channel mingograph was used to register the test material. On the mingogram are shown: 1. (= the first channel from the top) duplex oscillogram; 2. logarithmic intensity curve, high-pass filtered at 5oo cps.; 3. logarithmic intensity curve without filtering; 4. fundamental frequency curve; 5. logarithmic intensity curve, high-pass filtered at 2ooo cps.; 6. oscillogram; 7. logarithmic intensity curve, low-pass filtered at 5oo cps. But there was something wrong with this last curve (No. 7).

The integration times used for the intensity curves are 2.5 ms (for NF) and 5.o ms (for MM) for the curves 2, 5 and 7, and 5.o ms (for NF) and lo.o ms (for MM) for the curve 3. Measurements are estimated to be precise within ± o.25 cs. But since the border between the preceding vowel (in the frame) and the beginning of the closure period of the stop consonant is sometimes not so exact, there may in some cases be a little more uncertainty (about ± o.5 cs).

1. Results

1.o. General comments on the length of the open interval

It is generally said that the open interval in Japanese voiceless stops is not very long, and that the aspiration is weak. According to Han (2, p. 57):

> "Voiceless stops show a slight aspiration. This is most notable with the release of [k] followed by [i] and [ʉ] . The duration of the aspiration in this position is two to three centiseconds. Other stop consonants, and [k] before other vowels, show aspiration of one

to two centiseconds. The amount of aspiration is not a distinctive feature in Japanese, and it differs greatly from individual to individual and from dialect to dialect."

As will be shown in the following section, the stop consonant k of both NF and MM shows a longer open interval (except NF's ka's) than that which is described in Han (2). The same tendency, i.e. longer open interval, was also observed in other persons' speech in the previous investigation[6]. (Cf. the above-mentioned Fig. 1 in Mase (5).)

But a longer open interval does not necessarily mean a stronger aspiration. (Cf. 3.1.) In both persons' speech a longer open interval is caused partly by aspiration, partly by affrication, and partly by an interval of 'voicing lag' whose intensity is very much weaker than that of aspiration and affrication noise. By the way, the duration of the explosion is not stated in Han (2).

For comparison some ta-combinations (1o examples of each word) are shown here. (See Fig. 1.) The open interval of t is between 1.15 and 1.75 cs (NF's average value), varying from o.5 to 2.o cs (individual values), and for MM it is on an average between 2.65 and 2.95 cs when followed by a high-pitched a, and 5.77 cs when followed by a low-pitched a. Here the length of the open interval seems quite normal, except for the last sample of MM's recording, where the tendency is the same as in ka.

1.1. Average length of k- and S-syllables

The following figures are the average values of 1o or 9 examples of each word. (In individual words there is some overlapping.) Only the pairs where the vowel is partly (de)voiced are included.

(The symbol ">" is to be read as "longer in high-pitched environment", the symbol "<" means "longer in low-pitched environment", and the symbol "=" means "the same in both environments".)

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6) Spectrograms in the paper by Torii (6) show, as far as I can see, longer open intervals for k than that which is described in Han (2).

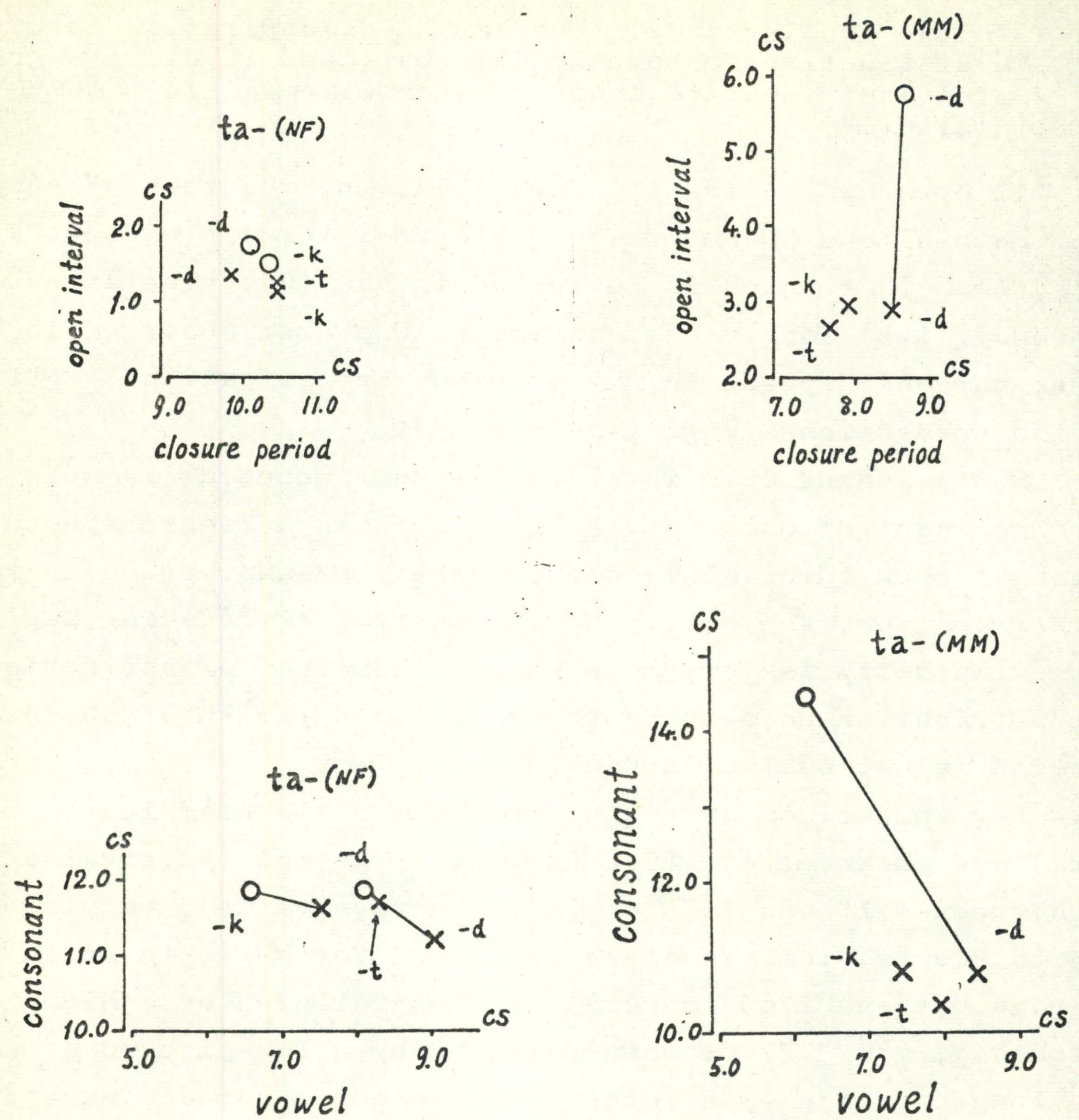

Fig. 1.

Average durations of closure period and open interval, and of consonant and vowel in <u>ta</u>-syllables.

X = in high-pitched environments, O = in low-pitched environments. -C = consonant following the syllable. Paired words are connected by lines.

1.1.1. The syllable (See Fig. 2)

In NF's speech the high-pitched syllable is in general (11 out of 15 pairs) longer than the low-pitched one (>o.7 - o.9 cs, except ka-m (>o.15 cs)). In ka-s both syllables have the same length. In 3 cases, the low-pitched syllable is longer. All of these are examples of ki- and ku- syllables, i.e. ki-d (<o.85 cs), ki-m (<o.15 cs) and ku-m (<1.9 cs).- The general tendency in MM's speech is just the opposite. The low-pitched syllable is longer than the high-pitched one (11 out of 13 pairs) except for ka-d (>o.3 cs) and ka-m (=). The difference is between o.5 and 1.2 cs, except for ka-s (<o.2 cs) and Sa-k (<2.5 cs). This seems to be due to extra-lengthening of the consonantal part.

1.1.2. The consonant (See Figs. 2 - 6 and 9)

The total duration of consonants (k, (t), S): All the consonants are longer in the low-pitched environment.

The closure period of stop consonants: except for NF's ka-k (>o.45 cs) (and ta-k (>o.1 cs)), and MM's ka-d (=), the closure period is longer before the low-pitched vowel than before the high-pitched one (cf. 1.4.).

The open interval (from the explosion to the beginning of the vowel): Except for NF's ka-t (>o.2 cs), the open interval is longer in the low-pitched environment, though the difference is not so great in NF's speach as in MM's.

1.1.3. The vowel (See Figs. 2 - 6 and 9)

The high-pitched vowel is longer than the low-pitched one, even though the difference is in some cases very small. In ku-m, the only example of u, the vowel duration is almost the same in both pitch environments. This is also true of MM's i's, where only the lenthening of the consonant in the low-pitched syllable is remarkable. Further, in individual cases of i and u, there is much overlapping. This is true of both persons' speech.

1.1.4. C/V ratio in the syllable

As is clear from 1.1.2. and 1.2.3., the ratio of the con-

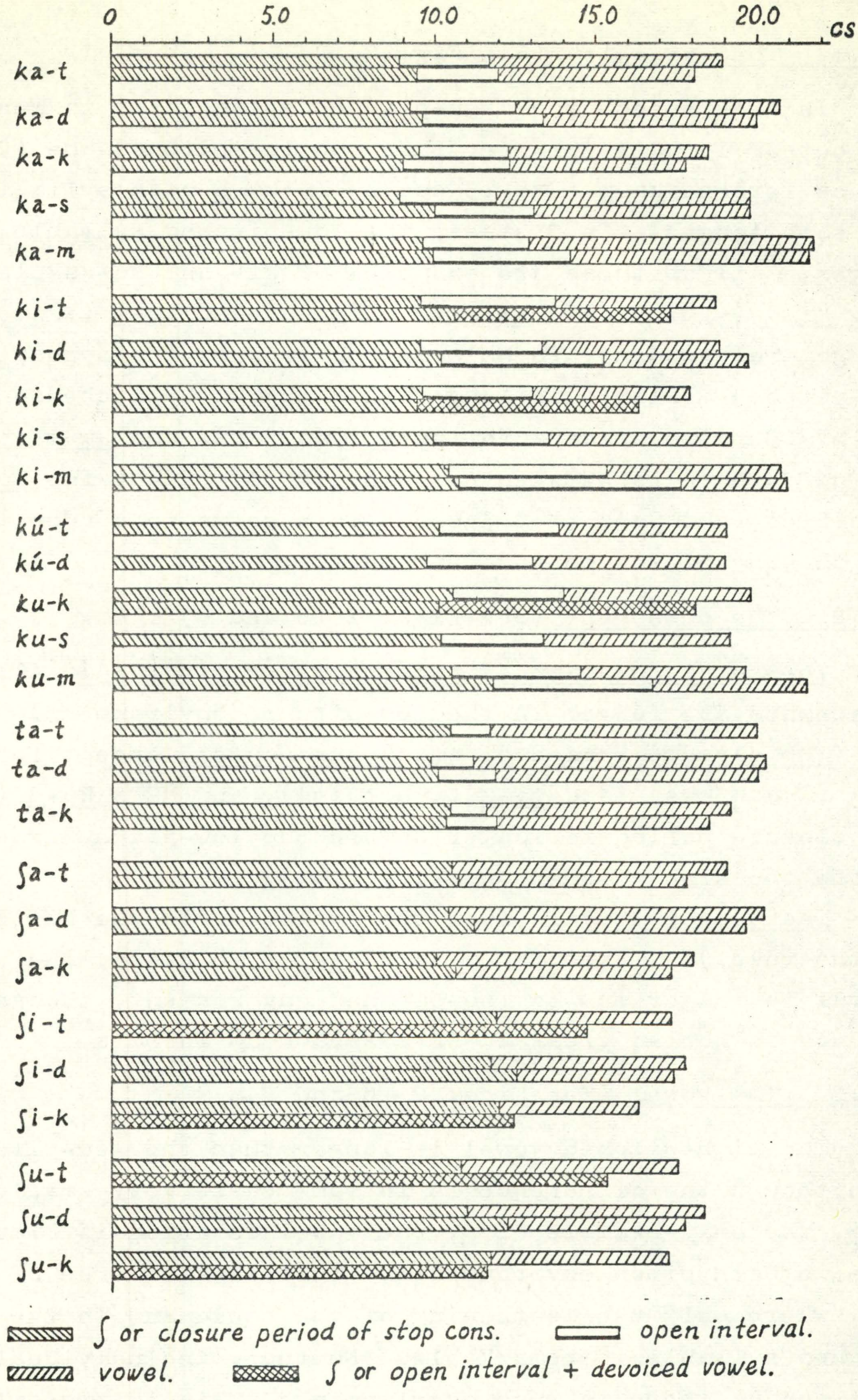

Fig. 2-a. Average durations (NF).
The first one in each pair is the high-pitched one.

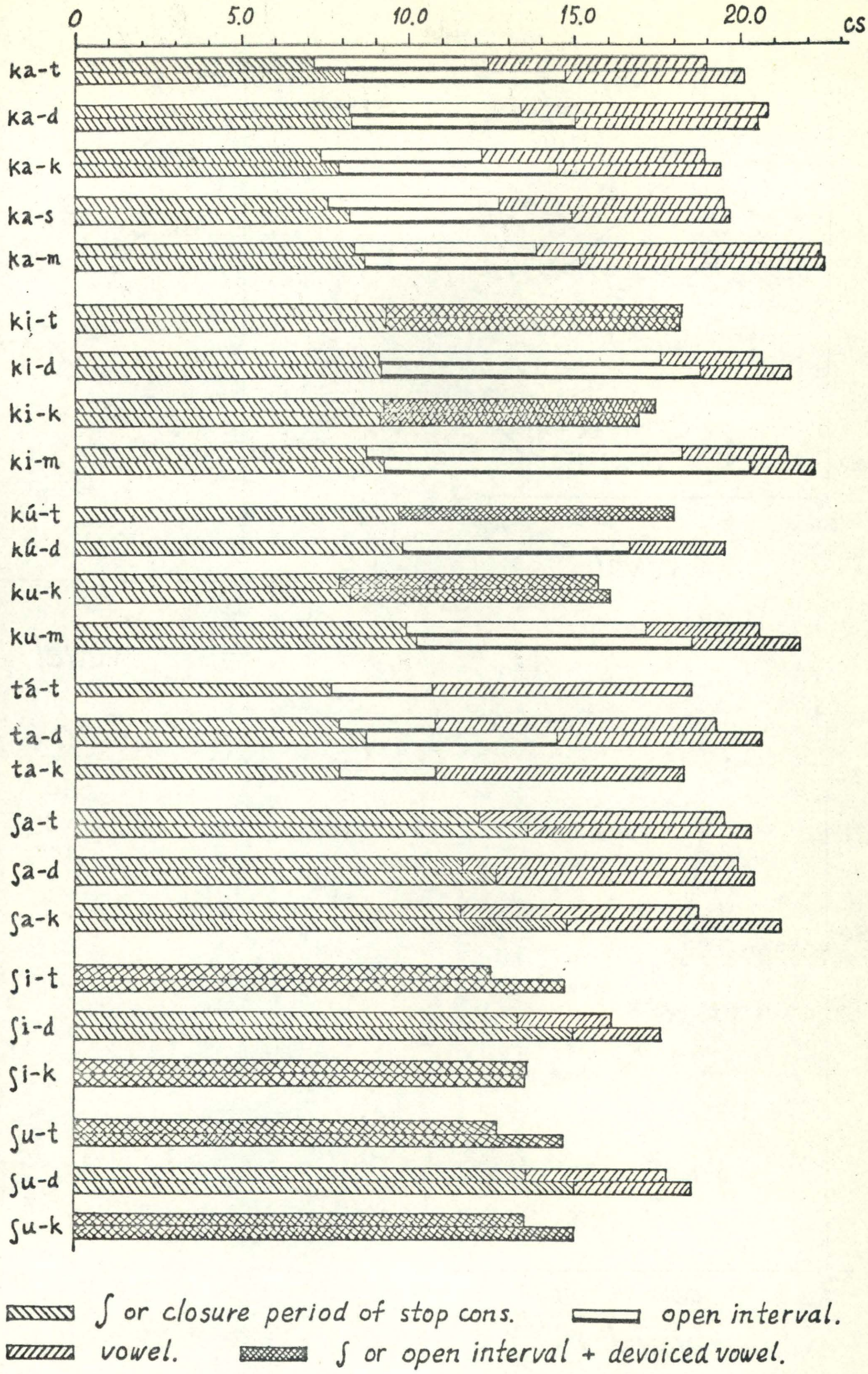

Fig. 2-b.

Average durations (MM).

The first one in each pair is the high-pitched one.

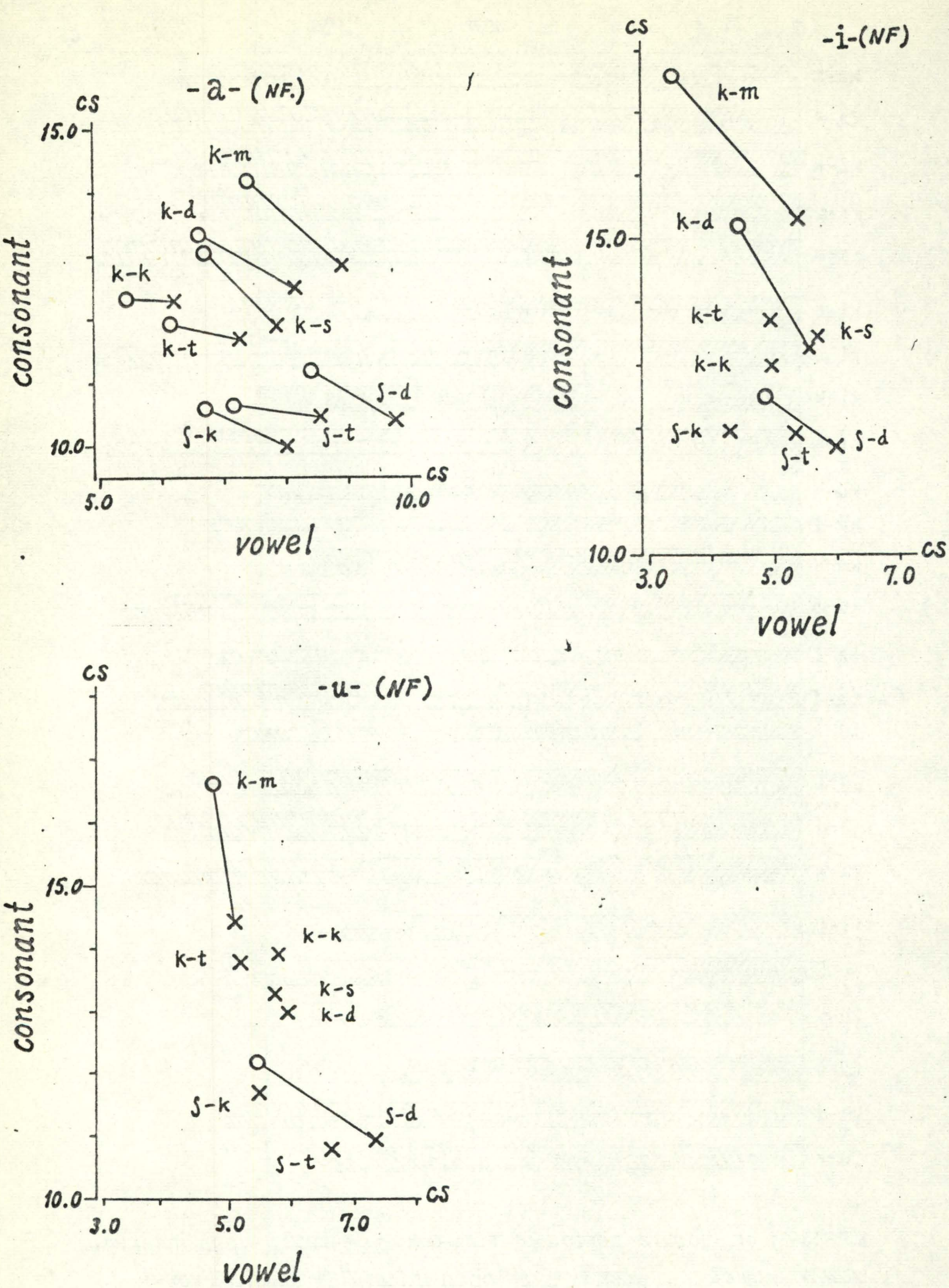

Fig. 3-a.

Average durations of consonant and vowel (NF).

(For symbols, see Fig. 1.)

