ARIPUC 18, 1984, p. 13-43

VARIABILITY AND INVARIANCE IN DANISH STRESS GROUP PATTERNS*

NINA GRØNNUM THORSEN

Three aspects of the fundamental frequency (Fø) pattern associated with the prosodic stress group in Standard Danish are examined in acoustic analyses of recordings by four speakers. (1) Evidence is presented in favour of previous statements to the effect that short stress groups will have Fø patterns which are truncated rather than compressed editions of those found with longer stress groups. (2) The shape of the Fø pattern can be considered basically invariant (for a given speaker) and independent of the segmental structure of the stress group, but its surface manifestation is modified by intrinsic Fø level differences between vowels of different tongue height, and by the intonational context. (3) Fø patterns in extremely long prosodic stress groups are investigated: With one speaker the falling slope is decomposed into a succession of two shorter ones, with a distinct partial resetting between them, which together describe an overall declination, much reminiscent of the way long sentence intonation contours behave. With three speakers the Fø course through the unstressed syllables is more akin to a mildly undulating wave. The initial fall levels out and falls again, or performs a slow fall-rise-fall.

I. INTRODUCTION

From various previous investigations the picture of the Fø pattern associated with the prosodic stress group in Standard Danish emerges fairly unambiguously. Its most salient features are summarized below.

A prosodic stress group consists of a stressed syllable and all succeeding unstressed syllables, if any. (Unstressed syl-

---

* A revised version appeared in *Phonetica 41*, 1984, pp. 88-102.

lables before the first stressed one in the utterance constitute a unit apart.) Its boundaries are purely prosodically determined, lying always immediately to the left of a stressed syllable. Accordingly, a prosodic stress group may cut across any number of syntactic boundaries, and across syntactic boundaries of any rank below the level of the sentence, cf. Thorsen (1978, 1980a).

More specifically, there is recent evidence to suggest that initial consonants are dissociated prosodically from the stressed vowel, cf. Thorsen (1982a, 1984) and Fischer-Jørgensen (1984), to the effect that prosodically the stress seems to begin with the vowel, and syllable initial consonants join up with preceding material, if any, or constitute a unit apart.

The Fø pattern associated with the prosodic stress group can be seen as an essentially invariant Fø wave, upon which the segments and syllables are superposed. In Standard Danish the stressed syllable hits the wave at the trough before the fairly steep rise to the Fø peak, which generally coincides with the first post-tonic vowel. If stressed plus first post-tonic syllable together are sufficiently short, however, the peak of the Fø wave will only be reached in the second post-tonic syllable, cf. Thorsen (1982a, 1982b). In other varieties of Danish the timing of stressed and unstressed syllables with respect to the trough and peak of the Fø wave will differ, and so may the slope of the rising and falling flanks. Stylized stress group patterns of Standard Danish and two Jutlandish dialects are depicted in figure 1; see further Thorsen and Nielsen (1981) and Fischer-Jørgensen (1984).

The magnitude of the rise from the trough to the peak of the wave is subject to contextual as well as individual variation.
(a) The rise is higher early on the intonation contour than late, and it is higher on less steeply falling intonation contours. These facts are reflected in the model in figure 2. The rise is smaller, and under certain circumstances it may even be absent, when the prosodic stress group contains only one unstressed syllable. In Thorsen (1980b) I attempt to account for these phenomena as purely context determined, involuntary variation of an underlying invariant pattern.
(b) Some speakers rise higher than others, and the slope of the rise as well as the fall through the post-tonics is also subject to individual variation. In one investigation (Thorsen 1980a) one speaker demonstrated a syntactically determined variation in the height of the Fø rise from the valley. The rise was highest to a post-tonic syllable belonging to the same word as the stressed syllable, lowest to a post-tonic belonging to the same word as the succeeding stressed syllable, and intermediate when the post-tonic syllable constituted a separate word between the two stressed syllables. In other investigations this same speaker does not, however, mark syntactic boundaries and structures tonally any more than do the other seven speakers I have looked at so far. See further below about distinctness levels.

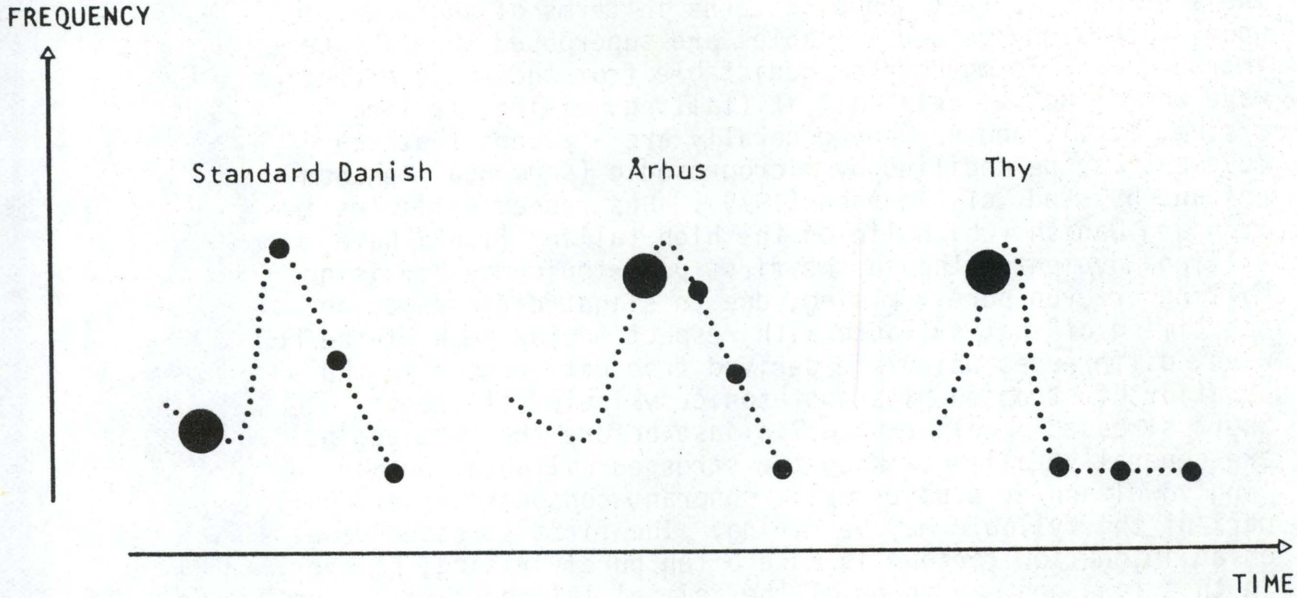

Figure 1

Stylized stress group patterns in three types of Danish: Standard Danish, Århus, and Thy. The big dots represent stressed syllables, small dots unstressed ones.

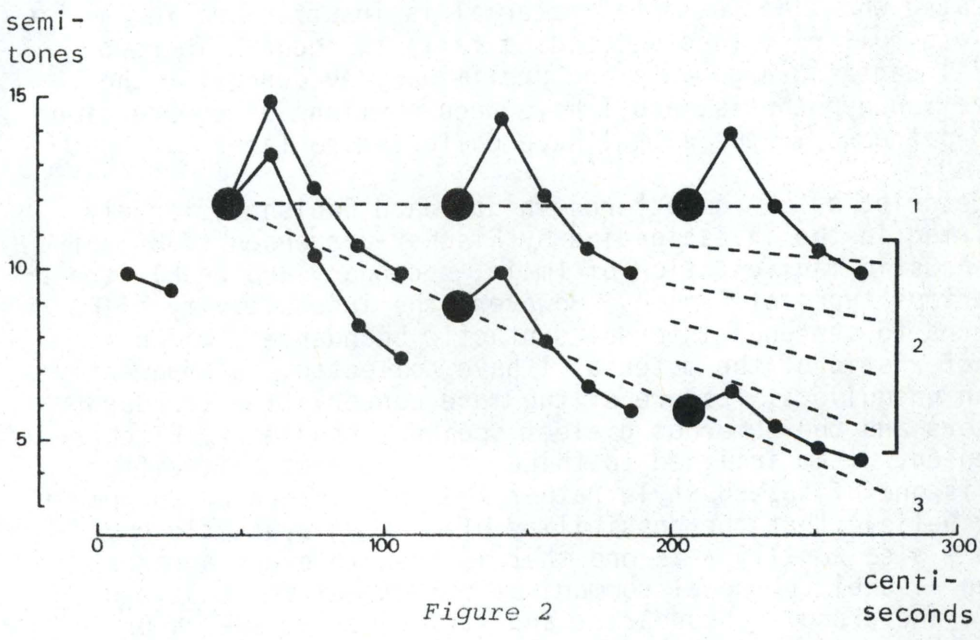

Figure 2

A model for the course of fundamental frequency in short utterances in Standard Copenhagen Danish. (1) Syntactically unmarked questions, (2) interrogative utterances with word order inversion and/or interrogative particle; non-terminal declarative and interrogative sentences (variable), (3) terminal declarative utterances. The large dots represent stressed syllables, the small dots unstressed ones. The solid lines represent the FØ pattern associated with prosodic stress groups, and the dashed lines denote the intonation contours proper.