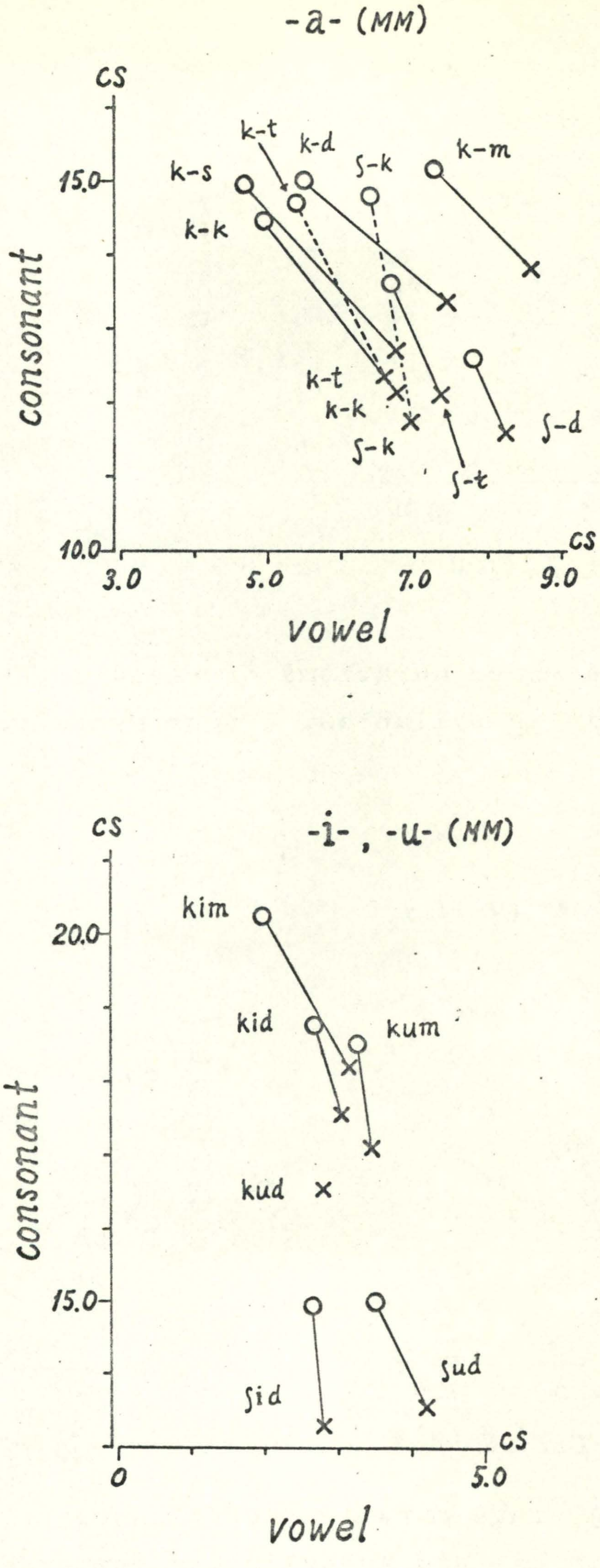

Fig. 3-b.
Average durations of consonant and vowel (MM).
(For symbols, see Fig. 1.)

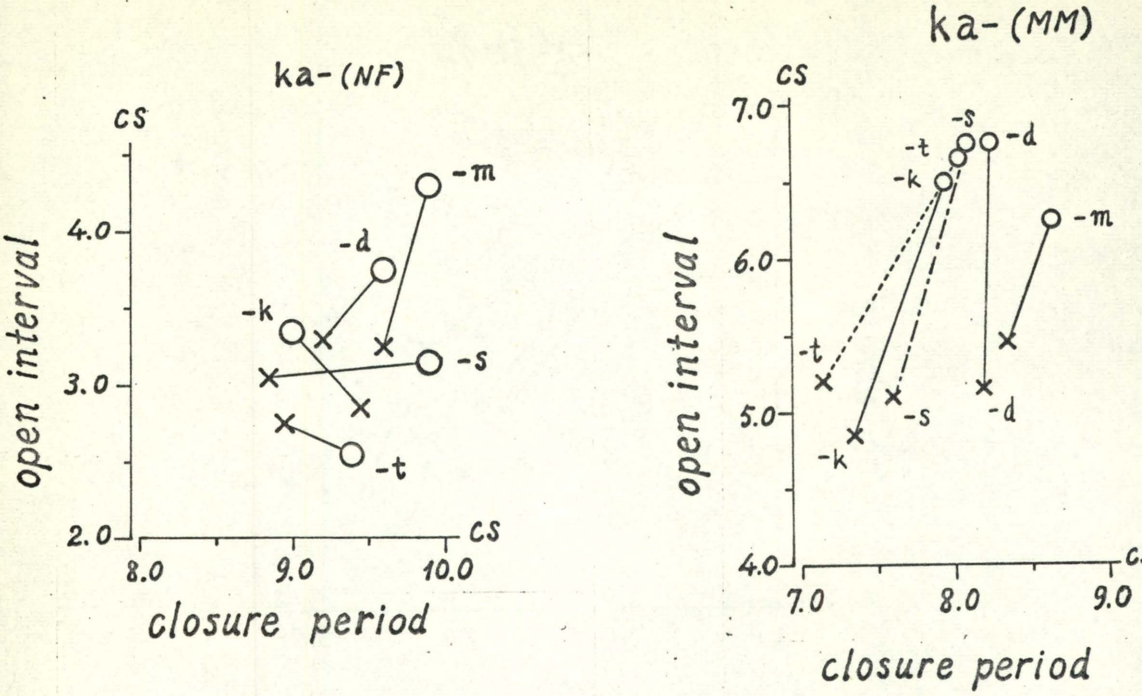

Fig. 4. Average durations of closure period and open interval in ka-syllables. (For symbols, see Fig. 1.)

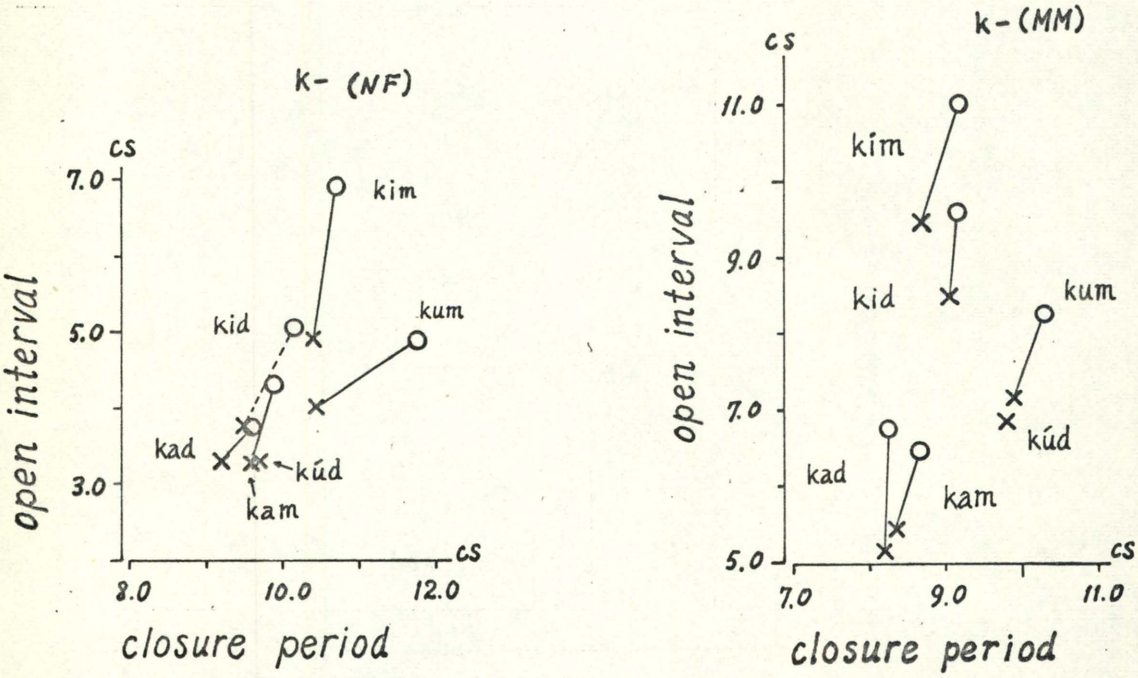

Fig. 5. Average durations of closure period and open interval in ki- and ku-syllables compared with those in ka-syllables. (For symbols, see Fig. 1.)

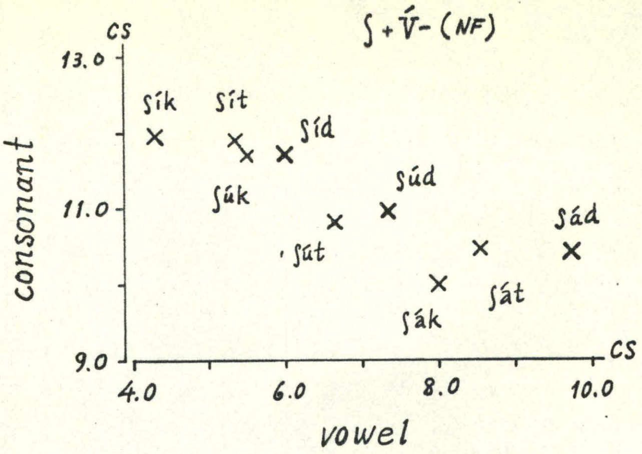

Fig. 6.

Average durations of consonant and vowel in high-pitched ʃ-syllables (NF). (For symbols, see Fig. 1.)

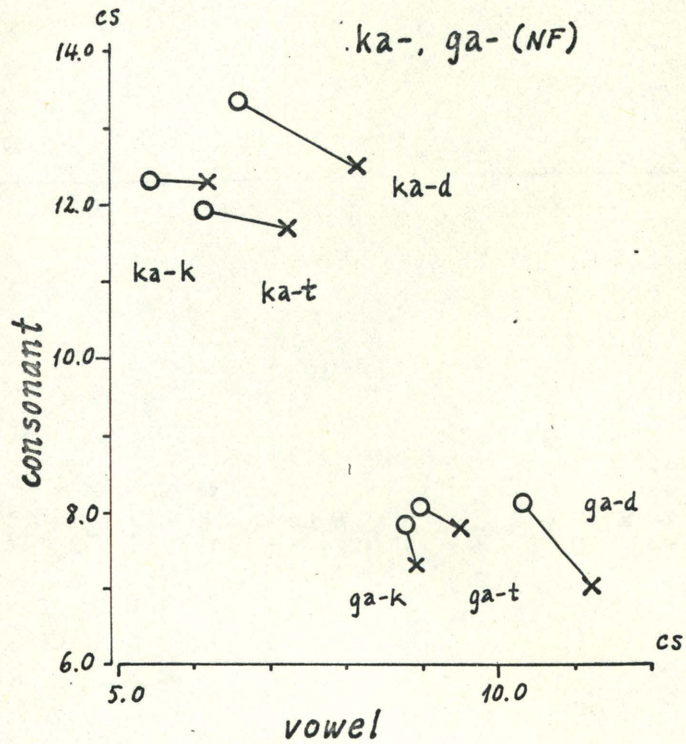

Fig. 7.

Average durations of consonant and vowel in ka- and ga-syllables (NF). (For symbols, see Fig.1.)

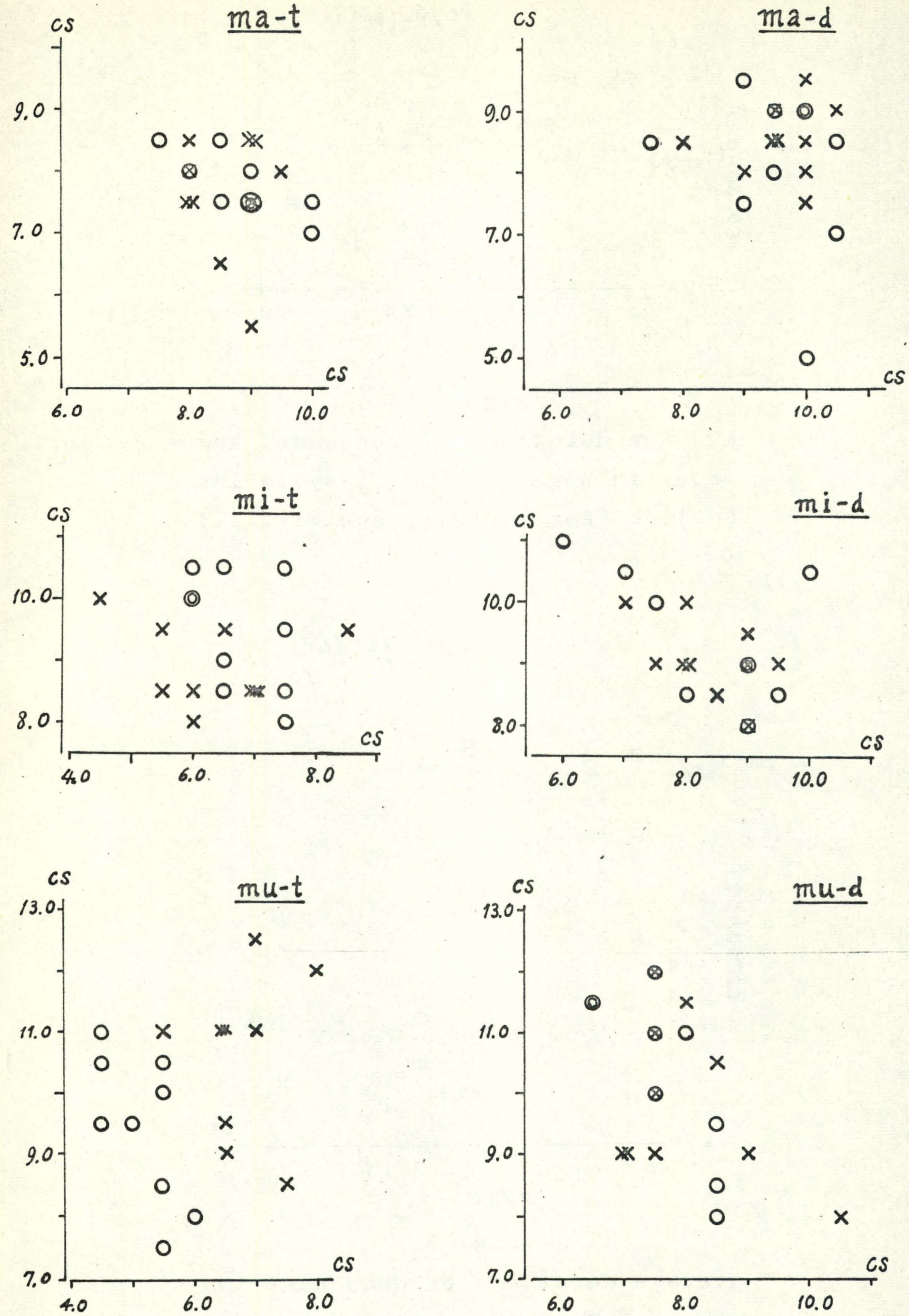

Fig. 8-a. Durations of consonant and vowel in words beginning with m- (NF) (single measurements). x-axis = vowel, y-axis = consonant.

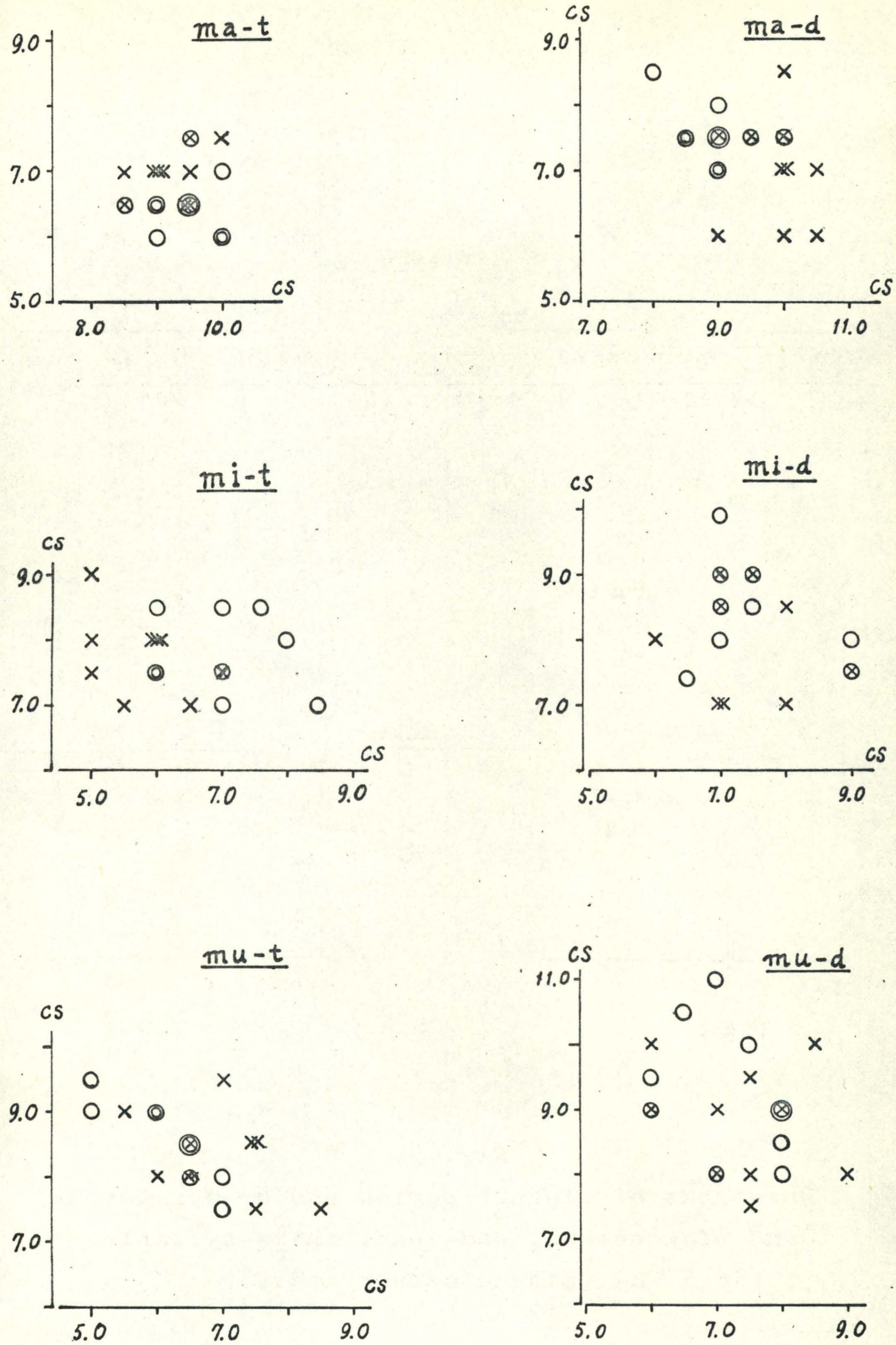

Fig. 8-b. Durations of consonant and vowel in words beginning with m- (MM) (single measurements). x-axis = vowel, y-axis = consonant.

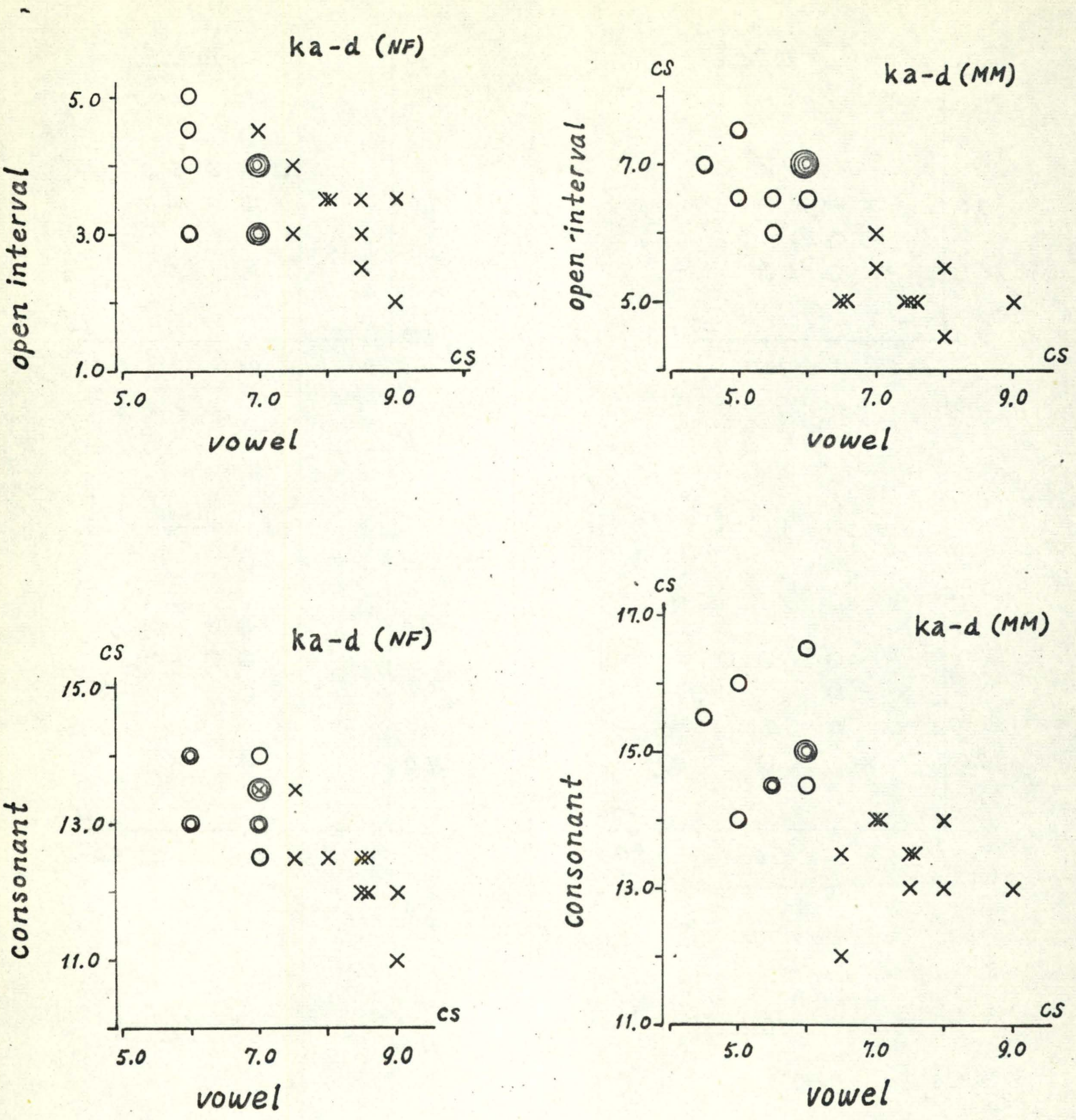

Fig. 9.

Durations of closure period and open interval, and of consonant and vowel in ka-syllables (NF & MM) (single measurements).

sonant to the vowel is greater in the low-pitched syllable. This is due either to the shortening of the vowel (NF's a-syllables, especially Sa-syllables), or to the lengthening of the consonant (MM's words as a whole, and NF's ki's and ku's).

1.1.5. Closure period/open interval (See Figs. 4 and 5)

Now, as was mentioned in o.1, when the beginning of the vowel becomes devoiced, the devoiced part must appear as the last part of the open interval of the consonant. That is, the open interval must be longer before the low-pitched vowel than before the high-pitched one. As was said in 1.1.2., the length of the open interval is longer in the low-pitched environment, except for NF's ka-t. As for the ratio of the open interval to the closure period, it is greater in the low-pitched environment, except for NF's ka-t, ka-s and ku-m. (The difference between the durations in high- and low-pitched environments is, however, small in ku-m.)

The general tendency is clear: the open interval is longer in the low-pitched environment.

1.2. Syllables with other initial consonants

1.2.1. ga (NF. 1o examples of each word). (See Fig. 7)
The difference in vowel length caused by a pitch difference can also be observed in syllables beginning with g, the voiced counterpart of k. But, in reality, NF's g in word-initial position is almost voiceless. Fully voiced g's are scarce: one instance of gà-d, one of ga-d and one of ga-t. The first half of the closure period is voiced in 3 instances of gà-t, 3 of ga-t, 6 of gà-d, 4 of ga-d, 5 of gà-k and 6 of ga-k.
How we get an auditive impression of g is not certain.
NF's g has a shorter closure period than k, and the following vowel is longer after g than k.

1.2.2. m-syllables (See Fig. 8)
m+V-syllables do not show a relevant difference of vowel length in different pitch environments. What seems more constant is the total syllable length: when the consonant is shorter, the vowel is longer, and vice versa.

(NB: The low-pitched mu-t is not a two-syllable, but a three-syllable phrase.)

1.3. The influence of surrounding consonants

The vowel a is, of course, much longer than i and u. As for the influence of the following consonant on the vowel, the tendency is as follows. In Sa-syllables, the vowel is longer before d than before t, and is longer before t than before k (this applies both to NF and MM). In ka-syllables the vowel is longest before m, and longer before d than before s, t and k, except NF's low-pitched a, which is on an average 0.1 cs shorter before d than before s. In general, the vowel is shorter before a voiceless consonant (i.e. between voiceless consonants) than before a voiced consonant.

The following consonant is sometimes longer and sometimes shorter (in NF's speech), and is often longer (in MM's speech) after a low-pitched vowel than after a high-pitched one. In many languages the postvocalic consonant is said to influence the length of the preceding vowel more than the prevocalic consonant does. The influence of the postvocalic consonant may also be found in Japanese. This influence may, however, be weaker in open syllables, as Japanese has, than in closed syllables. The problem is not taken up here.

The vowel u is said to be the shortest and i the next shortest of the five Japanese vowels.[7] But both NF's and MM's u is longer than i. This may be due to the fact that the following consonant is a dental or labial consonant. In the case of k + V, the place of articulation of k may have had some influence, too.

1.4.

A longer open interval in the low-pitched environment is much more clearly seen in isolated words, i.e. in absolutely initial position. But the beginning of the closure phase cannot, of course, be seen on the acoustic curve.

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7) N. Torii (6), M. Han (2).

2. Final remarks

From this restricted material I cannot draw any decisive conclusion. The following tendency is, however, clear. After k, S (and t, g), the vowel is evidently shorter in low-pitched syllables, but this is not true after m. This fact indicates that the shortening of the vowel is not entirely due to the pitch environment. The longer S and the longer open interval of the stop consonant can be interpreted as reflecting the devoiced beginning of the vowel. But at the same time the closure period is also longer in the low-pitched environment, which is against the supposition that the devoiced beginning of the vowel is manifested only in the open interval of the preceding consonant. We cannot tell exactly in which part of the consonant the devoiced part of the vowel should appear. What is more evident is that compensation takes place between the consonant and the vowel in such a manner that the total syllable length is kept almost constant. Thus, it can be said that the vowel is shorter after a voiceless consonant. That is the reason why i and u after and between voiceless consonants become devoiced, especially when they are unaccented.

3. Appendix

3.1. Aspiration and open interval

A stronger aspiration is sometimes perceived when the open interval is longer, but often this is not so. In order to see the relation between the auditory impression of aspiration and the duration of the open interval, a listening test was given to 1 Norwegian and 6 Danish phoneticians. Each of them listened to the tape through ear-phones, and answered questions concerning the degree of aspiration (and affrication); moreover they were asked to make comparisons with k-sounds in other languages. They were allowed to listen to the tape as many times as they wanted. They said that it was sometimes difficult to compare Japanese k with the k-sounds of other languages, since a low-pitched syllable often gave an impression similar to that of a weakly stressed syllable in other languages. If a low-pitched syllable gives such an impression, one would expect Japanese k to be heard as having a rather strong aspiration compared with k in other languages in the same (or a similar) accentual environment. But this does not appear from the answers. Since each of the listeners judged independently, there is, of course, no standard degree of 'aspiration', so comparisons should be made among k's within each person's judgment.

As for NF's speech, aspiration is seldom heard when the open interval is below some 2.5 or 3.o cs, except when it precedes a. In some cases a longer open interval is heard as having a stronger aspiration, but just the opposite response is also found with the same example. As for k before i, a stronger aspiration is often heard when the open interval is longer, especially when i is devoiced. The longest open interval in NF's paired words is 7.o cs. One listener heard the consonant in this case as being more strongly aspirated than the other member of the pair (4.5 cs), but the opposite answer was also given, and one person did not find any aspiration at all in the 7.o cs example. Nobody recognized a particularly strong aspiration there. - The tendency of judgment is the same as regards MM's speech, though the degree of aspiration was heard as being much stronger than in NF's speech. In MM's speech, a difference in the duration of the open interval of about 3.o cs did not favour the judgment that the consonant with the longer open interval has stronger aspiration.

From the above test, it seems that the judgment of strong(er) aspiration is not necessarily proportional to longer duration of the open interval. At least in the case of i and u, the judgment of stronger aspiration is more dependent on stronger energy than on a longer duration of the open interval, though the latter factor is of course important, too. It is probable that a longer open interval in the low-pitched environment often reflects an interval of 'voicing lag' in which the energy is not so strong.

3.2. Syllables including a completely devoiced vowel

The tendencies observed for two persons are a little different, but the tendency for a given syllable with a devoiced vowel is just parallel to that for the same syllable with a voiced vowel. That is, in NF's speech shortening of the syllable clearly takes place, while in MM's speech lengthening of the consonant is dominant.

Another matter is that the total duration of a syllable consisting of [ʃ] + a voiceless vowel, i.e. [ʃi̥] and [ʃu̥], is often not so much longer and sometimes even shorter than that of [ʃ] occurring before a voiced vowel (see Fig. 2). But we can clearly hear the difference between [ʃi̥] and [ʃu̥]. The auditive difference between [ki̥] and [ku̥] is also clear. I am not sure whether the auditive difference is aroused by different qualities of [ʃ]'s and [k]'s, or by the difference between [ʃ] or [k] + voiceless [i̥] or [u̥]. Both factors may most probably be taken into account.

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(4) Shiro Hattori, Gengogaku no Hoohoo ["Methods in Linguistics"] (Tokyo 196o), the chapter: "Phone, Phoneme, and Compound Phone" (in English), p. 751-763.

(5) Hideo Mase, "Acoustic Cues for the Perception of Accent in Japanese when the Accented Vowel is Devoiced", ARIPUC 3 (1968), p. 143-176.

(6) Noriko Torii, "Nihongo Sonaguramu ni tsuite no Jakkan no Koosatsu" ["Some Observations on Japanese Spectrograms"], Denki-Tsuushin Kenkyuuzyo (Tokyo 1957).

MORPHEME STRESS IN DANISH

Jørgen Rischel

1. Introductory remarks

According to the glossematic analysis by Hjelmslev (7) there is commutation in Danish between two syllable accents, one of which manifests itself as strong stress, and the other as weak stress. The opposite view is held by Andersen (1, p. 312-313), who claims that Danish has no word stress but only sentence stress. Andersen discards the evidence of distinctive stress placement by stating that the examples of commutation are either foreign words, which are not valid as proof of such a commutation in Danish proper (I return to the problem of genuine versus foreign words in section 1.1.), or special cases (with pretonic for-).

One type of proof given by Hjelmslev is the opposition between wordforms like forfald 'unavoidable absence' with strong stress on the first syllable versus forfald 'decay' with strong stress on the second (since many people are somewhat hesitant about the accentuation of the former word, it may be preferable to choose another example like forbenet 'the foreleg' versus forbenet 'ossified; pigheaded'). According to Hjelmslev forms like forfald 'unavoidable absence' have strong stress on both syllables in the "ideal" formal representation (which corresponds rather closely to the underlying, morphophonemic representations of generative phonology as of today), but one of the two stresses is replaced by a weaker stress under the dominance of the other. In sequences with ideally two strong stresses after each other either one or the other may be replaced by a weaker stress by a so-called "implication" (which in Hjelmslev's theory is a kind of syncretism between strong and weak stress). An example is fadøl 'draught beer' with stress reduction on øl versus fad øl 'barrel of beer' with stress reduction on fad. In a sense the stress patterns of fadøl and fad øl are commutable, which from an autonomous phonemic point of view might seem to make the analysis invalid. But, in Hjelmslev's words, "the commutation is a consequence of the implication, which, in turn, is a consequence of the syncretization, which is the signal" (8, p. 204), the stress relationships signalling specific types of constructions. From a generative point of view Hjelmslev is evidently right. The degrees of stress found in compound words and other syntactical constructions do not reflect different stress phonemes but are due to rules of grammar. On the other hand the difference between compound words with the root morpheme for as first member, and words with the prefix for- can be reasonably interpreted as a difference between phonemically strong and weak stress (cf. Basbøll (2), p. 39), i.e., there seem to be morphemes with and morphemes without inherent strong stress. In this sense the examples with for may be said to prove the phonemic status of stress.

The other type of proof given by Hjelmslev is the different stress placement in wordforms of foreign origin like korset 'the cross', kanon 'canon', plastic 'plastic (i.e., PVC, etc.)' with stress on the first syllable versus korset 'corset', kanon 'gun', plastik 'plastic art; plastic surgery' with stress on the second syllable. It may be argued (and it has indeed been argued, at least orally) that these examples are all suspect. Some of them (korset 'the cross', plastik) differ from the others in that they are morphemically complex.[1] The word pair remaining if these are discarded is a subminimal pair (kanon having a

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1) Hans Basbøll first called my attention to this peculiarity of the pair plastic - plastik.

long vowel in the first syllable if it means 'canon' but a long vowel in the second syllable if it means 'gun', a fact that obviously has something to do with the stress placement). There are, however, other more perfect minimal pairs (August as a personal name has initial stress, whereas the name of the month has final stress), and it is clear that stress is at any rate not entirely predictable from any immediately observable features of the segmental structure.[2]

In a generative phonology it may be proposed instead that stress depends on some more abstract feature of the underlying representations, a feature that does not always appear in the phonetic output except as stress (placement). One may wonder why Hjelmslev did not attempt to interpret intramorphemic stress placement in this way, i.e. as a signal of special structure types (as shown in 2.2. below this kind of approach is not entirely out of question). Anyway, the establishment of stress accent as a formal category plays a very important role in the glossematic analysis of the Danish expression system, since the definitions of syllable, vowel, and consonant depend upon it.

1.1. "Genuine" and "foreign" wordforms

It may be argued against the kind of proof constituted by such word pairs as plastic - plastik that they are not relevant to the structure of "genuine" Danish words. Noncompound polysyllables inherited from Old Danish have, on the whole (cf., however, section 7. below), stress on the first syllable, and except for the suffixes -(l)ig and -(n)ing noninitial syllables only contain "shwa". It is obviously of great interest to describe the structure of this restricted part of the Danish language and to state the simple stress relationships found here. However, it would be meaningless from a synchronic point of view to discard all other wordforms as not belonging to the Danish language.

2) For words with different stress placement see Hansen (6, p. 267 ff).

Words like kasket 'cap' must indeed be listed as Danish lexical entries in spite of non-initial stress, but it is of course possible to mark them by an abstract feature "+foreign". A categorization by means of such a feature would make it possible to set up a specifically simple set of rules for the inner core of "genuine" words, and an additional, more heterogeneous set of rules for the more peripheral words. It could be done, although it must be admitted that the dividing line is not very sharp. Non-initial stress is, for example, not avoided in strictly colloquial wordforms, cf. starut, stabejs, kanut (all with stress on the second syllable) 'strange fellow', so the intuition of Danish speakers about the foreignness of this stress placement is hardly very strong (as an example of the opposite, compare colloquial East Norwegian with such forms as `avis for a´vis 'newspaper' = Danish avis with stress and stød on the second syllable).

The problem with a division into "genuine" and "foreign" wordforms is that a mere dichotomy does not suffice at all. It is possible to set up at least five different categories, which roughly speaking represent increasing degrees of foreignness (with the reservation that many foreignisms may happen to follow the pattern of "genuine" Danish forms):

I. forms inherited from Old Danish.
II. loanwords from (Low) German, e.g. behandle.
III. words from Latin or Greek, like profet.
IV. words borrowed from French in a non-latinized form, e.g. gelé (gelatine belongs to III).
V. recent, entirely unassimilated words, mainly from English, e.g. week-end.

The first two categories are very closely related. They share numerous roots and suffixes (cf. handle - behandle, handling - behandling), and are probably impossible to keep entirely apart. The most important feature of the second category is that it exhibits some prefixes which can never take stress.

The roots and derivational affixes of the third category are almost entirely different from those of the first two categories (with the important exception of some few suffixes like -er-, -ing, -isk, cf. kanonisering 'canonization', magisk 'magic' with suffixes that are apparently related to those of håndtering 'profession', dansk 'Danish'). This nearly complementary distribution of not only root morphemes but also derivational affixes supports the validity of the categorization.

The relationship between the morphemes found in the remaining two categories and those found in the others, is less clear.

There can be no doubt that it would be interesting to study the Danish sound pattern with reference to such a categorization of the morphemes. However, this can hardly be done with stress rules alone. I do not even know to what extent it is at all possible to make a valid categorization on a synchronic basis. The present paper generally does not distinguish between native and foreign morphemes, although some appalling deviations from the general pattern are explained by the foreign origin of the morphemes in question.

1.2. Aim and disposition of the present paper

It is the aim of the present paper to study the stress placement in Danish wordforms and to determine to what extent it can be predicted from the structure of the wordforms. In order to avoid undue confusion of conditioning factors I shall begin by examining monomorphemic forms and proceed stepwise to the grammatically more complex types. The stress rules specific to compound words will only be touched upon very briefly, and those pertaining to other syntactical constructions will hardly be considered at all. Thus the present paper limits its scope to "lexical" stress, dealing with such problems as inherent stress versus lack of stress and predictable versus unpredictable stress placement. - The stress rules conditioned by syntactical structure will probably not pose problems that are essentially different from those found in analyses of other Germanic languages, cf. Chomsky-Halle (4), p. 89 ff, Kiparsky (9), Elert (5). However, before Danish can be profitably analysed from this point of view it must obviously be determined what the input to these rules is like, i.e. how the stress patterns of simple wordforms are generated (it being assumed that the stress rules altogether operate "outwards").

It seems to me particularly important to examine the segmental structure of monomorphemic wordforms in order to decide whether stress can be predicted (and hence inserted in phonetic representations) by sufficiently simple rules or whether it must be indicated in underlying representations. There is no doubt that the answer to this question depends (more or less) on one's methodological prerequisites. As long as there is no universally accepted way of comparing rule complexity with the "cost" of additional marks in lexical entries, and as long as there is no universally accepted way to distinguish between well-motivated and ad hoc solutions,[3] the best one can do is to present the data in such a way that the findings can be easily restated in a different framework. I have, therefore, organized the initial section on morpheme stress in such a way that stress is first considered in relation to surface structure and afterwards in relation to some hypotheses about the underlying form. The following sections, on polymorphemic forms, are of course not arranged in this "autonomous phonemic" fashion, but many points are stated in a very provisional form. A coherent set of rules is not presented until section 8., which gives a brief survey of the findings.

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3) Kiparsky rightly warns against too much abstractness in phonology.

1.3. Phonetic transcription

The phonological behaviour of Danish obstruents and vowels is characterized by the rather drastic effects of a series of late rules, which shorten vowels, weaken or devoice obstruents, and the like (cf. Rischel (11), (12)). In a discussion of stress placement a transcription which takes these late rules into account, is not expedient to use. It is simpler to establish a level of representation which expresses the differences that are relevant to the subject matter but does not give irrelevant details of the phonetic output, i.e. something like an autonomous phonemic notation.

In the present paper I use a notation of this kind. Its rather strange appearance is due to the fact that it mostly employs the letters of the Danish standard orthography (S.O.), i.e. it resembles a broad version of the Dania transcription slightly more than it resembles the IPA transcriptions used in some previous papers.

When comparing the data given here with data given in S.O. one should bear the following differences in mind:

(1) Vowel length is here marked by **:**. The S.O., on the contrary, marks vowel shortness in some word types by doubling the following consonant letter or by adding a d.

(2) The occurrence of stød is marked by **'**.

(3) Since the Danish vowels are often one degree lower than indicated in standard orthography, the present transcription has **e** for orthographic i in many wordforms, and similarly **æ** for e, **ø** for y, **ö** for ø, **o** for u, and **å** for o.

(4) The transcription has **ŋ** for orthographic ng (it is likely that the underlying form has /ng/, too, perhaps with the exception of French loanwords with orthographic n, nt like balkon, in which the lack of stød points to a single segment /ŋ/).

The fricative variants of /d, g/, orthographically d, g, are transcribed as **ð**, **ɣ** (in order to make the fricative pronunciation predictable in forms like metodisk as against parodisk with unaspirated stop and erotisk with (at least optionally) aspirated stop).

(5) The position of the main stress is indicated by an acute accent over the vowel. When necessary, secondary stress is indicated by a grave accent, and if degrees of secondary stress must be distinguished, the stronger is indicated by a circumflex in accordance with American usage. Since the paper does not deal with phonetic degrees of stress to any noteworthy extent, this rather inadequate system of transcription was considered sufficient.[4] It has the obvious advantage compared to the IPA system that no decisions need to be made concerning the location of syllable borders.

The most important deviations from the IPA transcriptions used in other articles on Danish phonology are:

(1) æ(:), ö(:), å: correspond to IPA [ɛ(:), œ(:), ɔ(:)]
å (in stressed wordforms) corresponds to IPA [ɒ]
a: corresponds (in some environments) to IPA [æ:]

(2) As mentioned above some vowel and consonant modifications due to late rules are disregarded.