The account of stress group patterns in terms of an Fø wave upon which segments and syllables are superposed should make intrasyllabic Fø movements predictable from the shape of the wave where the syllables hit it (falling, rising, falling-rising, etc.), and so they generally are - except that any movement may be modified by microprosodic (segmental) phenomena and by stød, cf. Thorsen (1979). Unstressed syllables in Standard Danish (which lie on the high-falling flank) have falling movements, though the first post-tonic may be rising-falling or even purely rising, due to slight differences in the timing of that syllable with respect to the peak of the Fø wave, differences which are derived from differences in the duration of stressed plus post-tonic syllable, cf. above. Short stressed vowels (which lie just before the rise begins) are generally falling. When the stressed syllable contains a long vowel and/or a postvocalic sonorant consonant, the final part of the syllable may be rising. The first stressed vowel on an intonation contour is more often purely rising, however. In this case one may think of the initial falling part of the trough of the wave as being cut off as an adaptation to the high initiation of the intonation contour.

Another consequence of the "passive" alignment of segments with the Fø pattern - the pattern making no timing adjustments to the segments or vice versa - is that Fø patterns should be truncated when the segmental material is insufficient for a complete full rise (and succeeding fall) to occur. Thorsen (1982a) contains arguments and preliminary evidence for the truncation hypothesis, and I have seen no signs of compression of Fø patterns in the data I have collected so far.

The description of Fø patterns in Standard Danish is largely confirmed in the investigation by Fischer-Jørgensen (1984) of the acoustic manifestation of (main, secondary and weak) stress in various types of Danish. However, the insensitivity of Fø patterns to sentence internal syntactic boundaries, which is characteristic of the material I have collected, is apparently not an unequivocal feature of the more conservative standard speakers and the numerous dialect speakers studied by Fischer-Jørgensen. I am inclined to think, though, that this difference is one of speech style rather than of dialect or sociolect, and I believe that the possibility of marking syntactic boundaries - also tonally - is one that is open to every speaker. Jørgen Rischel (personal communication) emphasizes that syntactic and prosodic boundaries and structures in speech production is not an either-or. We may conceptualize a highly articulate (distinct) level of production where the superordinate structure is imposed by the syntax, and at the other extreme a stage with a prosodic structure which works in terms of uniform principles of rhythmization and is independent of any syntactic boundaries (within the sentence). Between these levels are stages where the two structurings intertwine, and a speaker may choose to operate, i.e. produce his actual speech, from levels "above" or "before" the most exclusively prosodically structured one. - This choice would then correspond to what I termed choice of speech style above.

The present paper is an attempt to (1) provide (further) documentation for the truncation of Fø patterns in short prosodic stress groups; (2) provide documentation for the passive alignment of segments and syllables with the Fø pattern, i.e. to establish the (lack of a) relation between the segmental structure of the stressed and post-tonic syllable(s) and the location in time and frequency of the peak of the Fø pattern; (3) provide data on long prosodic stress groups (i.e. stress groups with a large number of unstressed syllables).

II. PROCEDURES

A. MATERIAL

1. Fø PATTERN TRUNCATION

If the truncation hypothesis is correct, a prosodic stress group consisting of one stressed syllable will contain less of an Fø rise than a prosodic stress group with one or more post-tonic syllables, and monosyllabic stress groups should be further differentiated according to the segmental composition of the stressed syllable: long or short vowel, voiced or unvoiced post-vocalic consonant(s).

Eight words with short and long vowel, succeeded by unvoiced obstruent(s) or a sonorant consonant were selected: *kit*, *Keats*, *bit*, *beat*, *guld*, *Kool*, *tin*, *team* [g̊ʰid̥ g̊ʰi·d̥s b̥id̥ b̥i·d̥ g̊ul g̊ʰu·l d̥ˢen d̥ˢi·m]. (Long vowels are indicated here with only one dot after the vowel symbol.) These words were embedded in terminal declarative utterances, as the second of four prosodic stress groups. The carrier sentences are listed in Appendix I,A with translations. The first stress group in these utterances was likewise monosyllabic, so we get a direct succession of three stressed syllables on a declining intonation contour. - The Fø pattern in these monosyllabic prosodic stress groups may be compared with the words with post-tonic syllables in the material to be described in the next section.

2. Fø PEAK LOCATION

If the shape of the Fø pattern is constant (for a given context and speaker, cf. the introduction) and if time compression does not occur, cf. above, the peak of the pattern should be constant in time and frequency with respect to the preceding Fø minimum and independent of the segmental composition of the prosodic stress group (long or short stressed vowel, one or two postvocalic consonants). A true peak can only be reliably identified in a continuously rising-falling Fø movement, and accordingly the material is made up of words which are voiced from the onset of the stressed vowel through two post-tonic syllables.

Twelve words were selected with short and long, and low and high stressed vowel succeeded by zero, one or two postvocalic consonants: *kanderne, kinderne, salmerne, skyldnerne, sadlerne, vidnerne, damerne, dynerne, talerne, kuglerne, bagerne, pigerne* [ˈg̊ʰanʌnə ˈg̊ʰenʌnə ˈsalmʌnə ˈsg̊ylnʌnə ˈsaðlʌnə ˈviðnʌnə ˈdæ·mʌnə ˈdy·nʌnə ˈdˢæ·lʌnə ˈg̊ʰu·lʌnə ˈbæ·ʌnə ˈbʰi·ʌnə]. The last two words have no consonant phonetically after the stressed vowel. These words were embedded in terminal declarative utterances, as the second of four prosodic stress groups. The carrier sentences are listed in Appendix I,B with translations.

3. LONG PROSODIC STRESS GROUPS

Seven prosodic stress groups were constructed, containing from three to nine unstressed syllables (the stressed vowels are indicated orthographically here with acute accents; reduced main stress (secondary stress) in the second part of the compounds is indicated with grave accents): *(journa)líst på Poli(tíken), ánsat på Poli(tíken), árbejdsmànd på Poli(tíken), spórtsredaktør på Poli(tíken), móderedaktør på Poli(tíken), údenrigsredaktør på Poli(tíken), údenrigskorrespondènt på Poli(tíken)*. These phrases were embedded in short terminal declarative utterances, which were variations on the same syntactic and semantic theme. The utterances are listed in Appendix I,C with translations.

The total of 27 utterances from the three corpora were mixed with 10 other utterances and 11 short texts to be recorded for other purposes. The 48 items were randomized three times, each randomization yielding two pages of reading material, totalling 6 pages, to be read twice by each subject, in order to obtain 6 recordings of each utterance (text).

B. SUBJECTS, RECORDINGS AND TECHNICAL PROCEDURE

Four phoneticians, two males (NRP and JBC) and two females (GB and NT (the author)) read the material, in two sessions on separate days. They all speak a form of Standard Copenhagen Danish. Subjects' style of speech can be characterized as conversational but distinct.

The recordings were made with semi-professional equipment (Revox A-77 tape recorder, Sennheiser MD21 microphone) in a quasi-damped room at the Institute of Phonetics on Agfa PE 39 tape, at 7½ i.p.s.

The tapes were processed by hardware intensity and pitch meters (F-J Electronics) and registered on a mingograph (Elema 800) at a paper speed of 100 mm/s. By adjustment of the zero-line of the pitch-meter to the lower limit of the subject's voice range and full exploitation of the record space of the mingograph galvanometer, a measuring accuracy of 1 Hz for males and 2 Hz for females is attained.

In unidirectional Fø courses with constant slope, only the beginning and end points were measured, according to a procedure outlined in Thorsen (1979, p. 63-66). In more complex Fø courses the turning points (minima and maxima) were measured as well. In the data on long prosodic stress groups the procedure was simplified and the unstressed vowels were represented by a single Fø point, the midpoint (in time as well as frequency), which was an uncontroversial procedure since all such vowels had monotonically falling Fø movements. (The Fø movements are all so short and slight that it does not much matter which point you choose as the one measuring point: the initial, medial or final (or any other) Fø value. Changing the location of the measuring point will transpose all the unstressed vowels by very nearly the same (negligible) amount upwards or downwards, relative to the stressed vowels in figure 6 below.) There are instances where two vowels cannot be reliably segmented from the intervocalic consonant (typically in -*korres(pondènt)* which is pronounced without any intervocalic consonant at all: [g̊ʰɒ(·)ʌs]), and the measuring points are then (somewhat arbitrarily) assigned time coordinates - relative to the onset and offset of the two vowels - in analogy with vowels where a midpoint can be unmistakably located. The distance in time of each point from the first Fø value measured (which is assigned the time coordinate zero) was also determined. Fø and time measurements were averaged over the six recordings by each subject. Average Fø values were converted to semitones (re 100 Hz) and average tracings drawn. No correction was attempted for intrinsic Fø level differences between stressed vowels of different tongue height.

Standard deviations on the average Fø and duration values are generally small, i.e. rarely above 5% of the mean, so production stability across different readings is rather good and the figures must be fairly reliable indications of speakers' behaviour.

III. RESULTS

A. Fø PATTERN TRUNCATION

Average Fø tracings of the eight mono-syllabic test words, together with the preceding and succeeding stressed syllable, are depicted in figure 3. The data will only be evaluated qualitatively.

The second of the three words in the tracings is the one primarily under scrutiny here. First of all, it is very evident that monosyllabic prosodic stress groups have nothing like the Fø rise which characterizes prosodic stress groups with one or more post-tonic syllables, see the words in figure 4. Secondly, the occurrence and magnitude of a rising Fø movement is coupled (though not narrowly correlated) with the duration of the voiced portion of the syllable: A stressed syllable with a long vowel succeeded by a sonorant consonant (*Kool*, *team*) tends to have a final Fø rise (with NRP the rising part

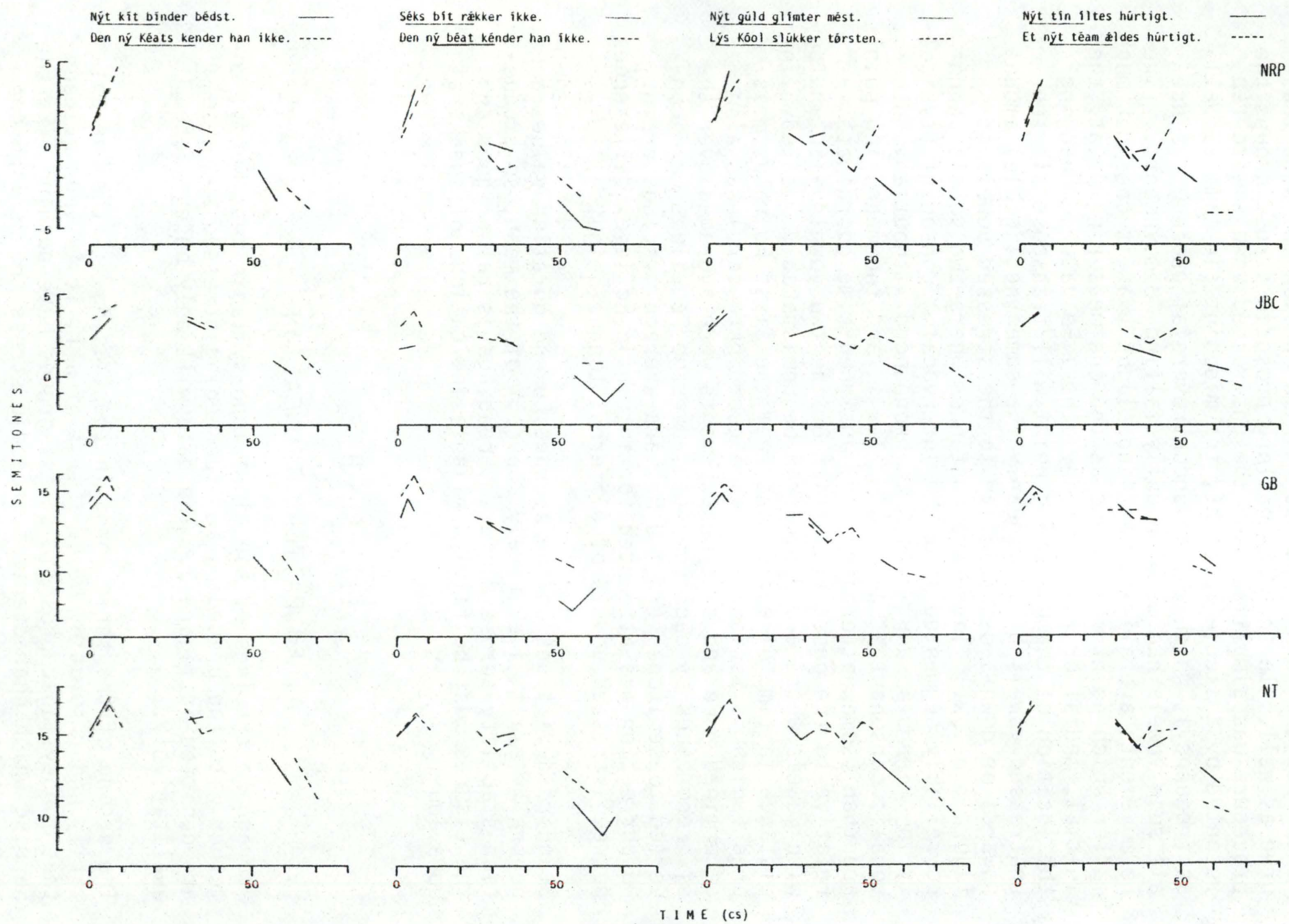

Figure 3

Fundamental frequency tracings (average of 6 recordings) of the underlined sequences identified at the top of the figure. The second word of each sequence contains either a short vowel (full line tracing) or the (nearly) corresponding long vowel (dashed line tracing). Two male subjects (NRP and JBC) and two females (GB and NT). Zero on the logarithmic frequency scale corresponds to 100 Hz.

even exceeds the preceding Fø fall - but in GB's *team* it is actually lacking). A short vowel succeeded by an unvoiced consonant (*kit*, *bit*) is unidirectional and falling with three subjects, though the fall is slight (extending over less than a semitone); one subject (NT) has a correspondingly very slightly rising movement in this condition. In the intermediate context, with a long stressed vowel succeeded by an unvoiced consonant (*Keats*, *beat*) or a short vowel succeeded by a sonorant consonant (*guld*, *tin*), the number of cleanly falling Fø movements equals the number of falling-rising movements (with very slight rises), except that JBC's *guld* is unidirectionally (but very slightly so) rising.

The first word in the tracings in figure 3 is likewise stressed and monosyllabic. Its Fø movement is rising. (Some of the words with long vowel and stød (*ny*, *lys*) have a rise-fall, where the falling part can most probably be ascribed to influence from the stød, cf. Fischer-Jørgensen, 1984.) The rising movement in these vowels can hardly be seen as a compression of the Fø pattern associated with a stressed plus post-tonic syllable(s), for a number of reasons. (1) A stressed vowel in the first stress group of an utterance will be rising also when it is actually succeeded by one or more unstressed syllables, so rising movements in this position are not peculiar to monosyllabic stress groups. (2) The initial falling part of this supposedly compressed Fø pattern is missing. (3) Lastly, there is no reason to assume that the first stress group in an utterance is subjected to time compression of the low+high-falling Fø pattern, when such is not the case in later prosodic stress groups. - I think a more likely explanation - as mentioned in the introduction - is to see the rising Fø movement in the first stressed syllable of an utterance as an adaptation of the Fø wave pattern to the high initiation of the sentence intonation contour: The first stressed vowel in an utterance is approached from a considerably lower value (or - if it is initial - from zero). The "ideal" slight fall plus rise succeeding this rapid movement or jump is smoothed out into one continuous rise.

The third prosodic stress group in the utterances had post-tonic syllable(s) (which are not depicted in the tracings in figure 3). There is no systematic difference between the stressed vowels of that stress group and the preceding ones in the figure, which is further evidence against compressed Fø patterns in monosyllabic prosodic stress groups. (In *rǽk(ker)* there are three instances of falling-rising vowel Fø movements: this vowel is longer than the other vowels in the same position and therefore contains the beginning of the rise to the post-tonic syllable.)