The last-mentioned point may seem to be in conflict with the claim made in section 1.2., i.e. that the placement of stress should be examined in relation to the phonetic structure of the wordforms. However, there is not the slightest doubt that the vowel and consonant modification rules in question are later than the rules assigning stress to simplex wordforms, and that the inclusion of all phonetic details would obscure rather than clarify the relevant facts. The relationship of stress placement to optional quantity and stød is not equally clear, and accordingly the latter features are marked consistently. To give an example: the first syllable of the definite form badet 'the

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4) Some of the shortcomings of autonomous phonemic transcriptions were discussed in Rischel (1o).

bath' has an underlying short vowel which is lengthened and gets stød according to general phonological rules of Danish. According to a late rule the vowel may be shortened again, but retains a quality different from that of short /a/. In such cases the transcription used here indicates length and stød: ba:'ðët. Thus, whenever a vowel is long at some stage in the derivation and is not shortened again by an obligatory rule, it is transcribed as long.

Finally, it should be mentioned that "shwa", orthographically e, IPA [ə] or (when fused with /r/) [ɒ], is represented by ë.

2. Stress placement in monomorphemic wordforms

2.1. Is stress predictable from the surface structure?

The placement of stress on one or another syllable of monomorphemic wordforms is to a high extent predictable from the syllable number and syllable structure of their phonetic representations. In the following, three kinds of conditioning factors will be distinguished.

2.1.1. Stress in relation to full vowels versus shwa

Monomorphemic wordforms of more than one syllable fall into two categories: (a) those of which the first vowel is a "full" vowel but all following vowels are ë (shwa), (b) those containing more than one syllable with a full vowel. The latter are almost exclusively words of foreign origin (with the exception of old compounds like véndu 'window'; forms like sá:li 'blessed, saved', rǽ:leŋ 'rail' may be considered "quasi-derivations" belonging together with the forms treated in 3.1. below).

Rule 2.1.-A Syllables with shwa are never stressed.

According to this rule the stress placement in the vast majority of noncompound wordforms is immediately predictable provided that shwa is distinguished from full vowels in the phonological representations.

Some occurrences of shwa are clearly derived from underlying full vowels, and it may be postulated that the remaining ones also reflect underlying full vowels, although they are always realized as shwa. In Hjelmslev's notation such indeterminate shwas are rendered as ε, which seems to be a reasonable interpretation if stress is considered distinctive. If, on the other hand, stress is to be inserted by phonological rules, the derivation of ë and æ from a common underlying vowel may still work in monomorphemic wordforms, but we shall be faced with a problem in morphemically complex forms, cf. arǽsd 'gaol' versus kǻlësd 'coldest'. In such a wider context it seems more immediately attractive to derive shwa from the vowel underlying the half-close front vowel e, since the vowel e is most uncommon in non-initial syllables (of non-compound words), except for the suffix (n)eŋ (where e may be said to replace ë, since the latter does not occur before ŋ). Apparent counter-examples like pasdél' 'pastil' versus físdël 'fistula' differ in stød, which must be generated or marked anyway. Other forms with non-initial short e can perhaps be considered distinctly "foreign" and thus set up as a group which does not make the general rules invalid although its members must be marked as exceptions to it. The words in this group are almost exclusively words of French origin with final stressed e, like sjelé 'jelly'; these belong to a larger category of words which are exceptional anyway (cf. 2.1.3. below).

No matter whether shwa is derived from /e/ or set up as a separate unit, it must be distinguished from the other vowels at a fairly early stage in the phonological rules. Here an additional problem presents itself: in forms like fløtër 'moves' /t/ is in "weak position" (cf. Rischel (12)) conditioned by the following ë and therefore unaspirated, whereas the same consonant in forms like mó:tår 'motor' is in "strong position" and aspirated. However, in ordinary speech the unstressed sequences ër and år tend to merge so that only the preceding consonant betrays the underlying difference. This merger of a full vowel and shwa must obviously be stated as a late rule, whereas the derivation of shwa in fløtër from a full vowel must be an early rule preceding all rules relating to "strong" and "weak" positions. It remains to be stated what is gained or lost by deriving all shwas from underlying full vowels. (For more details concerning alternations between full vowels and shwa see Rischel (11), p. 198-2o1.)

In the following it will be assumed that those shwas which do not alternate with full vowels in the surface representations and which condition a syllable division putting the preceding consonant (if any) in "weak position", are distinguished from full vowels in the underlying representations. This, however, does not exclude the possibility of deriving them ultimately from a full vowel.

2.1.2. Stress in relation to long versus short vowel

Rule 2.1.-B A long vowel in a stressed monomorphemic wordform carries the stress.

There is stress on the first syllable of mí:nus, só:lo but on the second syllable of matró:'s 'sailor', palǽ:' 'mansion' (note that word final stress is accompanied by stød if permitted by the composition of the syllable). Other examples with more syllables are pó:'dagra, petró:'leom, mausolǽ:om, kamæleó:'n (note that stress on the antepenultimate is accompanied by stød under the same conditions as word final stress).

There are a few morphemes that have two long vowels, e.g. paradis and possibly satyr. Such forms as paradis behave like compound words, i.e. the second long vowel has a reduced stress (secondary stress), the stress pattern of paradis being similar to that of compounds like sparegris 'piggy bank' (note, however, that according to section 3.4. below a sequence of two long vowels in the underlying form of a morpheme does not necessarily appear as a sequence of two phonetically long vowels).

It follows from what has been said that the placement of stress on long vowels is predictable from the surface structure. Consequently, if the underlying quantity relationships are identical with those of the surface structure, stress on long vowels need not be marked in lexical entries.

2.1.3. Stress in relation to syllable type

In monomorphemic wordforms of which all vowels are short there is a strong tendency to let the stress placement depend on the structure of the last syllable containing a full vowel. There are many irregularities (see below) but the general tendency can be formulated like this:

Rule 2.1.-C A stressed, monomorphemic wordform which contains no long vowel, takes stress on the last full vowel that is followed by a consonant.

Examples are: (with stress on the antepenultimate:) hásdië 'host (sacramental word)', kolóm'bia; (with stress on the penultimate:) kulísë 'side scene'; fiásgo, makaráni 'macaroni', víla 'villa'; (with stress on the last syllable:) kalát 'skullcap', absén't 'absinth', anorák, prován't 'provisions', masdodán't 'mastodon'.

There is a number of monomorphemic wordforms with two or more syllables which have stress on a short vowel followed by zero. Some of these are interjections such as uhá (also ú:há), others are words of French origin like pasé 'passé', tabló, kupé (type of car - the word for 'compartment' is more often pronounced kupé:'), sjalú 'jealous', sjelé 'jelly'. Most words of this category have a distinctly foreign character and must definitely be considered as deviating from the normal pattern of Danish, i.e. they should be listed as a set of exceptions which do not make the general rules invalid. They can be fully assimilated to the Danish pattern by a lengthening of the final vowel (as in kupé:'), by pronunciation of the final written consonant (bukǽt 'bunch of flowers' as against buké 'perfume of wine'), or by some other modification (I have heard sjosé (chaussé) 'set paving' pronounced sjau'sër by road makers, who probably use the word more than most other people).

Another type of exception is constituted by words ending in a short vowel which have stress on the antepenultimate instead of the penultimate. Such forms are not very frequent, however. Some of them are foreign names: áfrika (also á:'frika), pán'ama (or panamá:'), mál'aga (versus maláka); júpitår represents a related type of exception.

A quantitatively much more serious problem is posed by wordforms which end in a closed full vowel syllable but nevertheless have non-final stress. This category includes a number of names of foreign origin. Other reasonably common examples are: bóŋgalåu 'bungalow'; íslam, lókom 'privy', tálkom 'talc powder'; gálån 'gallon', hǽsjan 'hessian', rododǽndrån 'rhododendron', sjam'piån 'champion'; oráŋgutaŋ; ántabus (drug against alcoholism), fóŋkis 'functionalism', gǽsdus 'gesture', kándis 'rock candy', katëkísmus, rábtus 'craze', sdél'is 'goldfinch'; gálup, sénåp (or rather sénëp) 'mustard'; mámut; plásdik 'plastic'; bálasd 'ballast'; hárnisg 'harness', dámasg 'cane'.

It is possible to take care of a good deal of these exceptions to rule 2.1.-C by introducing an additional rule:

Rule 2.1.-D Word final syllables ending in a single nasal do not take stress (the stress being put instead on the preceding one, if possible).

However, the introduction of such a rule creates a new series of exceptions, namely words of French origin ending in orthographical n or nt. Some of these are pronounced with a long vowel plus n or a short vowel plus n't, in both cases with final stress, which does not violate any rule (examples are: makró:'n 'macaroon', agsǽn't 'accent' (in the sense of accentuation or accent mark)). Others, however, are pronounced with a short vowel plus ŋ; these wordforms likewise have stress on the last syllable and thus violate rule 2.1.-D,[5] unless this rule is modified in such a way that it applies only to nonback nasals. Examples are: balkåŋ́ 'balcony', agsáŋ '(foreign) accent'.

Forms like balkåŋ́ are deviating in much the same way as forms like sjelé. Final stressed vowels in polysyllabic wordforms are normally long and accompanied by stød, and similarly a final stressed sequence of vowel plus voiced consonant in polysyllabic wordforms normally has stød, cf. hotǽl' 'hotel'. This might be taken as evidence that the loanwords discussed here take final stress by a late ad hoc rule of the form: "Add stress to the last syllable of morphemes marked for "French accentuation"", all lexical entries having this deviating pattern being marked accordingly by some abstract feature. However, some more details must be mentioned here. Firstly, there is one (probably unique) bisyllabic morpheme ending in l which has final stress without stød: metál; this form would have to be marked as a "French" exception as well, which makes the category phonologically less well defined. Secondly, and more importantly, forms like balkåŋ́, sjelé take stød (and, as far as final vowels are concerned, length) in inflected forms in which a syllable is added to them: balkåŋ́'ën 'the balcony', sjelé:'ën 'the jelly'. This is due to a general rule of Danish phonology which also applies to unstressed final vowels: víla 'villa' - víla:'ën 'the villa', rǽ:leŋ 'rail' - rǽ:leŋ'ën 'the rail', and thus it does not contradict the assumption that the final stress in balkåŋ́, sjelé

5) Provided that ŋ is not derived from /ng/.

is due to a late rule.

The remaining exceptions to rule 2.1.-C cannot be taken care of by any simple rule. There is no obvious reason why, for example, there is final stress in palás 'palace', lakrís 'licorice', anǽks 'annex', obëlísg, krabásg 'cane', augósd (name of month) but initial stress in hǽlas 'Hellas', bǽlis 'daisy', ájaks (name), hárnisg, dámasg, áugosd (personal name), since we find quite analogous vowel-consonant sequences in both series. Similarly, there is no overt reason for the difference of stress placement between mál'aga and maláka, since it is reasonable to assume that the stød is dependent upon the stress placement rather than the other way round (the opposite view would lead to quite intolerable consequences in Danish phonology).

Thus, in spite of the partial coverage obtained by means of the few and simple rules stated above (2.1.-A,B,C,D) it must be concluded that the stress placement in polysyllabic morphemes is not entirely predictable from the surface structure, i.e., in autonomous phonemic terms stress is phonemic in Danish.

Nevertheless, the rules stated above are of some interest since they express the prevailing tendencies.

2.2. Stress and underlying representations

It was found in section 2.1. that the stress placement in most Danish morphemes can be predicted on the basis of a few simple rules. On this background it would seem reasonable to assume that the forms which do not agree with the rules differ somehow in their underlying representations from those that do agree with the rules, although the underlying difference may only be reflected in different stress placement.

There is in Danish no basis for postulating dummy vowels (constituting extra syllables) which vanish in the output representations after having triggered some stress placement rules (cf. Chomsky-Halle (4), p. 147-148). It is not either possible to take care of unpredictable stress placements by introducing a distinction between "tense" and "lax" vowels, since we already recognize a difference between long and short vowels and a difference between full vowels and shwa. There is no basis whatsoever for postulating more oppositions of this nature.

It may be postulated, however, that syllables with stress have either a long vowel or a long postvocalic consonant or a postvocalic consonant group in the underlying form. Wordforms like those cited in the last part of section 2.1.3. can then be distinguished like this in their underlying representations:

palas:	hæl:as
anæks	aj:aks
krabasg	dam:asg
etc.	etc.

According to these examples, a syllable with a long consonant takes precedence over a syllable with a final cluster. Similarly, a syllable with a long vowel takes precedence over a syllable with a final cluster (according to rule 2.1.-B), cf. names like á:dåks (a brand of film). If two syllables both exhibiting a short vowel which is followed by two consonants, compete about stress placement, the rule seems to be that the last one takes the stress if it ends in a stop consonant (kardǽsg 'brush, float', absén't 'absinth'), whereas the first one takes the stress if this is not the case (túrnips 'turnip'). Exceptions to the last-mentioned rule like hárnisg, áugosd (as a personal name) behave as if they were derivations (*harn-isk) or compounds (*af-gust) and may be marked for this pseudo-complexity in their lexical representations.

The French forms like balkåŋ́, sjelé cannot be covered by these rules. One might set up a rule according to which long vowels are obligatorily shortened before the velar nasal; this would permit us to represent words like balkåŋ with a long second vowel in their underlying forms. However, this kind of hocus-pocus would not help to explain the final stress in forms like metál, sjelé (since an underlying long vowel stays long before /l/ and zero, cf. forms like poká:'l 'goblet', idé:').

It being granted that the two kinds of loanwords exemplified by balkåŋ, sjelé must be taken care of by some special rule, the remaining monomorphemic wordforms can, with very few exceptions, by accounted for by a set of simple rules. One way to do this is to assign the feature [+stress] to every full vowel and to delete some of the stresses afterwards, "heavy" syllables (syllables containing a long segment or a postvocalic consonant cluster) conditioning the deletion of stress in lighter syllables according to a particular rank ordering. Another possibility is just to assign stress to the vowels that shall have stress, the rank ordering of syllables according to their segmental content being incorporated in an ordered set of rules. The problem of formalization must, however, be postponed until polymorphemic wordforms have been considered, too. At present, the rules will only be stated in an informal way according to the second solution:

Rule 2.2.-A A vowel segment containing the classificatory feature [+long] receives stress.

Rule 2.2.-B If rule 2.2.-A has applied vacuously, a vowel segment followed by a consonant segment containing the classificatory feature [+long] receives stress.

Rule 2.2.-C If rules 2.2.-A&B have applied vacuously, a vowel segment (the last vowel segment?) that is followed by two consonant segments of which the second is a stop, receives stress.

Rule 2.2.-D If rules 2.2.-A&B&C have applied vacuously, the first vowel segment that is followed by two consonant segments receives stress.

It may seem rather artificial to postulate underlying consonant length, since consonants are phonetically short in Danish in all environments (except for "syllabic" consonants representing a fusion of shwa plus consonant, or consonant plus shwa, according to a late, optional rule). However, there is some evidence that consonant length must be posited anyway, partly as a classificatory feature appearing in lexical entries and partly as a feature generated at some intermediate stage in the phonological rules. This is, at least, a possible way to explain (predict) the distribution of stød, and hence an analysis which postulates the existence of underlying consonant length as a feature which is deleted by a late rule, is not entirely without support from evidence of a different kind.

Underlying consonant length serves to generate the correct phonetic output in cases where the accentuation type manifested by stød is expected on grammatical grounds. It being assumed that Danish has a distinction like the Norwegian or Swedish one between "accent 1" (being grammatically predictable in forms like pǽn' 'pen', kát 'cat', or in the definite forms pǽn'ën, kátën, etc.) and "accent 2" (grammatically predictable, for example, in the plural forms pǽnë, kátë or in monomorphemic forms like ǽnë 'end'), we find that this distinction is neutralised everywhere except in syllables containing a long vowel or a vowel followed by at least one voiced consonant. In such syllables (with so-called phonetic stød-basis) "accent 1" may appear as stød, otherwise there is no phonetic distinction between the two alleged types of accentuation (this statement holds true only for some varities of Standard Danish). In this respect Danish differs radically from Norwegian and Swedish (note further that "accent 1" is the marked one in Danish, whereas it is generally considered the unmarked one in Norwegian and Swedish). It is, however, interesting that the (early) rules inserting "accent 1" and "accent 2" (or rather only the former, since the latter need not be marked at all) are very closely related to those of Norwegian and Swedish. The various manifestations of "accent 1" and its neutralisation with "accent 2" under certain conditions, must be taken care of by a later set of rules that are specific to Danish.

However, the situation is further complicated by the fact that even syllables with a voiced postvocalic consonant do not necessarily take stød under conditions where "accent 1" is expected on grammatical grounds, cf. vǽn 'friend' versus pǽn' 'pen'. On the other hand, there is invariably stød in monomorphemic wordforms that contain an additional consonant after the voiced one, cf. kán't 'edge', and similarly if the vowel is long, cf. pǽ:'n 'nice'. According to Hjelmslev (7), monosyllables with stød on a final voiced consonant such as man' 'man' has a latent /d/ after the postvocalic sonorant, whereas there is no latent consonant in forms without stød under similar conditions. /d/ is postulated here because it appears in derivations with -ig, cf. mándi 'manly'. However, I should rather like to speak about underlying length in such cases (it is not difficult to formulate a rule inserting d between long obstruents and the suffix in question). Accordingly, the phonetic forms may be generated from underlying forms differing in length:

¹væn → vǽn

¹pæn: → pǽn'

¹pæ:n → pæ:'n

This analysis does not take care of the accentuation in inflected forms like vǽn'ën. However, the fact that "accent 1" is manifested by stød here can be explained in terms of a rule which lengthens a postvocalic consonant before a following vowel (which in turn may be inserted by a phonological rule). This abstract consonant lengthening (which does not appear in the output except through its effect on accentuation) only takes place in certain cases; in other cases the vowel is lengthened instead, cf.

bað 'bath' definite form ¹baðët → bá:'ðët

væn " " ¹vænën → vǽn'ën

The lengthening of vowel or consonant is largely dependent upon the quality of the consonant; roughly speaking, vowels are lengthened before voiced approximants, whereas consonants are lengthened if they have partial or complete oral occlusion (i.e. both nasals and /l/ belong to the latter group; the classification of /r/ is most controversial). For more details see Basbøll (3).

Forms like vǽn must be interpreted as consisting entirely of short segments. They nevertheless take stress like other wordforms. We must, therefore, add a final rule to take care of forms of this kind:

Rule 2.2.-E If rules 2.2.-A&B&C&D have applied vacuously, the last full vowel is stressed.

Note that this rule (which also takes care of the form metál) makes the feature of consonant length redundant in final voiceless consonants provided that there is no preceding long syllable to attract the stress. Forms like bukǽt can be represented in lexicon with a final short /t/, but since analogous forms like kasgǽt must have /t:/ in order not to get initial stress by the application of the rules as they stand, the possibility of omitting the length mark in a number of individual cases may not be particularly interesting from the point of view of the pattern. In the input to the phonological rules the two forms must have analogous representations. It is more interesting to note that consonant length is redundant in monosyllables ending in a voiceless consonant (like hát). In such forms the final consonant is short and remains short according to general marking conventions.

It is not at present clear to me how much is gained by generating stress or rather the placement of stress from underlying segment length and syllable complexity.[6] The analysis attempted above may be criticized as being unduly abstract. Note, however, that in spite of the fact that there is no phonetically obvious parameter of length associated with the postulated underlying difference between long and short consonants, it is nevertheless a matter of terminology whether one should speak of absolute neutralization or not, since the accentuation effects are indeed very directly associated with underlying consonant length, the relationship being a perfectly regular one.

It is certainly possible to mark stress in lexicon, but then one misses all the true generalizations that can be made with reference to vowel length and consonant number, and the distribution of stød must be accounted for anyway.

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6) In his analysis of Norwegian Weinstock (13) prefers to derive both vowel length and stress from consonant length. From an autonomous phonemic point of view one might do the opposite (with equal or more phonetic justification).

3. Stress in forms with suffixes

3.1. Suffixes with and without inherent stress

Suffixes which contain no full vowel are never stressed, cf. the superlative ending in tǿnësd 'thinnest'.

Suffixes containing one or several full vowels may have inherent stress or no stress. The majority of these suffixes have stress, like ík in grafík, ísd in violinísd; this group includes all suffixes containing a long vowel, e.g. ǿ:'r in frisǿ:'r 'hairdresser', ǿ:'s in nervǿ:'s 'nervous'.