I think there is every reason to conclude that the Fø pattern associated with a prosodic stress group in Standard Danish is truncated rather than compressed in time when the segmental material is insufficient for a complete (falling-)rising (-falling) gesture to develop. - Likewise, the account of intrasyllabic Fø movements sketched in the introduction can be

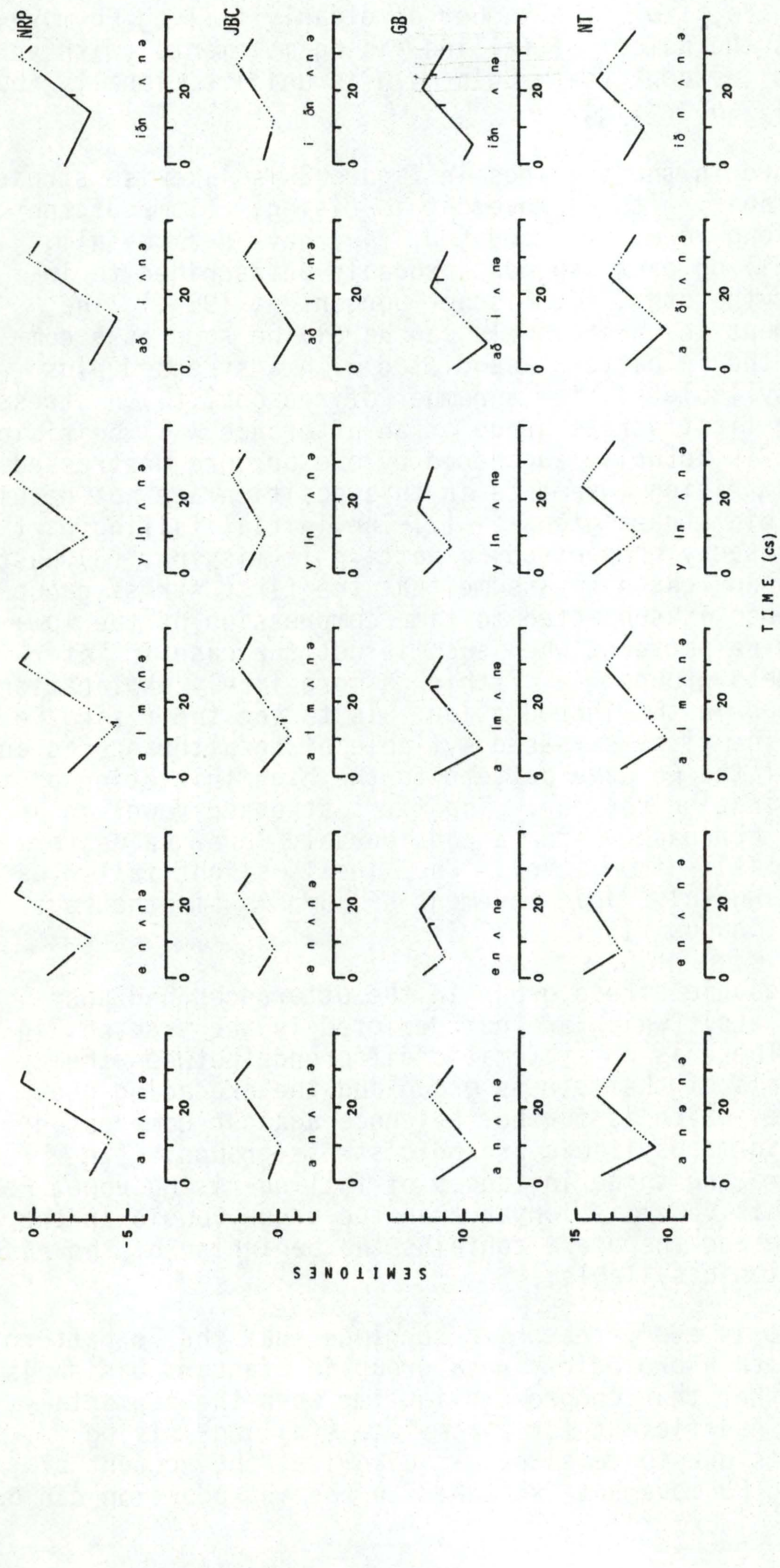

Figure 4

(continued on the next page)

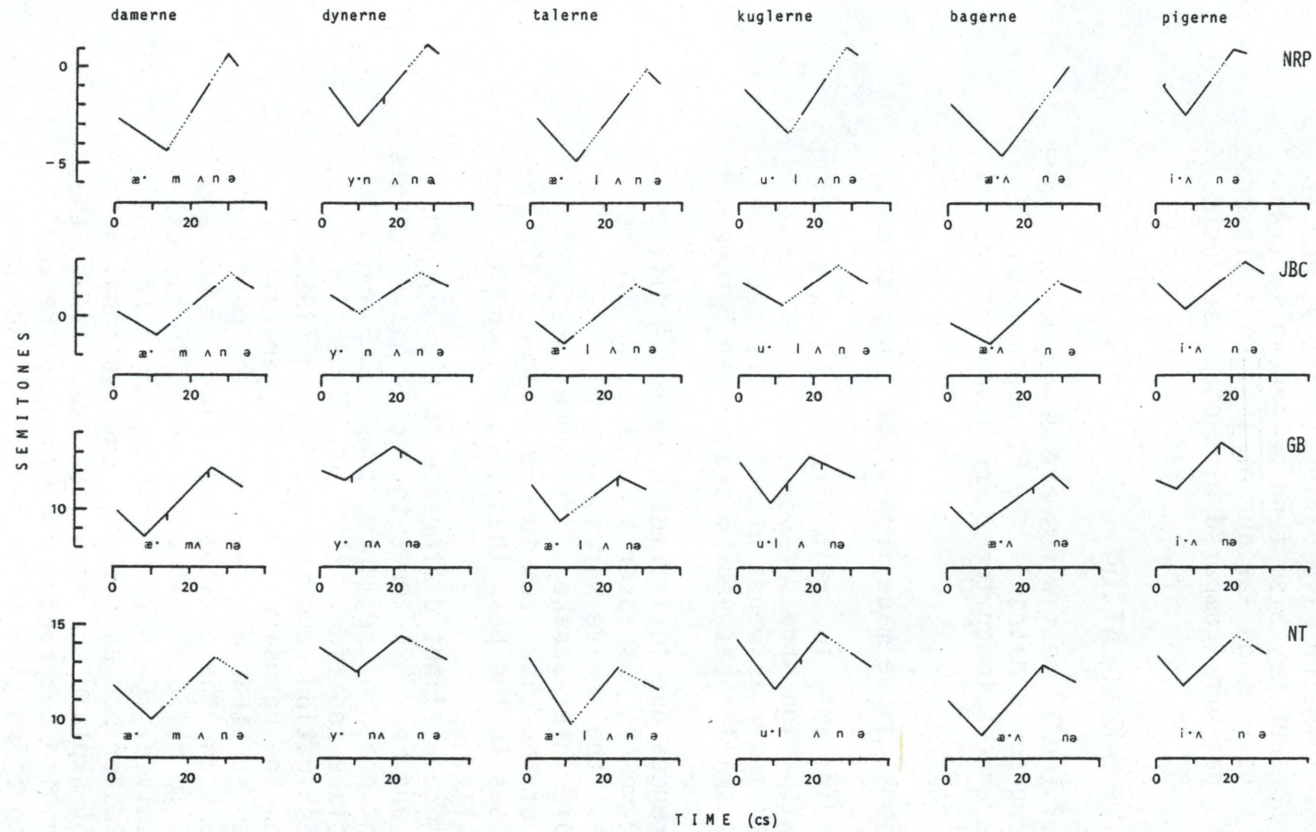

Figure 4

Fundamental frequency tracings (average of 6 recordings) of the words identified at the top of each half of the figure. To the extent that vowels and consonants could be reliably identified and segmented, vowels are traced in full lines, consonants in dotted lines. A vertical stroke indicates a segment boundary in accordance with the transcription beneath each tracing. Two male subjects (NRP and JBC) and two females (GB and NT). Zero on the logarithmic frequency scale corresponds to 100 Hz.

maintained: the first stressed syllable in an utterance is rising, whether it is succeeded by post-tonic syllables or not, in adaptation to the high beginning of the sentence intonation contour. Succeeding stressed syllables are falling, but a final (slight) rise may occur when the vowel is long and/or succeeded by a sonorant consonant. The occurrence or not of this rise is subject to intra- as well as inter-speaker variation. In other words, the timing of the stressed syllable relative to the valley of the Fø wave varies slightly, and as we shall see below a speaker may also tend to generally transpose (by a couple of centiseconds - right or left) his prosodic stress group on the Fø pattern, compared with other subjects.

B. PEAK LOCATION

Average Fø tracings of the 12 test words are depicted in figure 4. Average Fø and time coordinates of the Fø minimum, the Fø maximum and the difference between them, are given for each subject in Appendix II.

A number of observations can be made from visual inspection of figure 4:
1) Fø minima are considerably lower in words with low stressed vowel than in words with high stressed vowel.
2) Fø maxima are also lower in words with low stressed vowel, but the difference is smaller between Fø peaks than between valleys.
3) Apart from differences due to intrinsic Fø level differences in the stressed vowel, a speaker's Fø patterns are remarkably similar across the twelve words.
4) The most noticeable inter-speaker differences are the steepness and extent of the rise from the Fø minimum: NRP has higher and steeper rises to the peak than JBC, GB, and NT (in this logarithmic display).
5) There is furthermore a slight difference in the way subjects align segments and Fø: NRP tends to locate his Fø pivots later, relative to the chain of segments, than do GB and NT; JBC takes an intermediate position. (NRP and NT were also speakers for the investigation reported in Thorsen (1982b), and here the trend was the opposite: NRP would generally locate his Fø peak earlier than NT, relative to the post-tonic segments. The previous and the present recordings of NRP and NT do not give reason to believe that differences in speech style or rate are involved. On both occasions the speech of both subjects can be described as fluent, conversational but distinct, and I cannot explain the opposite tendencies in the two recordings as anything but random variation in the way speakers may choose to coordinate their laryngeal and supralaryngeal gestures, a variation with rather narrow limits or margins which cannot be transgressed, however.)

Some of the qualitative observations above are quantified in Table I.
1) The difference between Fø minima in words with low and high stressed vowel is statistically significant with all subjects, though of different magnitude for males (7-8 Hz,

Table I

Average time and frequency coordinates (mean of means, N=6) to Fø minima and Fø maxima in six words with low stressed vowel and six words with high stressed vowel. The difference between these two points and the slope of the Fø rise between them are also given. The level of statistical significance between the means is indicated, if p<0.05.

Subject		Fø minimum Hz	Fø minimum cs	Fø maximum Hz	Fø maximum cs	Fø max-min Hz	Fø max-min cs	Slope Hz/s = semitones/s
NRP	low	77.7	13.1	102.6	30.0	24.8	16.9	148 = 28.5
	high	84.4	11.0	106.5	26.2	22.1	15.2	147 = 27.6
	p <	0.0005	0.025	0.0005	0.025	0.01	-	-
JBC	low	94.2	10.2	112.0	29.3	17.8	19.2	93 = 15.8
	high	102.5	10.2	115.0	25.6	12.5	15.3	82 = 12.5
	p <	0.0005	-	0.005	0.0005	0.0005	0.0005	0.05
GB	low	167.8	7.6	198.7	24.5	30.8	16.9	184 = 17.3
	high	185.9	6.7	209.1	19.1	23.2	12.4	190 = 16.3
	p <	0.0005	-	0.005	0.0005	0.01	0.005	-
NT	low	177.8	10.4	214.1	25.7	36.3	15.3	240 = 20.8
	high	198.3	8.9	229.3	22.0	31.1	13.0	239 = 19.3
	p <	0.0005	0.025	0.0005	0.005	0.05	0.0005	-

corresponding to approximately 1½ semitones) than for females (about 20 Hz, corresponding to approximately 2 semitones).
2) The Fø maximum is likewise significantly higher in words with high stressed vowel with all speakers, but the difference is smaller (3-4 Hz, or half a semitone, with the males and 10-15 Hz, or one semitone, with the females). Note that all the words ended in the same sequence [-ʌnə], and the difference in the level of the Fø maximum is therefore not due to intrinsic differences in the post-tonic syllable(s). The only way to account for the difference in Fø peak level in the material is as a form of coarticulation or carry-over from the intrinsically different low and high stressed vowels. This is in complete accordance with Reinholt Petersen's (1980) observations and conclusions.
3) Since intrinsic differences between low and high stressed vowels are only partially carried over into the post-tonic vowel, we get a significantly smaller Fø rise from valley to peak after high stressed vowels than after low stressed vowels, though the difference is slight (3-8 Hz).
4) With NRP and NT the Fø minimum has a significantly smaller time coordinate, i.e. it occurs sooner after high stressed vowel onset than after low stressed vowel onset (about 2 cs), and
5) the Fø maximum is significantly earlier with all subjects in words with high stressed vowel (4-5 cs).
6) The effect of (5) is a rise of significantly shorter duration after high vowels with JBC, GB, and NT (2-4 cs) (even though in NT's case it is partially counteracted by the effect of (4)).
7) The slope of the rise differs among speakers, but for a given subject it is constant, irrespective of the nature of the vowel, except that JBC has a slightly but significantly steeper rise after low stressed vowels.

A further dependence upon the segmental structure of the stressed syllable (apart from the nature of the vowel) appears when *kanderne* and *kinderne* are compared with the other five words with low and high vowel, respectively. The stressed syllable of *kanderne* and *kinderne* has a short vowel in a phonetically open syllable, whereas in the other words there is either a postvocalic consonant or a long stressed vowel. The Fø maximum tends to be timed sooner in the two words with short stressed syllable than in the rest of the words (cf. Appendix II). This tendency is most marked with *kanderne*. With JBC and NT it is parallelled by a similar tendency for earlier Fø minima.

Any further systematic differentiation (within or across speakers) in Fø minimum and maximum values and timing, according to the segmental structure of the stressed syllable, is not apparent in the material. In the tracings of figure 5 the time course difference between words with short (*kanderne*, *kinderne*) and long stressed syllable is disregarded, and the grand mean of all six words with low versus high stressed vowel is presented. The line-up point is the Fø minimum.

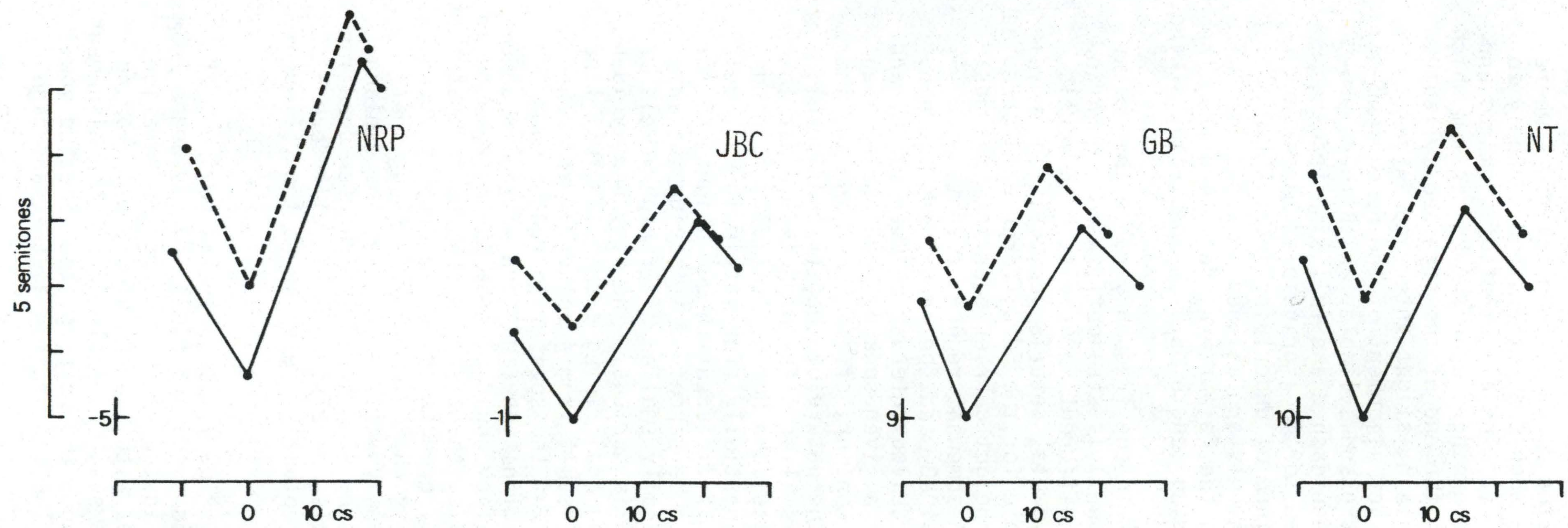

Figure 5

Average fundamental frequency patterns of 6 words with low stressed vowel (full line) and 6 words . with high stressed vowel (dashed line) depicted in figure 4 (mean of means).

For the clarity of exposition, let me present first the conclusions I have drawn from the data. (1) Invariance - where Fø patterns are concerned - should be understood to apply to production AND perception. (2) The alignment of segments and syllables with the Fø pattern hinges upon the Fø minimum which is linked up, roughly, with the end of the stressed syllable, but there is room for a certain, slight inter-and intra-speaker variation in the exact alignment of the Fø minimum with the segments of the stressed syllable. With these provisos, the difference between dashed and full line tracings in figure 5 can be accounted for in a principled manner and a hypothesis can be maintained of underlying invariant Fø patterns with which the segments are aligned in a passive fashion, being strung along the Fø pattern, departing from the minimum, like beads of varying length onto an undulating string.