The most important suffixes with unstressed full vowels are: i in kǿ:li 'cool', li in vǽnli 'friendly', isg in jǿ:ðisg, ikër in grá: fikër 'lithographic artist', eŋ, neŋ in má:leŋ 'paint', hǽlneŋ 'slope'. These are all similar in that the unstressed full vowel is a non-open unrounded front vowel. One may consider the possibility of deriving i, e in these cases from shwa, which would make stress largely predictable from the underlying distinction between full vowels and shwas in suffixes. This analysis is not entirely satisfactory, however, since it conceals the fact that there is some kind of connection between suffixes like isg and suffixes like ík, ité:'t, cf. grafík - grá:'fisg, æksæntrisité:'t - æksǽn'trisg. If consonants are assumed to differ in underlying length, the difference between stressed and unstressed suffixes can almost be accounted for by the morpheme stress rules formulated in section 2.2. The only exception noticed by me is isg, which is apparently related to sg, cf. jǿ:ðisg 'jewish' versus dan'sg 'danish'. It may be possible to cut off the i as a separate morpheme or pseudo-morpheme (appearing in the mutually related suffixes above and in more peripheral suffixes like the complex á:'riom in planetá:'riom). If there is an internal border in isg both parts of the complex must remain unstressed according to the stress rules set up in 2.2., which thus seem to apply to morphemes as well as monomorphemic wordforms.[7]

3.2. Suffix addition and stress deletion

In the following it will be assumed that each morpheme of a wordform is stressed or unstressed in some underlying representation, the morpheme stresses being introduced by early rules, i.e. at a point where the different kinds of phonological juncture are still symbolized in terms of the structure of the syntactic surface representation (except for morphemes which may have to be marked for stress or inability to take stress on a particular vowel). This approach (which of course does not agree with the formulation of stress rules in Chomsky-Halle (4)) seems to me meaningful since, for example, the accentuation of prefixes cannot be predicted except with reference to the morphemic composition of the wordforms. Thus, the stress rules are here put on roughly the same level as the rules generating "accent 1", which obviously must refer to boundaries reflected as /+/ in phonology, cf. makró:'n+ër 'macaroons' versus matró:në+r 'matrons', pó:'dië+r 'platforms' versus ká:no:'+ër 'canoes', obviously by early rules referring to the structure of morphemes. If we assume each morpheme to be specified by early rules for stress (inexactly referred to as "inherent stress"), word stress must be generated by a deletion rule plus a related shortening rule:

Rule 3.2.-A A morpheme stress is deleted if there follows another stress without intervening juncture of the type delimiting lexical entries (i.e. #).

Rule 3.2.-A′ A long vowel without stress is shortened before a syllable with a full vowel and optionally before a syllable with shwa.

violí:n+ísd+én:ë → violi:nisdén:ë → violinisdénë

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7) This presupposes either that the vowel of (n)eŋ is derived from shwa or that the final consonant is derived from one underlying segment (i.e. not from /ng/).

3.3. Additive and replacive suffix insertion

Suffixes containing a full vowel may either be added directly to the stem or replace the final part of it. The replacive transformation applies in particular if the stem ends in shwa, cf. jǿ:ðë with the derivations jøðénë 'female jew', jǿ:ðisg 'jewish', or metó:ðë - metó:'ðisg, but suffixes (or suffix clusters) like isg, ikër, isité:'t also seem to replace full vowels in some cases, cf. melodí:' - meló:'disg, where the shortness of the last vowel proves that the suffix is replacive isg (not additive sg as in partí:' - partí:'sg).

It is characteristic of replacive constructions that the consonant preceding the replaced vowel tends to retain the quality it should have before this original vowel, cf. the two variants of /d/ in jǿ:ðisg and metó:'ðisg versus meló:'disg. The former, i.e. ð, is in "weak position", but the latter, i.e. d, is in "strong position" in the underlying stem form (cf. Rischel (12)).

In many instances the stem to which the replacive suffixes are joined is otherwise found only with stressed suffixes. In such cases it may not be valid to claim that the replacive suffixes replace any particular sequence, but the wordforms may nevertheless behave as if the suffixes replace a "dummy" syllable with stress. The presence or absence of a syllable of this type in the underlying form of the stem is sometimes apparent from the consonant quality. A typical example is the root morpheme /lo:g/ in logík 'logic', ló:'gisg 'logical', ló:'gikër 'logician' versus the derivative suffix /lo:g/ in filoló:γ 'philologist', filoló:'γisg (or filoló:'gisg), filologí:'. The root morpheme (which is not very clearly related to the derivational suffix from a synchronic point of view) does not occur alone but only with suffixes as in logík, which may be termed a "quasi-derivation" since the presence of a suffix ík is obvious, cf. etík, kritík, and other analogous forms. In accordance with the fact that ló:'gisg, ló:'gikër are felt to be derived from logík, the /g/ keeps its quality as a stop consonant determined by strong position. In the form filoló:'ɣisg, on the other hand, the suffix isg may be taken as either added to filoló:'ɣ or replacing the suffix of filologí:', and accordingly, there is some vacillation in the pronunciation. With /p t k/ the difference between underlying weak and strong position is probably not made very consistently.

Purely additive suffixes do of course not behave like this. A stem final consonant to which an unstressed suffix is added, remains in weak position, cf. ábeð 'abbot', plur. ábeðër, whereas the addition of a stressed suffix puts the consonant in strong position (stated otherwise: the syllable border comes before the consonant), cf. the feminine derivation abedísë 'abbess'.

3.4. Stress shift and preservation of underlying vowel length before replacive suffixes

Alternations like arisdó:'tëlës - arisdoté:'lisg 'Aristotelian', dǽ:mån or dæmó:'n - dæmó:'nisg 'demoniacal', kán'ada - kaná:'disg, kaná:'diër 'Canadian', mártỳ:'r - martý:'riom 'martyrdom', pá:radì:'s - paradí:'sisg 'paradisiac', sá:tan - satá:'nisg 'satanic' show a tendency for unstressed replacive suffixes to cause the preceding morpheme to take stress on the last syllable. Moreover, the wordform gets "accent 1" (i.e. stød if phonetically possible), also in cases where the underlying stem is an "accent 2" form, cf. metó:ðë - metó:'ðisg (jó:ðë - jó:ðisg without stød points to a difference in the treatment of foreign and nonforeign lexical items).

(In their analysis of English Chomsky and Halle (4) set up a distinction between the adjective-forming suffix -ic(al), which they represent as /ik+æl/, and the noun-forming suffix -ic, which they represent as /ik/. In their own words, they resort to this artifice to account for the fact that the former suffix places stress on the immediately preceding syllable (4, p. 88). The corresponding Danish suffixes are replacive isg and ík, respectively. The underlying form of the latter is /ik:/ according to the analysis proposed here; that of the former is probably /i+sg/. There is no possibility of a solution like the one proposed by the said authors for English.)

The fact that the length is shifted from one vowel to the other in cases like sá:tan - satá:'nisg might suggest that the root morpheme in such forms has two underlying long vowels: /sa:ta:n/, of which the second is shortened by some phonological rule unless it has received stress. However, it is difficult to see how such a rule could be formulated in general terms without shortening also the last vowel of paradis, martyr. One way to except the latter words from such a shortening rule would be to mark them as quasi-compounds, i.e. with an internal boundary of the kind associated with lexical items, i.e. #. This somewhat arbitrary solution may be avoided if we take both vowel lengthening and stress attraction to be directly conditioned by the suffix /i/ in isg, iom, etc.:

Rule 3.4.-A Stress is moved to the vowel immediately before replacive suffix /i/.

Rule 3.4.-A′ A vowel separated from replacive /i/ by one consonant, is lengthened.

The ability of the suffix to trigger this complex of rules must be marked as an abstract feature of it. The suffix found in kø:li 'cool', etc., which is superficially similar to the replacive suffix (element) in question, does not trigger the rules. Ultimately, the difference has obviously something to do with the status of the suffixes as foreign or nonforeign.

3.5. Vowel length and stress in the suffix "-or"

Forms like lǽktår 'lecturer' - definite form lǽktår(')ën - plural læktó:rër show that the nomen agentis suffix "-or" appears in two shapes: with short unstressed å and with long stressed ó:. If an underlying form is posited with /o/, both the opening in final syllable before /r/ and the lengthening to o: before a voiced approximant followed by a vowel tie in well with the general phonological rules of the language. It may seem strange that the lengthening is not found before the definite article, but this is true also of some monosyllables, cf. bǽr 'berry' - definite form bǽr'ëð (the lengthening rules applying to monosyllables with suffixes added to them are treated in detail in Basbøll (3)).

If the above analysis is correct, the lengthening rule in question must be prior to the rules assigning stresses to vowels, since the sequence /or/ does not fulfill the conditions for stress before the vowel is lengthened.

4. "Heavy" suffixes

Some suffixes (of German origin), in particular -hed, -dom, -skab, and partly -agtig, are stressed like the second part of compounds, the rhythmical patterns of djǽrvhè:'ð 'frankness', mándȁm' 'manhood', klóɣsgà:'b 'wisdom' being similar to those of bjǽrɣgè:'ð,'mountain goat', dǿðsdȁm' 'death sentence', bóɣsgà:'b 'bookcase'. This suggests that the suffixes are characterized by being separated from the preceding stem by a boundary of the type /#/ unlike the suffixes treated in section 3., which were preceded by /+/.

The stress insertion rules given in section 2.2. apply to these suffixes. Two of them have a long vowel: /he:d/, /sga:b/, the others have a long consonant or a consonant cluster after the vowel, i.e. they fulfill the conditions for the rules in 2.2. to apply. However, the stress deletion rule 3.2.-A does not operate across a boundary of the /#/ type. For sequences with this type of boundary see further section 6.

5. Prefixes and stress

Prefixes are characterized by occurring only word initially before a root morpheme. The Danish prefixes all have short vowels followed by none or one consonant (apart from the somewhat questionable prefix ent-), so they cannot possibly be stressed, according to the rules, provided that they are separated from the following morpheme by /+/ rather than /#/. This difference of boundary distinguishes between /får+fal:/ 'decay' with a prefix and /får#fal:/ 'unavoidable absence' with a succession of two lexical units each of which gets stress according to 2.2.

The prefixes u 'un' and on (und-) 'away from (?)' [8] differ from the other prefixes in that they appear both with and without stress. I see no other way of explaining this than by considering them to be quasi-lexical items separated from the following morpheme by /##/, the unstressed variants being caused by a rule deleting /##/ in certain cases (the existence of a /##/ deletion rule in English is postulated by Chomsky and Halle (4), p. 86, this rule taking care of alternative stress patterns on words like analyzable). The same deletion rule is found with some regular compounds, and it will therefore be discussed in the next section.

The special status of the prefixes u and on must of cause be explained by their role in the syntactical component of Danish grammar (which is not considered here). From a purely distributional point of view u clearly differs from other prefixes in that it can occur before a prefix, cf. ubesgrí:'vēli 'indescribable', which is another testimony of the fact that it has a special grammatical status.

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8) and similarly the foreign prefixes de, a (the latter probably only with stress).

6. Compound words

As stated above compounds are normally characterized by their members being joined by junctures of the /#/ type. Within each sequence bounded by /#/ the stress deletion rule applies, but the remaining stress of each sequence is retained although the relationship between the members of the compound is signalled by differences in the degree of stress. If there are more than two such degrees, the lower degrees tend to be indistinguishable from absence of stress: a compound like undervandsbåd 'submarine' has normally no more stress on the third syllable than underbetalt 'underpaid', in which the third syllable is a prefix.

The rules generating degrees of stress in compounds will not be considered any further in this paper.

In some cases there seems to be a stress metathesis rule operating at a very late point in the phonological rule complex, compounds like stationsforstander being often pronounced sdasjó:'nsfårsdàn'ër instead of sdasjó:'ns-fårsdan'ër. The compound, which means 'station master', definitely contains the lexical item /får/ 'for, front', not the prefix /får/, but the existence of the latter may have conditioned the frequent use of the form with apparent metathesis.

7. Compound words and similar stretches with /+/ instead of /#/

Quite a few compounds exhibit the stress pattern typical of sequences with /+/ junctures, i.e. with deletion of all but the last stress. This peculiar structure is found in a good many place-names and in a restricted number of ordinary compounds, but it seems to be associated in particular with stretches containing the suffixes i, li (orthographically -ig, -lig). Examples are: ansé:'li 'magnificent', l̲æ̲t̲s̲é̲n̲'̲d̲i̲ 'rash', sansý:'nli 'probable', mæ̌ðgö:'rli 'tractable', telfårlá:'ð̌ëli 'reliable'.

This category is joined by a large number of words with the prefixes on and particularly u, e.g. onsé:'li 'shy', ugýl'di 'invalid', uhǽl'di 'unlucky', utál'i 'innumerable', ubönhǿ:'rli 'relentless', ulasaigő:'rli 'impossible to do'.

Many wordforms of this category are also deviating in that the parts of which they consist (when the suffix has been removed) do not both occur alone, or if they do, they may only occur with a different meaning or in a deviating phonetic shape. It might be assumed that the particular stress pattern were due to this opacity of the wordforms, but in fact the same stress pattern is found also with some forms which are entirely transparent, whereas others have the ordinary compound stress pattern, cf. uhǽl'di versus úvæ̀nli 'unfriendly'.

Somehow, the stress patterns probably depend upon how these adjectival forms are generated in the syntactical component. As for the forms with the negative prefix, it seems that those which are quite obviously composed of the prefix plus an independent adjective, have /#/, i.e. the stress pattern of compounds, whereas those which are generated via a noun to which the negative prefix has been added, have /+/, i.e. no prefix stress. Finally, forms of which the nucleus is a verb (e.g. umésdëli 'inalienable') have /+/ (ugýl'di may represent this type). These superficial considerations are, of course, quite inadequate from the point of view of syntax, but they suffice to suggest that there may be a syntactical explanation of the stress patterns whereas it would not be possible to predict them on purely phonological grounds.

8. Summary and formalization of rules

This paper attempts to show that stress in Danish is largely predictable not only in "genuine" Danish words but also in words of foreign origin, with the exception of a number of loanwords from French, which must either be taken care of by quite specific rules or marked as "French", or the like (a binary distinction of ±foreign is hardly sufficient to explain the heteogeneous character of the lexicon).

As for the commutation pairs listed in the beginning of the paper, kórset and korsét differ in their underlying representations as /kårs+ëd/[9] versus /kårsæt:/, fórfald and forfáld are respectively /får#fal:/ and /får+fal:/, kánon and kanón are respectively /ka:non/ (?) and /kanó:n/, plástic and plastík are respectively /plastik/ and /plast+ik:/.

It has been suggested in this paper that there is a phonemic distinction in Danish between shwa and other vowels. This may be taken care of by the feature "tense". It is further postulated that length is a classificatory feature distinguishing long and short vowels as well as long and short consonants in the underlying representations, although consonant length is deleted by a late rule. (It would be possible to speak of geminated vowels and consonants in order to avoid the feature "long", but I see no particular advantage in doing so.) Finally it is assumed that there are two kinds of marked boundaries in the word-forms: /#/ being the type of boundary that marks off lexical items, and /+/ being a morpheme boundary which does not have this property.

Whereas Chomsky and Halle in their description of

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9) If this is a verb form, there is certainly a syllable with shwa, whereas the analysis of definite forms is controversial.

English put stress on wordforms by one main stress rule (with minor modifications by later rules), I have tentatively used a rather different approach. As presented in this paper, the Danish "main stress rule" consists of three sections, which do not belong directly together in the rule hierarchy. The first section (rules 2.2.-A&B&C&D) puts stress on each morpheme whose segmental structure permits it to take stress according to these rules. The second section (rule 2.2.-E) puts stress on wordforms (applying vacuously if they already have got morpheme stress). Finally, the third section (rule 3.2.-A) delete stresses before later stresses in the same wordform. A supplementary rule shifts stress to the position immediately before certain "replacive" suffixes (rule 3.4.-A), probably before the application of the last part of the main rule. - The rules demand for their application an input consisting of stretches bounded by /+/ or /#/. Some of these stretches are supposed to exhibit a replacement of /#/ by a boundary type of a lower rank (replacement by /+/ or simply deletion). The "/#/ deletion rule" cannot be stated in the present paper, since it demands a good deal of syntactical considerations and probably belongs to the syntactical component of grammar.

The approach used in this paper violates the principles laid down in Chomsky's and Halle's book (4) since it postulates that certain stress rules operate with reference to boundaries of the /+/ type. This heresy has something to do with the fact that so many conditioning factors enter into the stress generating rule(s): position of long vowel segment, position of long consonant segment, position of postvocalic consonant cluster(s), and the distinction between full vowels and shwa. Since the subrules associated with these conditioning factors are disjunctively ordered, the rule complex becomes rather involved. Moreover, the rules generating "accent 1", and the later rules converting this abstract accent into _stød_ under phonetically definable circumstances, should also be taken into account.

As far as I can see, there is only one point of disagreement between the principles governing the stress placement in monomorphemic wordforms and those governing the stress placement in polymorphemic noncompound wordforms. This point has to do with the unstressed full vowel suffixes, which can only be distinguished from the stressed ones if the latter are marked as "foreign": *húrtisd* 'fastest' having minus for this feature, *gardísd* plus. This is intuitively an extremely satisfactory solution.

I do not want to insist that stress is generated together with "acc. 1", or lexical. It is possible to generate word stress by rules operating on a representation with /+/ and across such boundaries. This requires a rule for prefixes and probably a shortening rule for cases like *solísd* 'soloist' vs. *ró:lisd* 'calmest' if the former has /o:/, cf. *só:lo*.[10]

With these reservations it should be possible to set up the rules suggested in this paper in such a way that they apply to noncompound wordforms (i.e. within #-bounded strings). They are given here with a minimum of symbol use (disjunctive ordering permits further simplification):

Rule 8.-A

$$\begin{bmatrix} \text{V} \\ +\text{long} \end{bmatrix} \rightarrow [1\ \text{stress}] \ / \ \text{X}\underline{\quad}\text{Y}$$

where Y contains no $\begin{bmatrix} \text{V} \\ +\text{long} \end{bmatrix}$ and X,Y no $[1\ \text{stress}]$

Rule 8.-B

$$\text{V} \rightarrow [1\ \text{stress}] \ / \ \text{X}\underline{\quad}\begin{bmatrix} \text{C} \\ +\text{long} \end{bmatrix}\text{Y}$$

where Y contains no $\begin{bmatrix} \text{C} \\ +\text{long} \end{bmatrix}$ and X,Y no $[1\ \text{stress}]$

Rule 8.-C

"Foreign" stress rule

$$\begin{bmatrix} \text{V} \\ +\text{tense} \end{bmatrix} \rightarrow [1\ \text{stress}] \ / \ \text{X}\underline{\quad}\text{C}\begin{bmatrix} \text{C} \\ -\text{cont.} \\ -\text{nasal} \end{bmatrix}\text{Y}$$

10) Vowel length is definitely phonemic in Danish.

where Y contains no $\begin{bmatrix} \text{C} \\ \text{-cont.} \\ \text{-nasal} \end{bmatrix}$

and X,Y no [1 stress]

Rule 8.-D

$\begin{bmatrix} \text{V} \\ \text{+tense} \end{bmatrix} \rightarrow$ [1 stress] / X___CCY

where X contains no CC
and X,Y no [1 stress]

Rule 8.-E

$\begin{bmatrix} \text{V} \\ \text{+tense} \end{bmatrix} \rightarrow$ [1 stress] / X___C

where X contains no [1 stress]

With a more complete knowledge of Danish prosody it should be possible to reformulate the rules entirely to get something like the rules sketched by Weinstock (13). It would be interesting to see to what extent the various Scandinavian languages agree in their treatment of foreign words of different categories.

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COMPARATIVE PHONETIC-ACOUSTIC ANALYSIS BEFORE AND AFTER SPEECH THERAPY OF VOICES SUFFERING FROM RECURRENS PARESIS

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1. Introduction

Within the field of speech therapy very little research has been done on the effectiveness and results of speech training.

This report deals with three cases of paralysis of the recurrens nerve caused by operative damage after struma operations. The voices were tape recorded before and after the speech therapy. Afterwards the recordings have been phonetically analyzed in order to get some kind of quantitative description of the change in voice quality.

The investigation is only meant as as pilot investigation showing possible methods for analysing speech defects such as dysphonia caused by paresis, etc.

2. Recurrens paresis

Patients with partial defects of the recurrens nerve often undergo very typical changes in voice quality. The voice sounds dull, soft, feeble, hoarse, and unstable with a considerable amount of noise in the acoustic spectrum. Occasionally the unstability is so marked that the voice sounds diplophonic.

During the (often very short) period of voice training the quality of the voice normally changes, and the voice develops into a lighter, more modulated, and less noisy quality without tendency to diplophonia. The fundamental frequency[1] is lowered, and the intonation range is increased.

3. The patient material used in this investigation

The three voices are characteristic examples of the voice change taking place in connection with recurrens paresis, the first one being a weak, dull voice with a poor content of overtones and almost exclusively used in the head register, and the second and third ones being hoarse, grating voices with characteristic tendencies of diplophonia.

3.1. Case No 1, (TH) :

Woman 48 years old, operated March 25, 1963.

Clinical investigation June 14, 1963: Left vocal fold immovable in intermedian position, with slight concavity and shortening. Right vocal fold with free mobility, but not reaching left vocal fold during phonation.

Speech therapy from August 16 till November 8, 1963, a total of 19 lessons of 25 minutes each. Recording dates: September 3 and September 17, 1963 (after 7 lessons).

Clinical observation November 8, 1963: Left vocal fold in median position, not concave. Right vocal fold with good mobility, reaches left vocal fold with good occlusion during phonation.