The difference in placement in the frequency range (higher in words with high stressed vowel) is straightforward. High and low vowels have inherently different Fø levels, high vowels having higher Fø than low vowels, ceteris paribus. The physiological mechanism responsible for the Fø difference in stressed vowels of different tongue height carries over into the post-tonic syllable, though with somewhat reduced effect. See further Reinholt Petersen (1980) and the references therein. If the magnitude of the perceived interval between valley and peak is to be the same (for a given speaker, and for a given location on the intonation contour, cf. figure 2 and the introduction), irrespective of the nature of the stressed vowel, then the Fø rise should be smaller after high than after low vowels. This reasoning rests upon Hombert's (1977) findings that listeners compensate (partially) for intrinsic Fø level differences between vowels of different tongue height, so for a low-to-high Fø interval to be perceived as having the same magnitude, it must be physically smaller after high vowels than after low vowels, ceteris paribus. The very nearly identical slopes in the (falling and) rising dashed and full line tracings in figure 5 could result from a voluntary and controlled gesture on the part of the speaker to render such movements with a certain inclination (and then JBC falls somewhat short of the ideal). They could also be due to a muscular or mechanical constraint, i.e. these slopes are the fastest that each speaker can comfortably produce in the recorded speech style and rate (in which case there must be something that speeds up JBC's rise from low vowels). Whatever the explanation, the near constant rising slopes cause a shorter duration of the rise after high vowels, or else the peak will "overshoot" and be too high perceptually, relative to the valley of the pattern (cf. above).

High vowels are shorter than low vowels, ceteris paribus, cf. Fischer-Jørgensen (1964) and Bundgaard (1980) for evidence from Danish. This is reflected in the difference in the duration of the initial fall in words with low and high vowels, being longer in words with low vowels, cf. Table I. If the alignment of segments and Fø hinged upon the onset of the stressed vowel, such a difference in Fø fall had no raison d'être, and high and low vowels would simply occupy a shorter or longer stretch on an Fø pattern with a time constant pivot. If, on the other hand, we assume that the alignment of segments and Fø pattern hinges upon a coordination of the Fø minimum with some point later in the chain (as presupposed in figure 5) approximately around the end of the stressed syllable, then we would expect the Fø pattern in words with a low stressed vowel to extend further "backwards" from the Fø minimum than in words with a higher, and shorter, stressed vowel. With this account the small difference between *kanderne*, *kinderne* and the rest of the words with respect to the absolute timing of the Fø minimum (earlier versus later) is a natural consequence of the fact that these two words have shorter stressed syllables and therefore shorter initial falling movements, i.e. earlier Fø minima, than the rest of the material.

To conclude this section: Fundamental frequency patterns associated with prosodic stress groups in Standard Danish can be considered underlyingly invariant if we take invariance to apply to both production and perception. Departing from the Fø minimum, located near the end of the stressed syllable, the Fø pattern develops its rise-fall independently of the segmental composition of the stressed and post-tonic syllable (short or long stressed vowel; zero, one or two intervocalic consonants). The one major influence upon the physical manifestation of Fø patterns stems from the (high-low) nature of the stressed vowel. The whole pattern is transposed upwards and the rise is abbreviated in prosodic stress groups with high versus low stressed vowels, in a hypothesized interplay between an intrinsic, physiologically determined constraint and a perceptual demand for equal low-high pitch intervals. The underlying invariance leaves room for a good deal of inter- and intra-speaker variation, however. Different speakers have different magnitudes and/or slopes in the falling and rising part of the Fø pattern. The coordination of Fø minimum with the stressed syllable varies slightly - with the same speaker - from one word to the next, as witnessed by figure 4, but considering the words as a whole there is also an overall trend towards relatively later segment/Fø minimum intersections with some subjects than with others.

As mentioned in the introduction, Fø patterns are subjected to further modification as a function of their intonational context. This contextually determined variation may be automatic and involuntary, or it may be more directly speaker controlled, cf. Thorsen (1980b). Whichever it is, we may still consider the underlying Fø pattern an invariant entity which is subject to certain sandhi modifications.

C. LONG PROSODIC STRESS GROUPS

Average Fø tracings of the seven prosodic stress groups, including the succeeding stressed syllable, are depicted in figure 6. The two stressed vowels (the heavier dots) are designated V_1 and V_2 , respectively in the following. (V_1 was not the first stressed vowel in the utterance as a whole, however. It was preceded by one prosodic stress group.) V_2 was an [i] in all seven utterances, whereas V_1 varied. No correction for intrinsic Fø level differences between V_1's of different tongue height is attempted in the figure. - Let me mention first a couple of aspects which tie up with the preceding section, then briefly touch upon a relation which could deserve a more thorough treatment (for which this material is not suited, however), and then I shall proceed to the matter under scrutiny here, namely the tonal behaviour of the unstressed syllables in the seven prosodic stress groups in figure 6.

As in the peak location material above, NRP has the highest rise to the first post-tonic syllable. - The difference in intrinsic Fø level between vowels of different tongue height is clearly reflected in V_1 in figure 6. - We may note in passing that the duration of the prosodic stress group increases progressively with increased number of unstressed syllables.

I have previously stated (1978 and 1980b, for example) that in short utterances (i.e. containing no more than three to four stress groups) the stressed syllables will be distributed along straight lines, whose declination varies with the function of the utterance. These lines constitute the intonation contour proper. (With the rather modest range of variation - well within the octave - exhibited by Standard Danish speakers in the type of utterance and style of speech investigated, intonation contours will be approximately rectilinear, irrespective of the mode of display - logarithmic or linear.) With increased utterance length, in terms of a larger number of (equally long) prosodic stress groups one or more partial resettings of the intonation contour occurs, i.e. the sentence contour is decomposed into a succession of shorter phrase contours, each with its own declination, the ensemble of which exhibit an overall downdrift. The division of the intonation contour into prosodic phrases bears no simple relation to syntactic structure; see further Thorsen (1982c).

The assumption of straight line intonation contours in short utterances implies tacitly that the time and frequency intervals between neighbouring stressed syllables should be directly proportional. The greater the distance in time, the greater the frequency interval. However, till now I have only ever investigated utterances with fairly equal prosodic stress groups (containing two to four post-tonic syllables). With a set of utterances such as the ones treated here we should be able to form a more precise idea of the way the stressed syllables are scaled in relation to each other in terminal declarative utterances. But due to shortcomings in the way the material is structured I shall restrict myself to the formulation of a hypothesis, which is then open to testing in a future experiment.

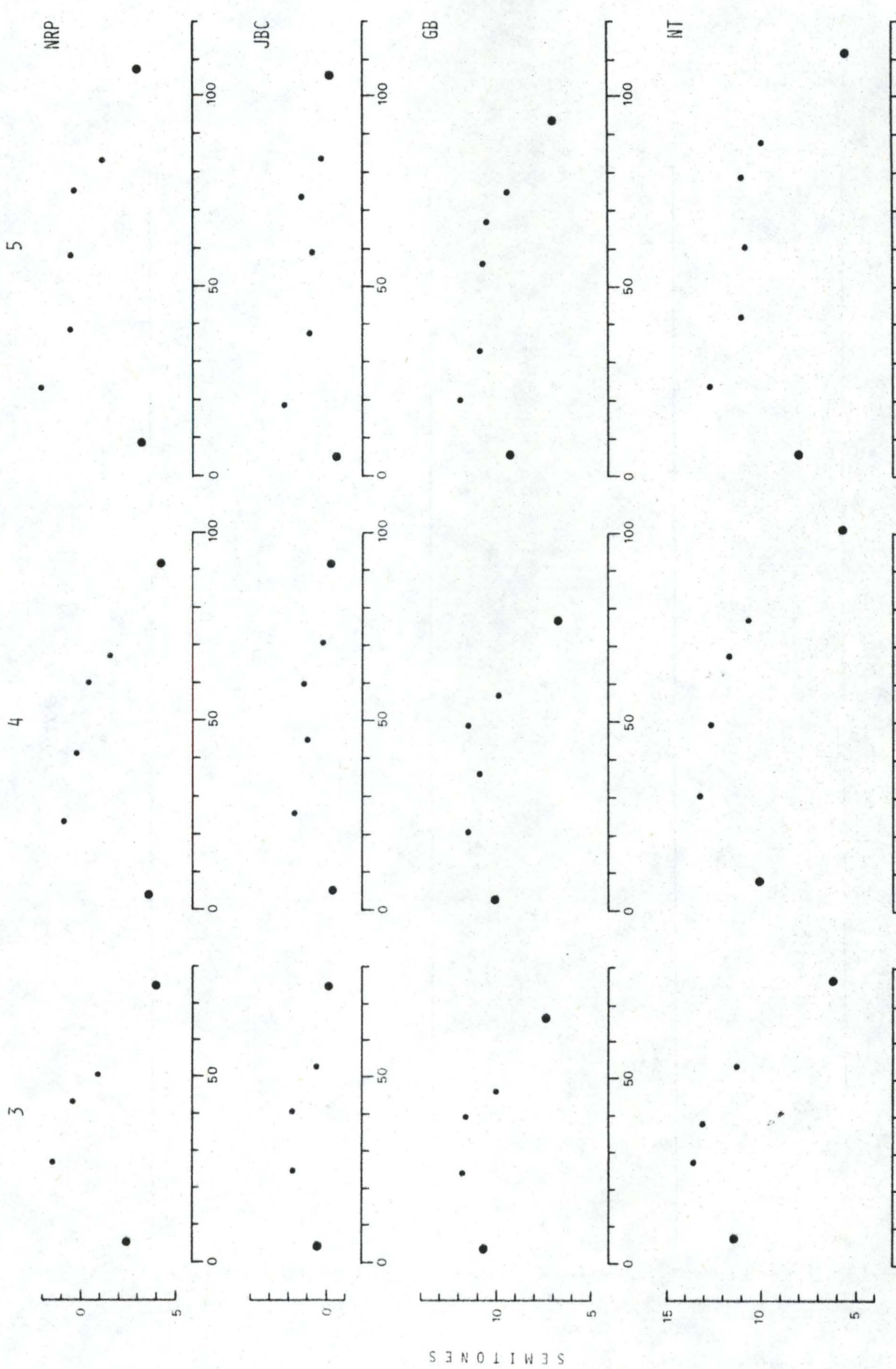

Figure 6

(continued on the next pages)

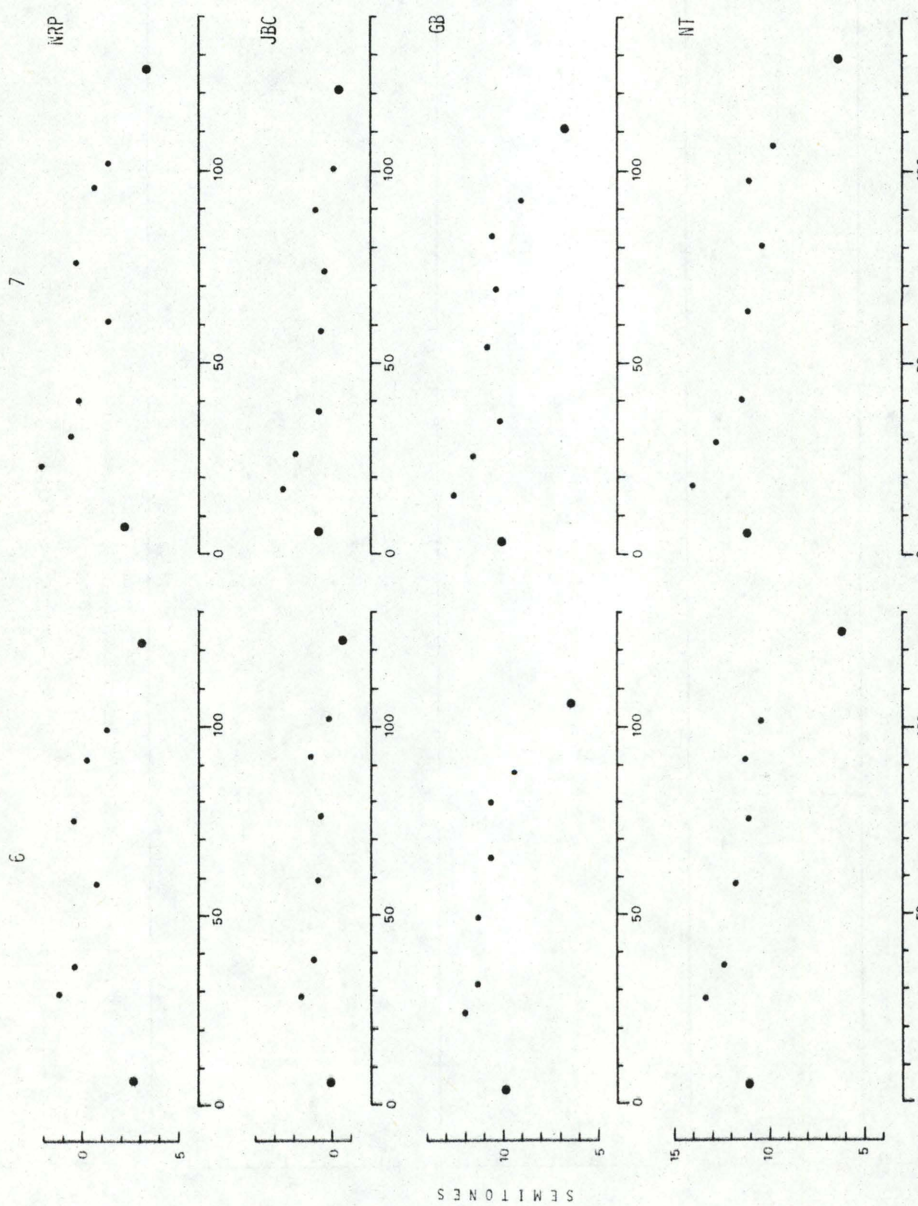

Figure 6

(continued on the next page)

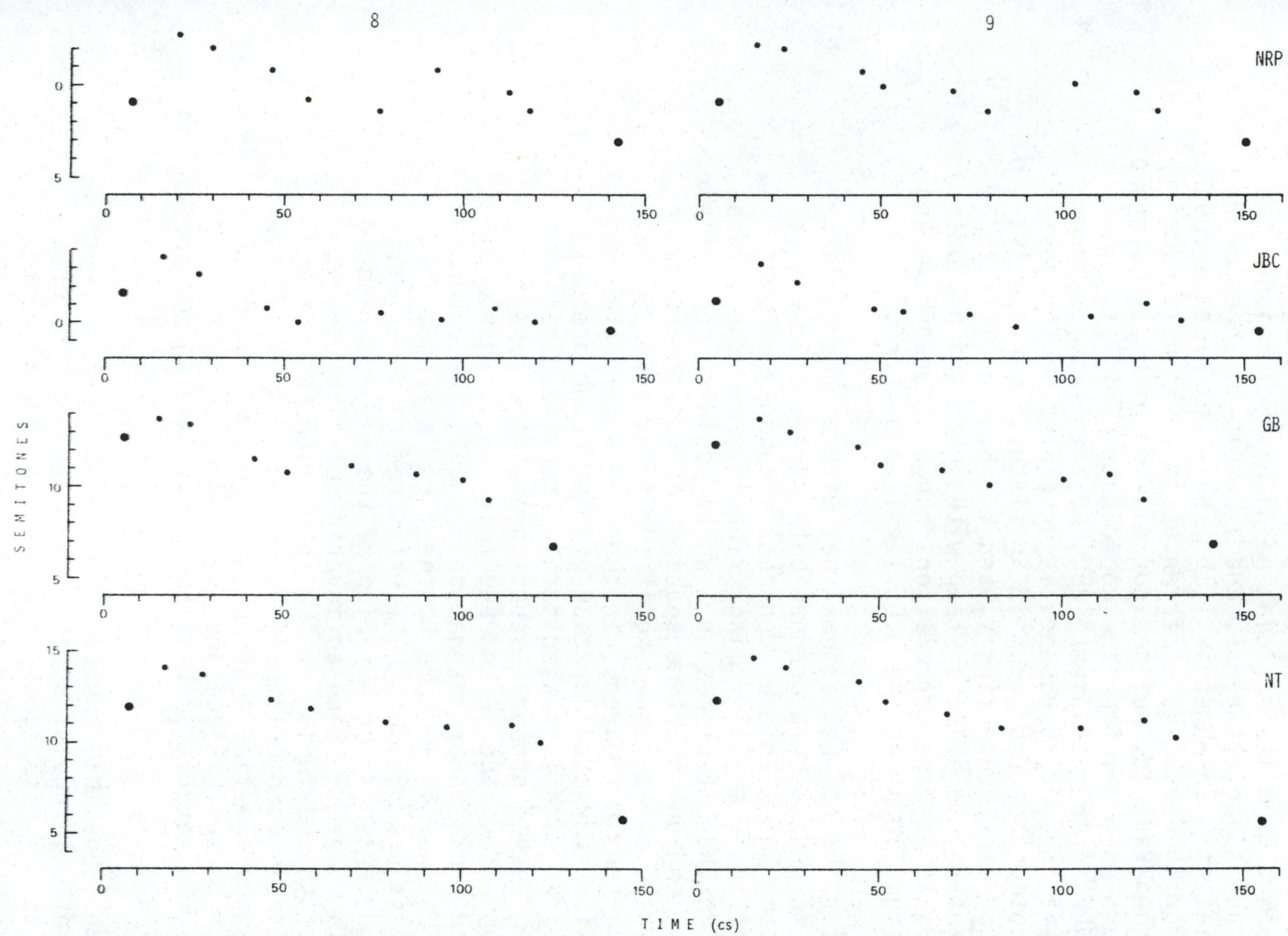

Figure 6

Slightly stylized fundamental frequency tracings (average of 6 recordings) of prosodic stress groups with a varying number (from 3 to 9) of unstressed syllables. The stressed vowel of the succeeding prosodic stress group is included. Stressed and unstressed syllables are indicated with big and small dots, respectively. Two male subjects (NRP and JBC) and two females (GB and NT). Zero on the logarithmic frequency scale corresponds to 100 Hz.