3.2. Case No 2, (RH) :

Woman 43 years old, operated October 16, 1963 for a struma from which she had suffered for twenty years.

Clinical investigation November 15, 1963: Right vocal fold immovable in paramedian position. Left vocal fold with free mobility and good occlusion during phonation.

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1) In the following the shorter term "pitch" has been used in the sense of fundamental frequency.

Speech therapy from November 15 till December 16, 1963, a total of 17 lessons of 25 minutes each. Recording dates: November 12 and December 2, 1963.

Clinical observation December 13, 1963: Both vocal folds with good mobility and good occlusion. Thus the right-sided recurrens paresis has disappeared.

In the first recording this voice, which is predominantly characterized by a very hoarse, grating phonatory quality, discloses glimpses of normal function. This is clearly heard at least in one word and observed in this word as well as in other cases of shorter duration in the sonagrams and pitch curves. (This agrees with the description of the laryngoscopic appearance in the first clinical investigation: "a good occlusion during phonation", and suggests a functional rather than organic cause of the marked tendency to diplophonia before speech therapy.)

The two voices mentioned above have been treated only with speech exercises, whereas the third one mentioned below was treated introductorily with speech exercises and then, as this gave poor results, with paraffin injection in the paretic vocal fold, and finally again with speech therapy.

3.2. Case No 3, (EH) :

Woman 44 years old, operated October 15, 1954.

Clinical investigation October 25, 1968: The patient has through many years - after a struma operation 14 years ago, which caused her to lose her voice - got accustomed using a high-pitched maidenlike register. Laryngoscopic picture: Right vocal fold is seen immovable, shortened, and concave in paramedian position. Left vocal fold with free mobility and normal appearance.

Speech therapy after operation from November 17, 1955 till May 28, 1957. Resumption of speech therapy from September 2, 1968 till February 5, 1969, 3o lessons. Then paraffin injection February 12, 1969, and finally speech therapy from February 24 till June 8, 1969, 12 lessons. Recording dates:

September 6, 1968 (diplophonia and head register)
February 24, 1969 (after paraffin injection)
April 28, 1969 (1o lessons after injection)
January 12, 197o (7 months after cessation of Speech therapy).

Clinical observation April 28, 1969: Right vocal fold immovable, slightly concave in respiration position. Left vocal fold with normal mobility. Good occlusion during phonation, voice normal.

Before the paraffin injection this voice practised two types of function, one with a marked diplophonia without any moments of normal function, and another with a thin, high-pitched head register.

4. The speech therapy

The primary aim has been to show possible methods for analyzing dysphonic speech before and after speech therapy. Of course, any expedient method for training the voice can be used. These three cases were all treated with professor Svend Smith's method of speech therapy. This method aims at the training, not of the individual, weakened musculatures, but of the whole functional-dynamic relation between the expiration pressure and the voice muscular activity. The subglottal pressure is developed and trained during the phonation by means of the abdominal-diaphragmatic respiration, so that the increase of pressure reflectorily triggers off the antagonistic resistance in the larynx musculature as a whole. In this way the distribution of muscular energy between stressed and unstressed (accentuated and unaccentuated) phonatory activities is trained as a reaction to the increased subglottal pressure.

This process is utilized with special reference to the function of the accentuated syllables in normal speech, and therefore the methodology has been referred to as

"The Accent Method".

5. The acoustic analysis

Very little has been written in the phonetic and phoniatric literature about the acoustics of dysphonia.

A few sonagrams appeared in Visible Speech (2). These sonagrams give objective proof of the lack of harmonics in dysphonic speech, especially in the F2-F3 region.

The auditive result of too little energy in this frequency region is a shift in timbre in the direction of rounded back vowels (a more dull quality). According to I. Lehiste and G. Peterson (1) the vowel identification is reduced to 5o % if all energy above 11oo cps is filtered away. A similar reduction in intelligibility would probably occur with a dysphonic voice which only contains harmonics below 11oo cps. Furthermore, Svend Smith (3) has found in recordings of numerous patients (at the Institute of Speech Disorders, Hellerup, Denmark) that the spectrum above 1ooo cps is intensified during the speech therapy.

It thus seems that a registration of the relative energy above 1ooo cps should be a possible way of indicating the spectral changes during the voice training.

There is often a good deal of noise to be seen in voices with recurrens paralysis. It is caused by an insufficient glottal closure. It may be observed in sonagrams, especially in narrow band sections, where the noise occurs between the harmonics in the upper part of the spectrum (most clearly seen in the sections of [a] , Fig. 5).

The typical change in the mean pitch during treatment of the recurrens paresis patients normally starts with a considerable fall, and towards the end of the therapy the average pitch may be raised again. The intonation range is often expanded, which gives the impression of a more lively voice.

Diplophonia may be observed both on sonagrams (narrow band sonagrams as well as wide band sonagrams) and on mingograms showing recordings of the pitch.

The actual analysis is mainly based on mingograms. Fig. 1 shows the record/reproduce procedure. The most important traces are no. 5: fundamental frequency, no. 6: intensity above 1ooo cps, and no. 7: intensity below 1ooo cps.

6. The phonetic material

Unfortunately the recordings of patient no. 3 (EH) are based on another text than the recordings of patients no. 1 (TH) and no. 2 (RH). Short segments of the texts containing a few sentences (duration about 6o seconds) have been chosen from each recording for the acoustic analyses.

In the first two cases the analysis is based upon 39 words containing 21 stressed and 18 unstressed vowels, and in the third case the analysis is based upon 22 words containing 12 stressed and 1o unstressed vowels. All the vowels have been analysed by means of a pitchmeter and two intensity meters with external filters as shown in the block diagram (Fig. 1). In several cases sonagrams have been made, too.

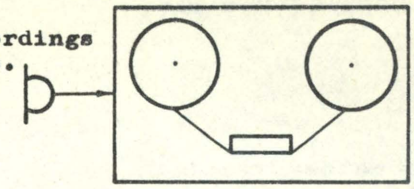
7. The illustrations

Patient no. 1 (TH): The vowels [oˀ] and [a] in the sentence "forstod hvad der var blevet sagt" [fɒˈsdoˀð va dɛʁ vɑ ble:ð ˈsɑgtʰ] have been chosen as typical examples of the changes in the spectral composition during the voice therapy. A comparison of the cross sections of the two vowels (Fig. 3) before and after the voice training shows the intensified energy in the upper part of the spectrum.

The mingograms of the same text (Fig. 4) indicate an increase of the higher frequencies, which may be seen in trace 5 and 6 under the arrows. After voice training trace

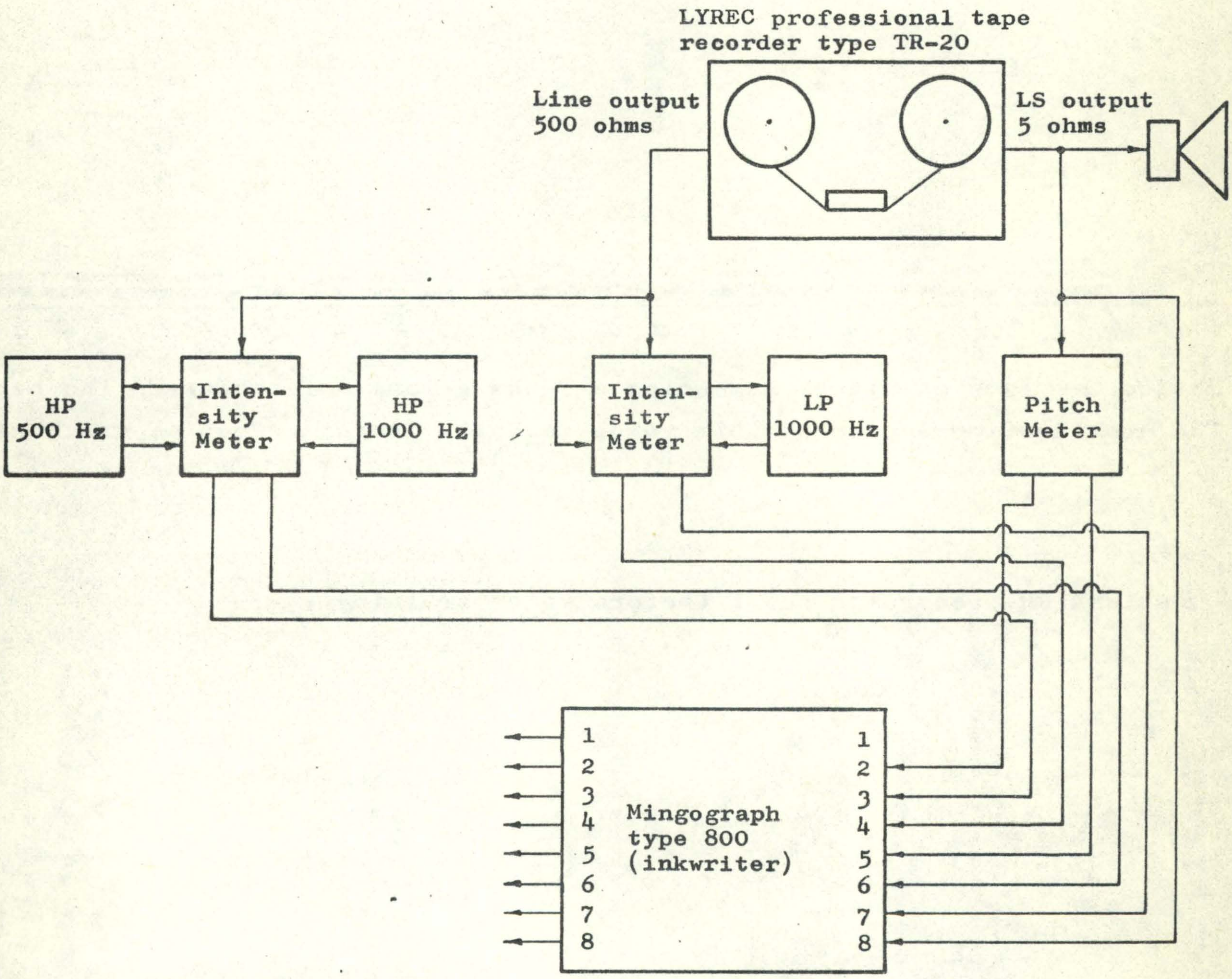
RECORDING PROCEDURE

Microphone recordings of the patients.



Patients T. H. and R. H. recorded by means of a LYREC professional tape recorder. Patient E. H. recorded by means of a UHER type 4000 L tape recorder.

PLAYBACK AND PROCESSING PROCEDURE

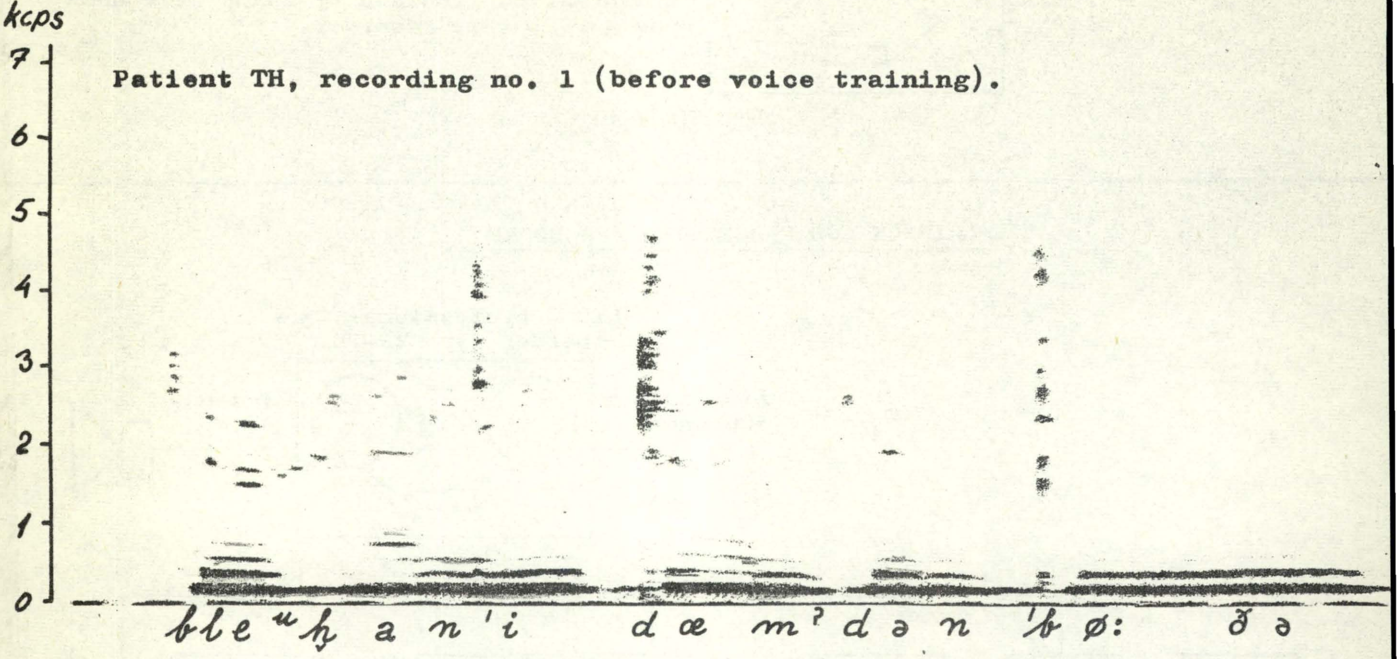


The mingograms consist of the following 8 traces:

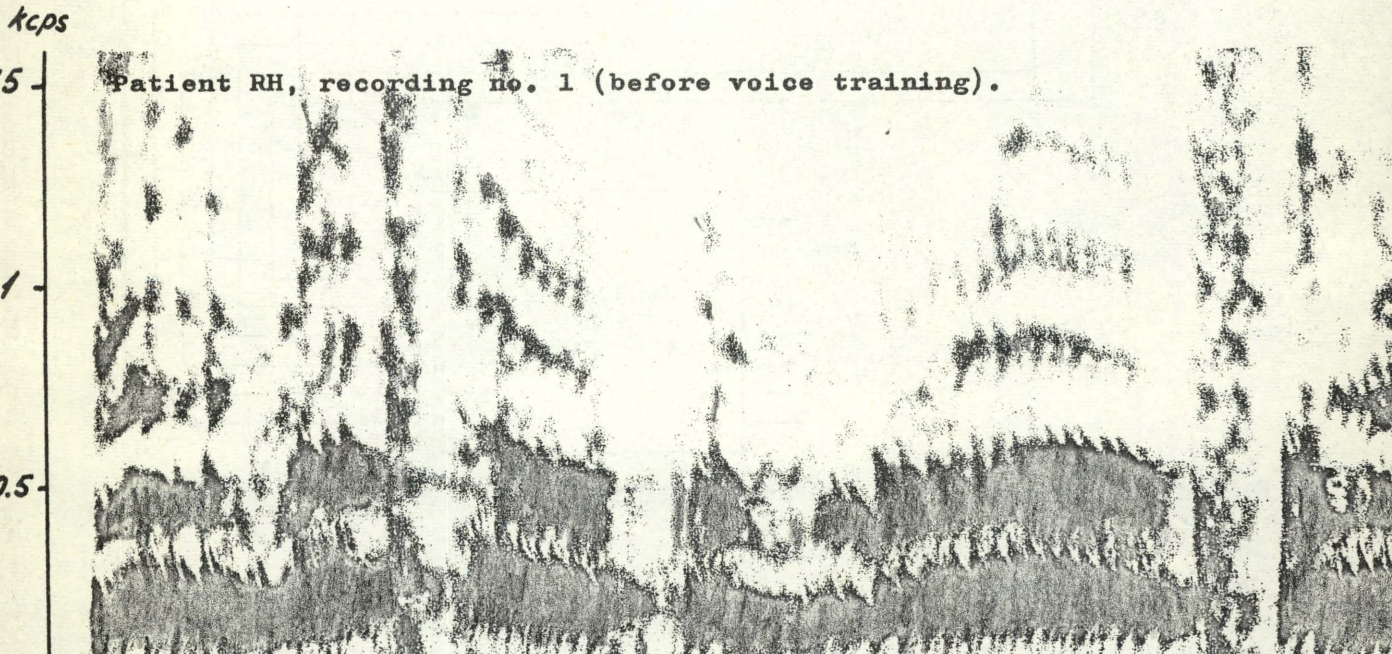
1. 1/1 and 1/100 sec. time marking.
2. Duplex oscillogram.
3. Intensity level with highpass filtering at 500 cps, integration time 2.5 ms, and logarithmic scale display.
4. Intensity level with full frequency range, integration time 5 ms, and linear scale display.
5. Fundamental frequency, bandpass filtered at 60-150 cps.
6. Intensity level with highpass filtering at 1000 cps, integration time 10 ms, and linear scale display.
7. Intensity level with lowpass filtering at 1000 cps, integration time 10 ms, and linear scale display.
8. Normal oscillogram.

Fig. 1.

TYPICAL SONAGRAMS OF TWO DIFFERENT FORMS OF UNILATERAL PARALYSIS OF THE RECURRENT LARYNGEAL NERVE CAUSED BY OPERATIVE DAMAGE.



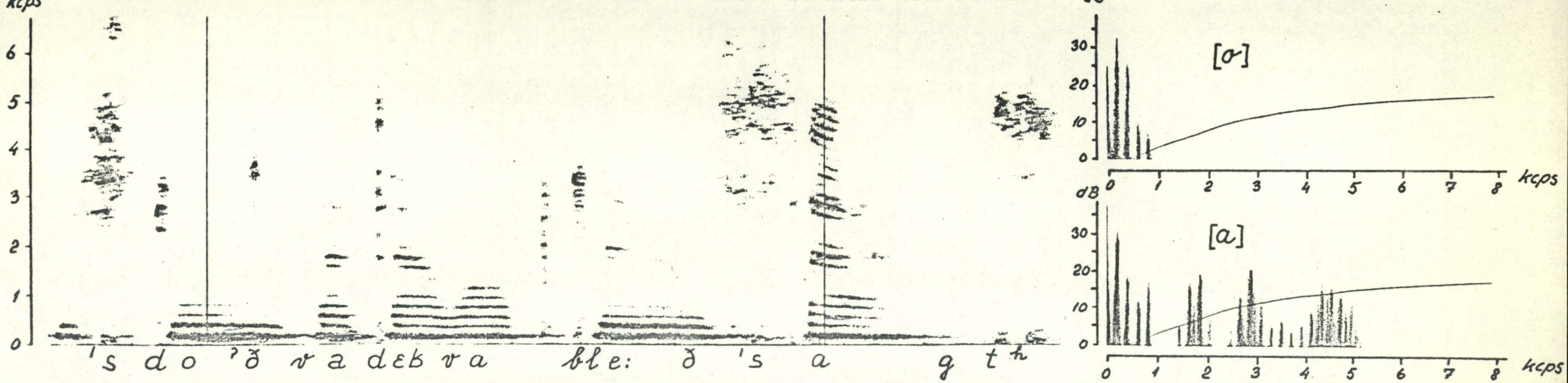
Notice the lack of higher harmonics and the strong noise between the harmonic The auditive impression of this voice is dull, languid, feeble, and hoarse.



Notice the tendency to diplophonic phonation. The auditive impression of this voice is unstable, grating, and hoarse. Occasionally the phonation may switch to head register (not shown in this sonagram). Scale magnifier has been used.

Fig. 2.

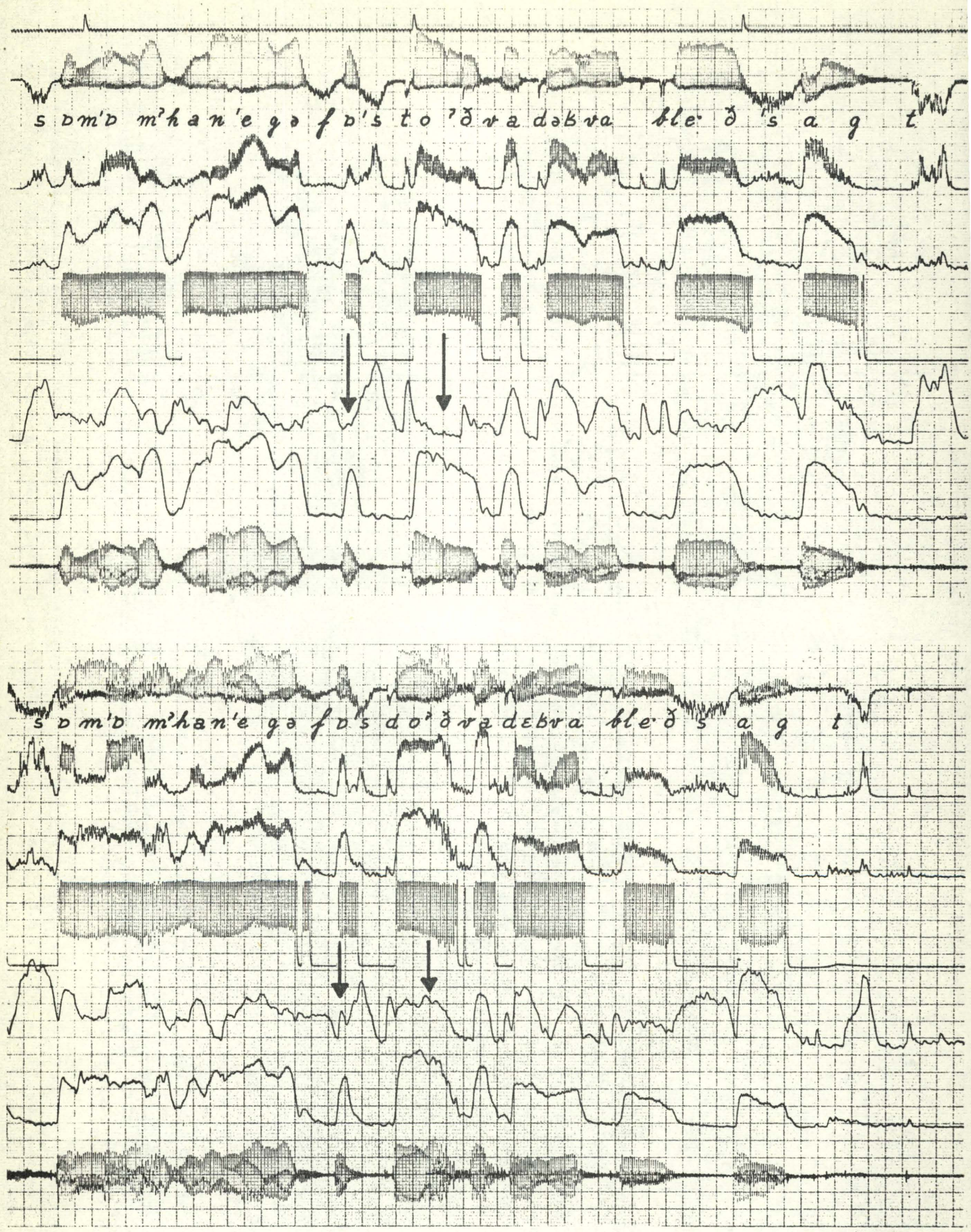
SONAGRAMS OF PATIENT TH BEFORE AND AFTER VOICE TRAINING



On this sonagram the vowels [o] and [a] have been selected for a more informative analysis of the spectral composition at a given moment. These analyses are shown to the right. Notice the total lack of the harmonics above 1000 cps in the [o], and the very weak higher spectrum in [a]. Between 4000 and 5000 cps in [a] there is a good deal of fricative noise, possibly due to insufficient glottal closure.

Notice here how the harmonics are intensified after the voice training. Compare the two section analyses of [o] and [a] before and after voice training. The harmonics in [o] are re-cognizable up to at least 3,500 cps, the intensity levels of the formants are raised, and the formants stand out more clearly.

Fig. 3.



Notice especially the relation between the energy above 1000 cps (trace 6) and below 1000 cps (trace 7) before voice training (the upper mingogram) and after voice training (the lower mingogram).

During the voice training the intensity of the higher harmonics has been considerably enforced. An enforcement of the lower harmonics in relation to the fundamental frequency can be observed when comparing the oscillograms of the two recordings.

Fig. 4.

no. 5 (the energy above 1ooo cps) contains a good deal more energy in relation to trace no. 6 (the energy below 1ooo cps) than before the training.

A similar comparison of the vowels [a] and [ɑ] in the same sentence spoken by patient no. 2 (RH) is presented in Fig. 5. Especially the vowel [a] contains much more noise before than after the therapy. The noise is considerably reduced through the training.

The tendency to diplophonia may be noticed in the left part of the sonagram, but it is more clearly observed in the mingograms of the same sentence (Fig. 6).

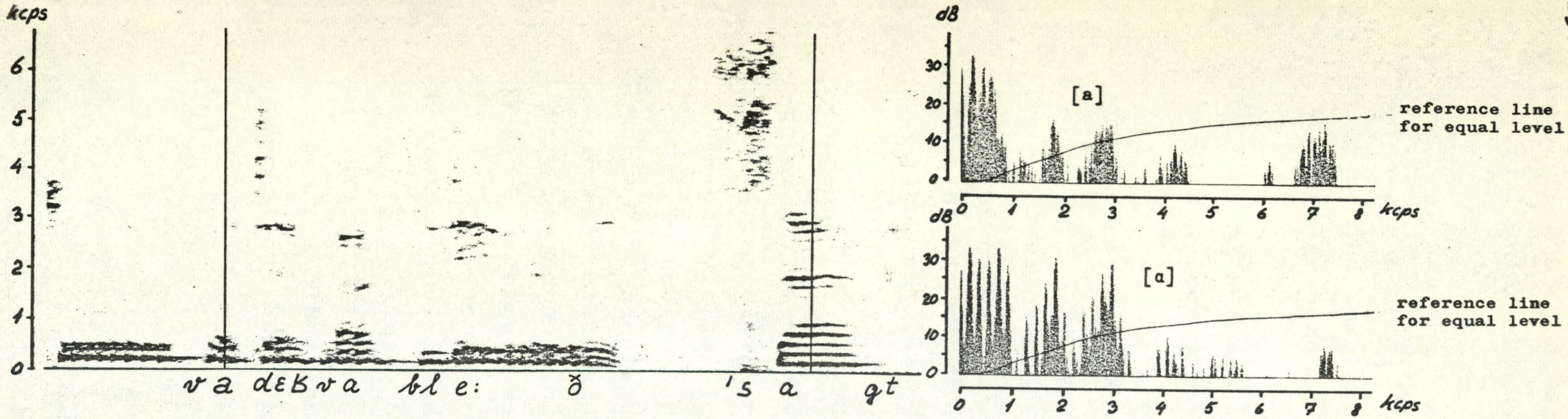
The curves show that the diplophonia attacks both the pitch and the intensity level.

In cases of recurrens paresis it is often seen (very clearly, for example, in the word "sagt" [s ɑ gtʰ] spoken by patient no. 2 (RH)) that there are sporadic elements of the normal phonation. When this is the case, the function is often easily trained in a rather short time. If it is not the case, as for instance where there is a constant, marked concavity of the paretic vocal fold, paraffin injection can be necessary in order to obtain sufficient glottal closure in the chest register. An example of a voice of that kind is shown in the two upper illustrations of Fig. 9, patient no. 3 (EH). As previously mentioned this voice practised two modes of phonation before paraffin injection: a chest register function with marked diplophonia and without moments of normal function, and a head register function, very high-pitched and with a "thin" timbre.

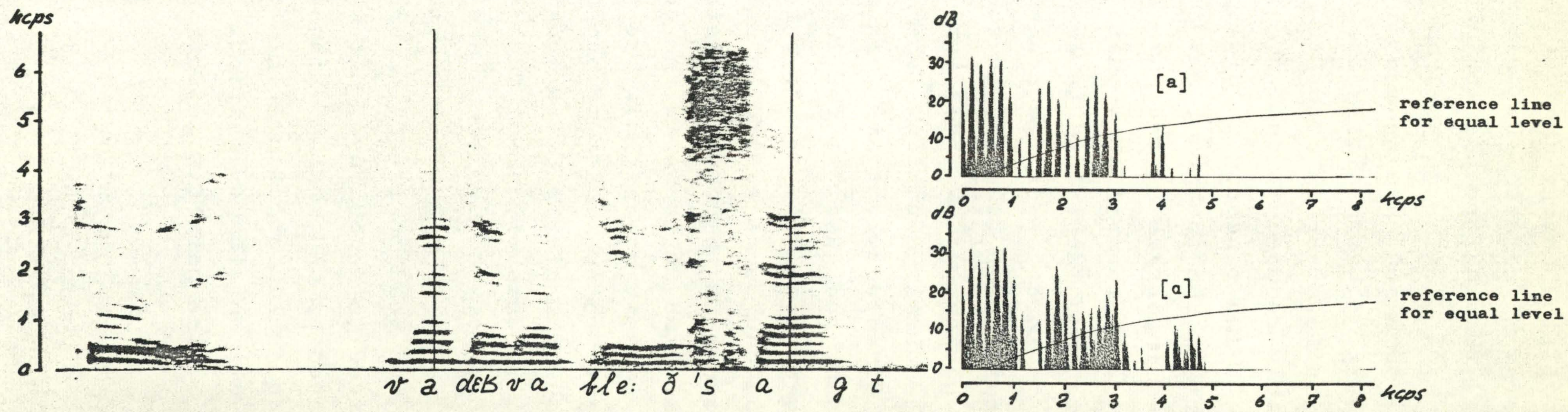
It is sometimes possible to make sufficient occlusion in the head register, though the paretic vocal fold is observed to be concave. It may be supposed that this is caused by the strong extension in the longitudinal direction, which stretches the excavated vocal fold and thereby levels out the excavation.

The paraffin injection causes an immediate ability to

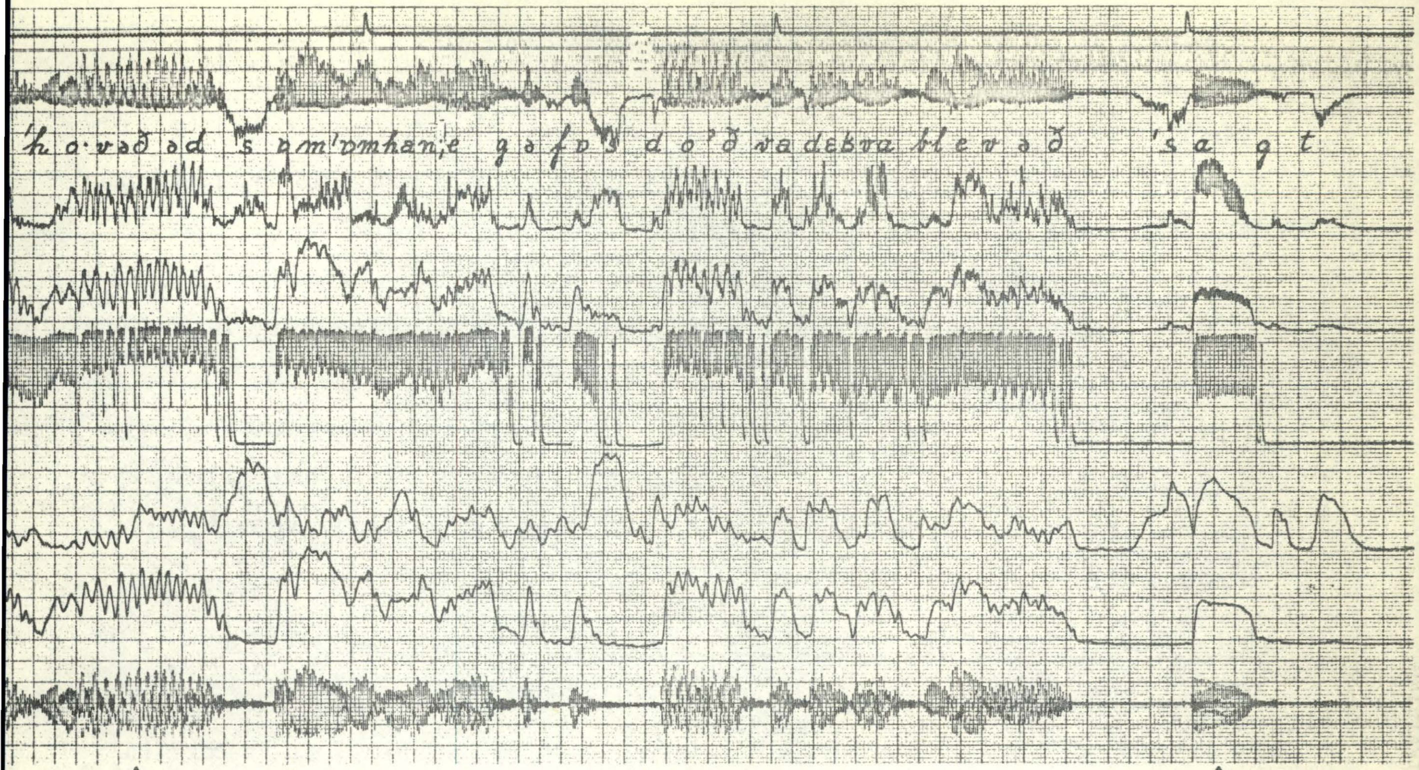
SONAGRAMS OF PATIENT RH BEFORE AND AFTER VOICE TRAINING



Sonagrams of voices with recurrent paralysis normally show spectra with very weak higher harmonics as is seen in the upper sonagram [a] . However, if the voice occasionally displays a function with normal distribution of spectral energy as shown in the upper sonagram [ɑ] it should be possible to train this function.



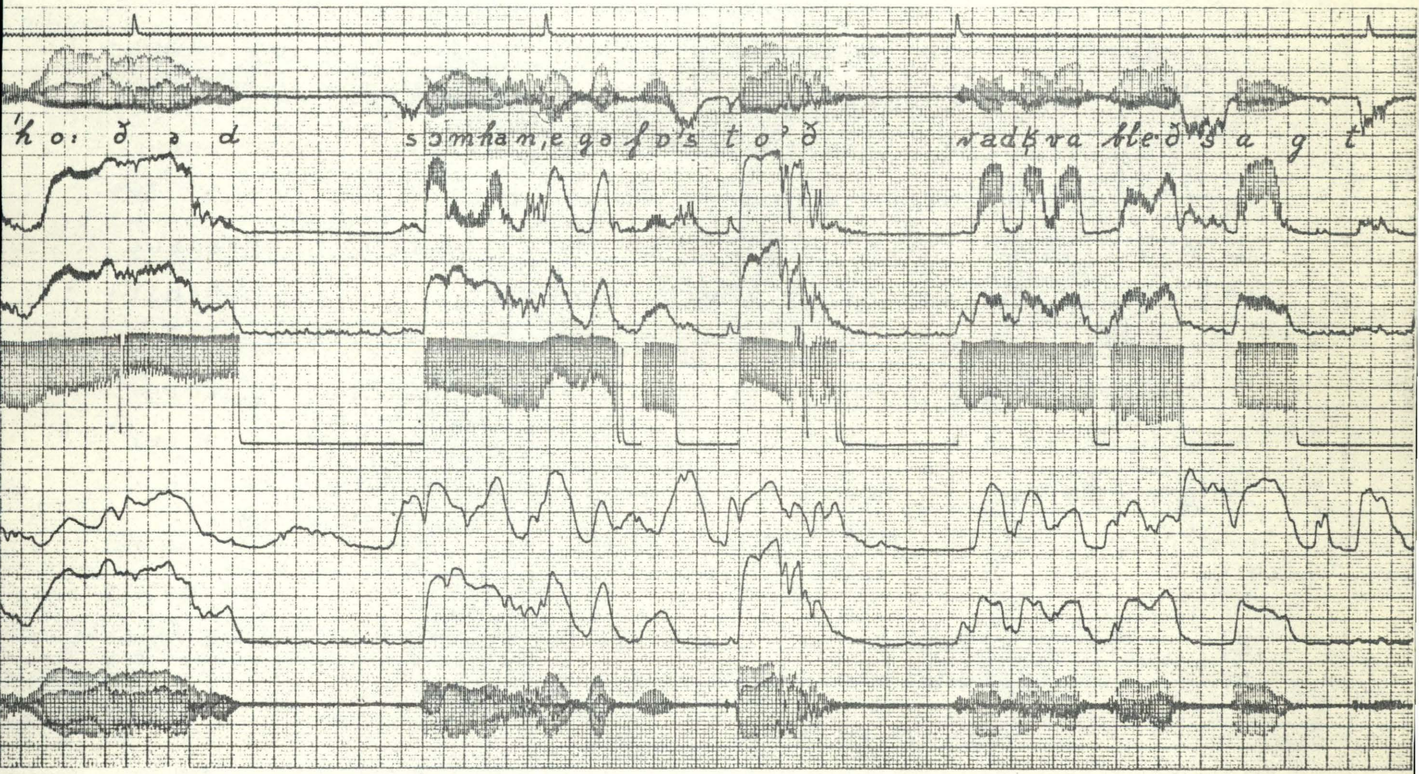
After a voice training period of less than 2 months the correct chest register function is reestablished. All the vowels now have considerably stronger harmonics (compare [a] before and after the voice training).



This mingogram shows very clearly

a) that the normal chest register function may appear spontaneously (see the last word [sɑgt]),

b) the way in which the diplophonia modulates the phonation. Both the fundamental frequency and the intensity level is continuously shifted between two levels (see the first word [hovəðəd]).



The same text recorded after a voice training period of less than two months. Notice the totally different traces of the fundamental frequency and the intensity levels.

Fig. 6.

produce a normal chest register voice. Speech therapy afterwards stabilizes and strengthens the chest register; this is seen in Fig. 9, illustration no. 3. The final result of the training is shown in the bottom illustration, Fig. 9. Notice the intensified spectrum above 1ooo cps.

The progress of patient no. 3 (EH) is excellently illustrated by means of the mingograms of the four tape recordings. Segments of the mingograms are shown in Fig. 1o. The text is the same as in Fig. 9: "pippede klagende" [pʰibəðə klaːɣnə] . The arrows indicate the places where the most typical changes in the intensity level above 1ooo cps may be found.

8. Statistical treatment[2] of the changes in voice quality

Each word has been measured for minimum and maximum pitch. Afterwards, the arithmetic mean pitch, the pitch variation range in cps, and the relative pitch variation range in percentage of the arithmetic mean pitch have been calculated.

The overall intensity and the intensity above 1ooo cps have also been measured for each of the vowels. Then the overall intensity level has been normalized to 45 dB in all recordings, and the intensity level of the upper part of the spectrum adjusted in accordance herewith. In this way it has been possible to make a direct comparison (in dB) of the intensity levels above 1ooo cps in the different recordings. The standard deviations of the data and the above-mentioned averages with 99 % confidence intervals have been calculated by means of a standard computer program taking in account the different degrees of freedom caused by the different numbers of data.

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2) Carl Ludvigsen has assisted us in discussion of the statistical treatment.

Statistical calculations based on measurements of pitch and intensity before and after voice therapy

SD = Standard deviation

CI = Confidence interval

	unit	before speech therapy			after speech therapy			change during therapy		number of
		means	SD	99 % CI	means	SD	99 % CI	change ± SD	CI better than	vowels
Mean of max. pitch	cps	208	14.6	208 ± 9.0	186	14.9	186 ± 9.2	-22 ± 8.6	99.9 %	21 stressed vowels
Mean of min. pitch	cps	174	4.3	173 ± 2.6	144	9.9	144 ± 6.1	-30 ± 5.9	99.9 %	
Mean pitch	cps	191	8.2	191 ± 5.1	165	10.0	165 ± 6.2	-26 ± 17.1	99.9 %	
Absolute mean pitch variation in words	cps	34	13.9	34 ± 8.6	42	15.5	42 ± 9.6	+ 8 ± 10.2	99.5 %	
Relative mean pitch variation in words	%	17.8	7.3	——	25.4	9.4	——	+ 7.6 ± 8.7	99.9 %	
Overall mean intensity	dB	45	2.5	45 ± 1.6	45	1.8	45 ± 1.1	——	——	
Mean intensity above 1000 cps	dB	15	5.2	15 ± 3.2	21	6.5	21 ± 4.0	——	——	
Normalized mean intensity above 1000 cps	dB	15	5.2	15 ± 3.2	21	6.5	21 ± 4.0	+ 6.1 ± 3.8	99.9 %	
Mean of max. pitch	cps	206	12.6	206 ± 8.6	180	12.8	180 ± 8.4	-26 ± 9.7	99.9 %	18 unstressed vowels
Mean of min. pitch	cps	175	5.5	174 ± 3.8	146	11.5	146 ± 7.9	-29 ± 6.3	99.9 %	
Mean pitch	cps	190	7.6	190 ± 5.2	163	10.0	163 ± 6.8	-27 ± 6.7	85 %	
Absolute mean pitch variation in words	cps	31	12.0	31 ± 8.2	34	14.8	34 ± 10.1	+ 3 ± 12.2	68 %	
Relative mean pitch variation in words	%	16.3	6.3	——	20.8	9.1	——	+ 4.5 ± 6.7	98 %	
Overall mean intensity	dB	45	2.6	45 ± 1.8	45	2.4	45 ± 1.7	——	——	
Mean intensity above 1000 cps	dB	15	5.1	15 ± 3.5	21	5.2	21 ± 3.5	——	——	
Normalized mean intensity above 1000 cps	dB	15	5.1	15 ± 3.5	21	5.2	21 ± 3.5	+ 6.1 ± 3.6	99.9 %	

Patient No. 1. (TH)

Fig. 7.

Statistical calculations based on measurements of pitch and intensity before and after voice therapy

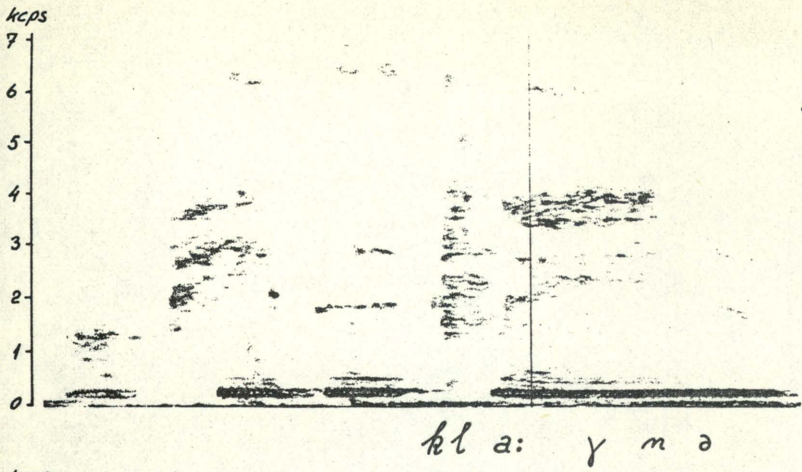
SD = Standard deviation
CI = Confidence interval

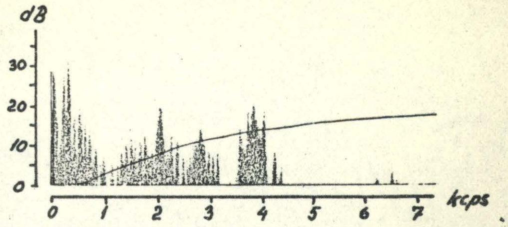
	unit	before speech therapy			after speech therapy			change during therapy		number of vowels
		means	SD	99 % CI	means	SD	99 % CI	change ± SD	CI better than	
Mean of max. pitch	cps	246	36.7	246 ± 26.0	220	37.2	220 ± 23.1	-26 ± 40.1	98 %	21 stressed vowels
Mean of min. pitch	cps	153	17.0	153 ± 12.1	156	17.9	156 ± 11.1	+ 3 ± 22.3	35 %	
Mean pitch	cps	200	21.8	200 ± 15.4	188	23.7	188 ± 14.7	-12 ± 22.8	96 %	
Absolute mean pitch variation in words	cps	98	40.0	98 ± 28.3	68	40.0	68 ± 25.6	-31 ± 35.0	99.5 %	
Relative mean pitch variation in words	%	49	20	——	36	21.3	——	-13 ± 20.6	98 %	
Overall mean intensity	dB	46	2.3	46 ± 1.5	44	2.2	44 ± 1.9	——	——	
Mean intensity above 1000 cps	dB	19	4.2	19 ± 2.9	19	5.8	19 ± 3.7	——	——	
Normalized mean intensity above 1000 cps	dB	18	4.2	18 ± 2.9	20	5.8	20 ± 3.7	2.4 ± 5.8	90 %	
Mean of max. pitch	cps	228	25.7	228 ± 23.1	207	24.7	207 ± 17.5	-21 ± 25.5	75 %	18 unstressed vowels
Mean of min. pitch	cps	151	17.1	151 ± 15.4	161	19.4	161 ± 13.7	+10 ± 18.3	93 %	
Mean pitch	cps	189	17.0	189 ± 15.3	184	17.8	184 ± 12.6	- 5 ± 17.3	60 %	
Absolute mean pitch variation in words	cps	77	27.3	77 ± 24.5	46	26.7	46 ± 19.0	-31 ± 27.0	99.5 %	
Relative mean pitch variation in words	%	41	15.9	——	25	14.5	——	-16 ± 15.9	99.9 %	
Overall mean intensity	dB	45	2.2	45 ± 1.7	43	2.8	43 ± 1.9	——	——	
Mean intensity above 1000 cps	dB	17	3.8	17 ± 2.9	19	4.2	19 ± 2.8	——	——	
Normalized mean intensity above 1000 cps	dB	17	3.8	17 ± 2.9	21	4.2	21 ± 2.8	+ 3.8 ± 5.8	97 %	

Patient No.2. (RH)

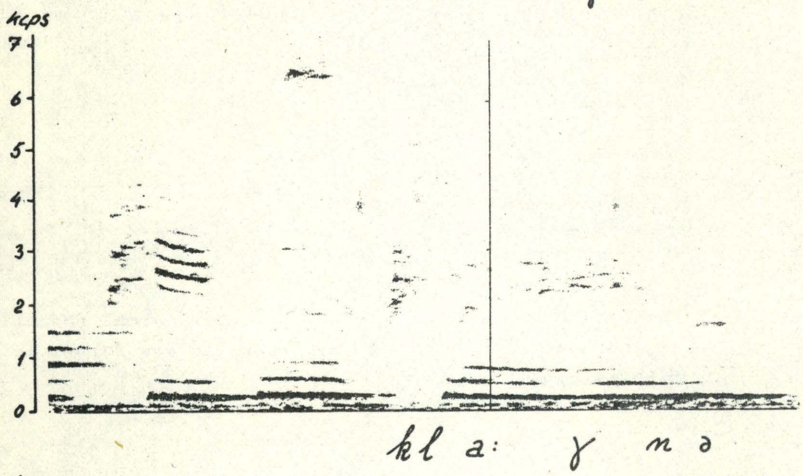
Fig. 8.

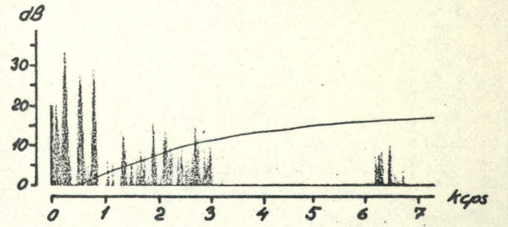
SONAGRAMS OF PATIENT EH BEFORE INJECTION OF PARAFFIN, AFTER INJECTION OF PARAFFIN, AND AFTER VOICE TRAINING.



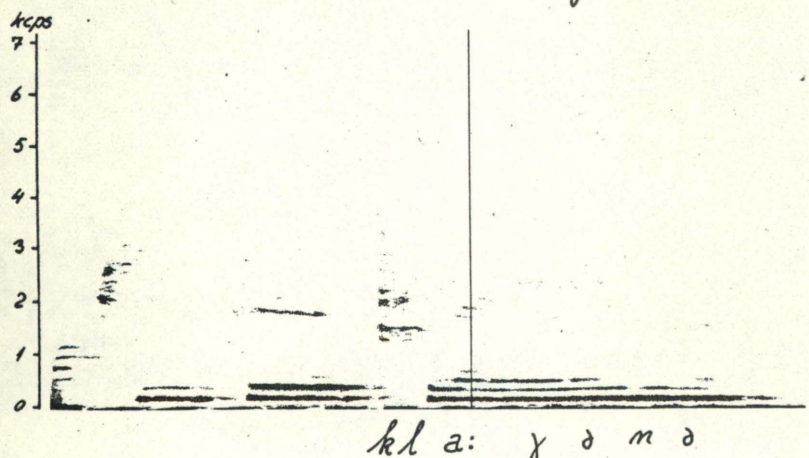


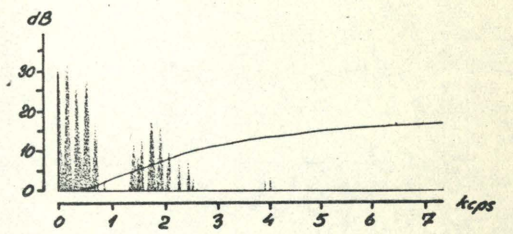
Recording no. 1
(The normal phonation before operation)
The vowel formants consist mainly of noise.



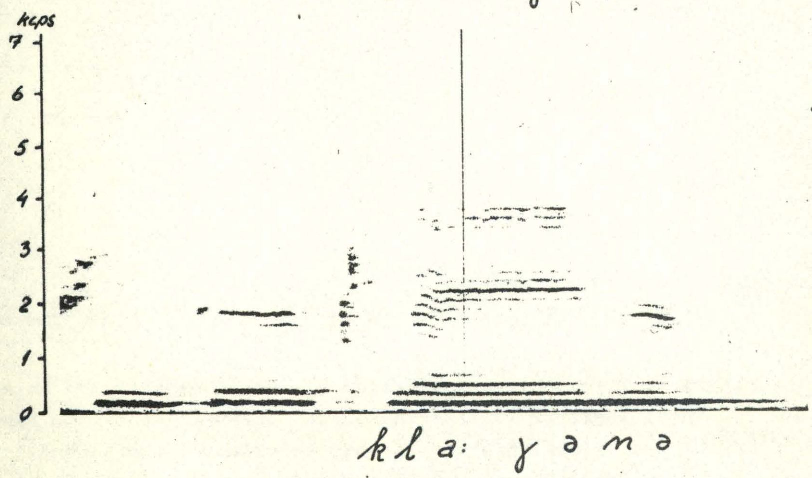


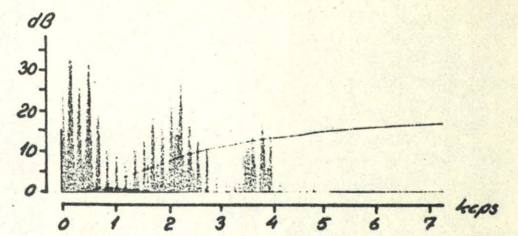
Recording no. 2
(Head register function before operation)
The fundamental frequency is too high, and the spectrum above 1000 cps consists mainly of noise.





Recording no. 3
(After injection of paraffin)
The fundamental frequency is lowered, and there is no tendency to diplophony any more.

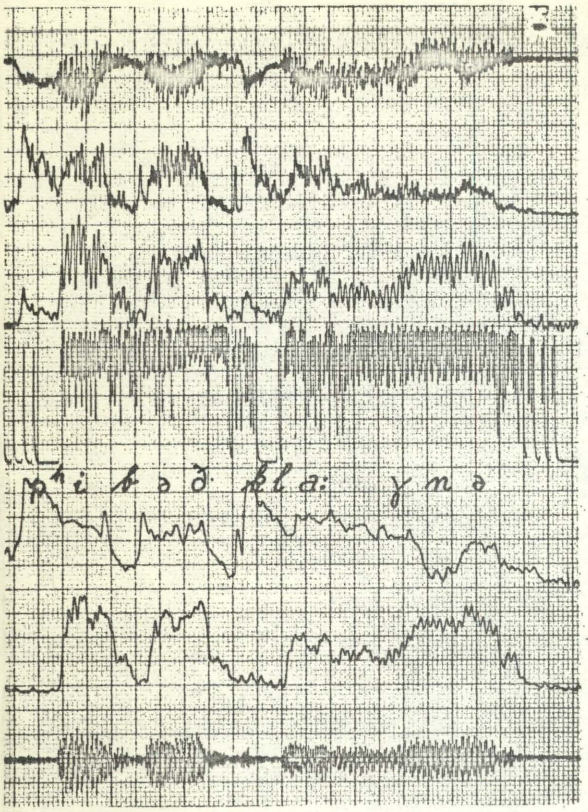




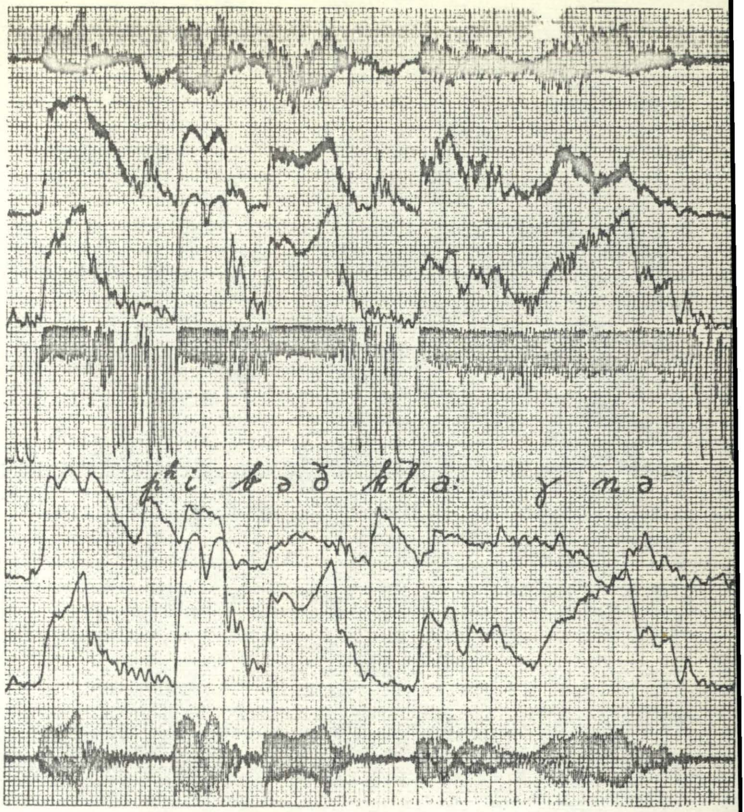
Recording no. 6
(After voice training)
Both the sonagrams and the section of [a] look quite normal in this recording.

Fig. 9.

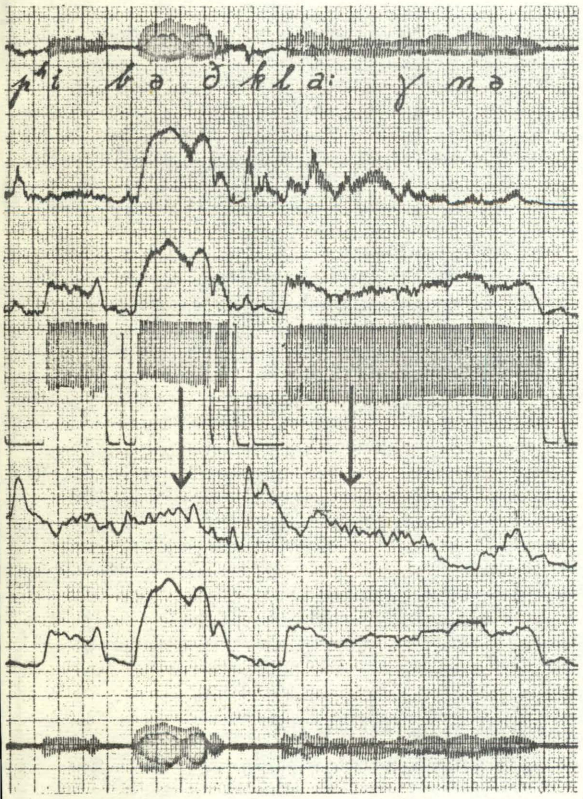
MINGOGRAMS OF PATIENT EH BEFORE INJECTION OF PARAFFIN, AFTER INJECTION OF PARAFFIN, AND AFTER VOICE TRAINING.



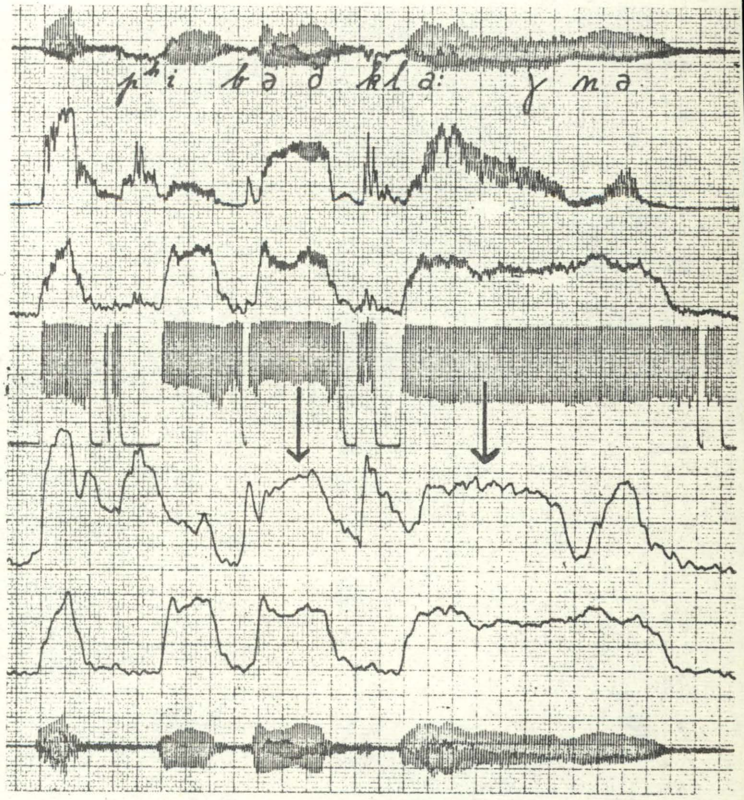
This recording shows the normal phonatory situation with the right recurrent nerve paralyzed. Notice the unstable and very diffuse traces especially for the fundamental frequency which sounds very diplophonic.



Patient EH was able to produce a rather normal phonation in the head register, but only when she was forced to use high voice effort.



After paraffin injection into the right vocal fold the normal chest register function is re-established, but still the higher part of the spectrum is too weak.



After a voice training period of about one year the normal chest register is trained and the intensities of the higher harmonics are enforced (to be seen clearly when comparing the differences between trace 6 and trace 7 in the last two mingograms).

Fig. 10.

Finally, the pitches and intensities respectively before and after speech therapy have been compared and the levels of confidence have been estimated.

For patient no. 1 (TH) these comparisons are based completely upon paired sets of data. Therefore, the standard deviation of the "change during therapy" can be calculated from $s = \sqrt{s_x^2 + s_y^2 - 2 \cdot r \cdot s_x \cdot s_y}$, where the correlation coefficient r varies between o.745 and o.48o. For patient no. 2 (RH) and patient no. 3 (EH) most of the data are paired, too.

The statistical calculations for the first two patients are shown in Fig. 7 and Fig. 8.

8.1. Stressed contra unstressed vowels

The calculations are separated into data obtained from stressed and from unstressed vowels. We expected to find some differences especially in the spectrum above 1ooo cps between the stressed and the unstressed vowels. This is apparently not the case. (E.g. patient no. 1 (TH): during the voice therapy the spectrum above 1ooo cps exhibits an average increase of 6.1 dB both in stressed and unstressed vowels.)

8.2. Changes in pitch during the voice therapy

The change in pitch is one of the most prominent changes during the voice training. Normally the pitch drops considerably in the beginning of the period of therapy, after which the pitch is raised a little in the final stage of the training. These general findings may be confirmed by means of recordings no. IV, V, and VI for patient no. 3 (EH), where the average pitch levels are calculated to 22o, 18o, and 184 cps for the stressed vowels and to 24o, 183, and 186 cps for the unstressed vowels.

Patient no. 1 (TH) and patient no. 2 (RH) have only been recorded before and after the speech training. They also show a significant lowering of the pitch during the training. The fall is 14 % both in stressed and unstressed vowels for patient no. 1 (TH) (level of significance better than o.ool) and 6 % in the stressed vowels for patient no.2 (RH) (level of significance better than o.o5), whereas the unstressed vowels are nearly unchanged.

Normally the intonation range is extended during the voice training. In this respect patient no. 1 (TH) is also typical. The word intonation[3] is increased by 7.6 % (level of significance better than o.ool) from 17.8 % to 25.4 % in relation to the mean fundamental frequencies. Patient no. 2 (RH) is atypical in this respect. In spite of a considerable fall in the maximum pitch during the training, the minimum pitch is almost unchanged. This naturally results in a reduced intonation range (from 49 % to 36 % for the stressed vowels, and from 41 % to 25 % for the unstressed vowels, both differences being significant, - see Fig. 7 and 8).

8.3. Changes in the spectral composition

Real investigations of the spectral changes have not been undertaken. Some sonagrams (Fig. 2,3,5 and 9) give visual impressions of the spectral changes. Only one parameter has been registered and calculated: the change in mean intensity level above 1ooo cps in relation to the intensity level of the full frequency spectrum.

All patients show an increased content of energy above 1ooo cps after the speech training (the F2 - F3 region is emphasized which results in a higher degree of intelligibility). The higher frequencies are increased by 6.1 dB for patient no. 1 (TH) (level of significance better than

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3) The differences between the highest and the lowest pitches in 39 random selected words.

o.ool), about 3 dB for patient no. 2 (RH) (level of significance better than o.oo5), and 3 dB for patient no. 3 (EH) (level of significance better than o.1).

9. Summary

The aim has been to point out some possibilities for objective determination of the changes in voice characteristics during voice therapy. The material used consists of tape recordings made before and after the therapy.

This pilot investigation shows that measurements of the pitch and the normalized intensity level above 1ooo cps are two usable parameters for that purpose. (The change in pitch gives a rough indication of the physiological changes during the therapy, and the changes in the spectral composition may to some extent give us information about the change in intelligibility.)

The three patients used all show both considerable lowering of the average pitch and enforcement of the upper region of the acoustic spectrum.

The statistical calculations inform us about the statistical significance of the observed changes.

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