In Appendix IIIa time and frequency coordinates to the two vowels depicted in figure 6 are given, as well as the slope of the straight line that would connect them. It appears that V_2 ([i]), which is the end point of the intonation contour, is very nearly constant, and the very slight variation is not correlated with the duration of the preceding prosodic stress group. The behaviour of V_1 is obscured by the variation in vowel quality, and the relatively large variation shows no clear trend (apart from its correlation with vowel height). Consequently, the slope between V_1 and V_2 exhibits an apparently random variation. In Appendix IIIb I have performed a rough compensation for intrinsic Fø differences in V_1. The frequency variation is then reduced, but the correlation with stress group duration (as expressed by the time coordinate of V_2) is non-significant (NRP) or non-existent (JBC, GB and NT). In other words the variation in V_1 frequency is unrelated to the duration of the prosodic stress group it initiates. Conversely, the slope of the line connecting V_1 and V_2 shows a clear and significant tendency to be less steep with increased prosodic stress group duration (the correlations range between 0.71 and 0.85 and are significant at the 0.05 level or better).

Let me then, for the moment, assume that with an appropriate measuring and compensation procedure <u>both</u> stressed vowels in figure 6 had come out with near constant frequency values, irrespective of their mutual timing. The only way the intonation contours in the utterances as a whole could be rectilinear, in spite of the non-uniform time spacing of the second and third stressed syllables, would be if the first stressed syllable (not depicted in figure 6) in the utterance <u>decreased</u> in frequency with increased duration of the second prosodic stress group, i.e. with increased total utterance duration. (The longer the second prosodic stress group, the less steep is the line connecting the second and third stressed vowels. With an assumed rectilinear intonation contour, the extension of this line "backwards" in time to the first stressed vowel will also be less steep, i.e. the first stressed vowel will be lower in frequency as the duration of the second prosodic stress group increases.) Such an inverse relation between the Fø level of the beginning of the intonation contour and its total length is counterintuitive, and would be in distinct opposition to previous findings, on Danish as well as other languages, cf. Thorsen (1982c) and the references therein. Spot checks in the material reveal that this is also not the case here.

There are several possible sources of error in the procedure. The reduction of all vowels, short as well as long, to one point may not be felicitous; the compensation for intrinsic Fø level differences with equal amounts across all speakers is bound to be unsatisfactory; the influence from different syllable initial consonants is not accounted for at all. Therefore I do not wish to carry the discussion further than to hypothesize that the stressed vowels of an utterance are scaled without regard to their mutual timing. A stressed vowel is lower than the preceding one by a certain amount. However, this frequency interval is sensitive to utterance length in another way, namely as defined by the total number of stressed syllables. The interval between the only two stressed syllables of a terminal declarative is larger than between a pair of stressed syllables in a declarative with three or four prosodic stress groups, cf. Thorsen (1982c). In other words, we may conclude that (a) variation in prosodic stress group length entails a variation in the slope of the lines connecting neighbouring stressed syllables, and (b) variation in the number of prosodic stress groups (stressed syllables) entails a variation in overall slope.

Two distinct patterns of behaviour emerge where the <u>unstressed</u> syllables in the prosodic stress group are concerned. NRP treats the unstressed syllables in much the same fashion that long sentence intonation contours are produced, whereas JBC, GB and NT employ a different strategy.

When the number of unstressed syllables equals or exceeds six, NRP decomposes the falling slope into two separate, successive slants with a distinct partial resetting between them (of an order of magnitude of 1.5 to 2.0 semitones). ("Partial" because the post-tonic of the second declination does not reach the level of the first post-tonic in the stress group.) The two slopes together describe an overall downdrift. The factor determining the location of the resetting could be one of several: (1) In these utterances it coincides with the first word boundary in the stress group. (2) It occurs after a syllable with secondary stress, i.e. after a syllable which in non-compounded form would have main stress and would accordingly be succeeded by an Fø rise to the succeeding post-tonic syllable. Consequently, this secondary stress and the succeeding unstressed syllables could be said to constitute a pseudo-prosodic stress group. "Pseudo" because the secondary stress does not fall into place on the intonation contour with the truly stressed syllables of the utterance. (3) This same boundary is also the boundary before a prepositional phrase, i.e. a major syntactic boundary. Whether one or the other factor is decisive in NRP's speech can only be found out in a new material.

With JBC, GB and NT the humps and bumps in the declining unstressed syllables hardly deserve the name of resetting, and they are furthermore not consistently located - relative to the chain of syllables. I prefer to describe these Fø courses as very slightly undulating S-shapes or waves, where an initial fall levels out - or rises slightly, depending on the speaker and on the length of the stress group - and then falls again at the end of the pattern.

It is conspicuous that the four speakers apparently attempt not to let the Fø pattern transgress the intonation contour, i.e. the unstressed syllables do not drop below a line connecting the two stressed vowels, except in the two longest stress groups with JBC. In a previous analysis (Thorsen, 1982c), one subject (JR) distinguished himself from other speakers by his very sharply falling post-tonics which (though their number did not exceed three) often happened to cut through the intonation contour proper. He might, accordingly, have represented yet another distinct pattern of behaviour in this material.

Differences between subjects aside, the long prosodic stress groups here bear witness to a less passive control of the Fø pattern than I have previously assumed, at least when the prosodic stress group is sufficiently long. There are apparently limits (set by each speaker) to the extent of Fø declination tolerated in a series of post-tonic syllables, and when this limit is reached measures are taken to restore the pattern, at least in planned, read speech. Spontaneous speech may be less neatly regulated in this respect.

IV. FINAL COMMENTS

My final comments will serve as a sort of footnote to the title of this paper. A low plus high-falling Fø pattern associated with a stressed plus one or more unstressed syllables, truncated to a greater or lesser degree as the prosodic stress group is cut short of segmental material, is retrievable in every circumstance. The pattern is subjected to considerable "free" (i.e. inter-and intra-speaker) as well as contextual variation. I do not know which of these facts is most significant and amazing from the point of view of speech production and perception, but I do think that we should pay more attention to the variability in speech production, in casu in the production of prosodic phenomena. This is an aspect that models tend to gloss over and ignore: by their very nature linguistic models rather stress the invariance aspect and underrate the plasticity exhibited by speakers in a number of ways and conditions. However, the variation within or across speech production "items" is by force a greater challenge to any model which seeks to quantify its elements, than is the invariance.

ACKNOWLEDGEMENT

Thanks to Jørgen Rischel who made a number of suggestions for clarifications in the manuscript.

REFERENCES

Bundgaard, M. 1980: "An acoustic investigation of intrinsic vowel duration in Danish", *Ann. Rep. Inst. Phon., Univ. Cph. 14*, 99-120

Fischer-Jørgensen, E. 1964: "Sound duration and place of articulation", *Zeitschrift für Phonetik, Sprachwissenschaft und Kommunikation 17*, 175-207

Fischer-Jørgensen, E. 1984: "The acoustic manifestation of stress in Danish with particular reference to the reduction of stress in compounds", *Ann. Rep. Inst. Phon., Univ. Cph. 18*, 45-161

Hombert, J.-M. 1977: "Development of tones from vowel height?" *J. Phonetics 5*, 9-16

Reinholt Petersen, N. 1980: "Coarticulation of inherent fundamental frequency levels between syllables", *Ann. Rep. Inst. Phon., Univ. Cph. 14*, 317-354

Thorsen, N. 1978: "An acoustical analysis of Danish intonation", *J. Phonetics 6*, 151-175 (A more extensive version was published in *Ann. Rep. Inst. Phon., Univ. Cph. 10*, 1976, 85-147.)

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

Thorsen, N. 1980a: "Word boundaries and Fo patterns in Advanced Standard Copenhagen Danish", *Phonetica 37*, 121-133

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

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

Thorsen, N. 1982b: "Selected problems in the tonal manifestation of words containing assimilated or elided schwa", *Ann. Rep. Inst. Phon., Univ. Cph. 16*, 37-100

Thorsen, N. 1982c: "Sentence intonation in Danish", *Preprints of Papers for the Working Group on Intonation*, XIIIth Int. Cong. Ling., Tokyo 1982 (summary of two reports in *Ann. Rep. Inst. Phon., Univ. Cph. 14*, 1980, 1-29, and *15*, 1981, 13-47)

Thorsen, N. forthcoming: "Fø timing in Danish word perception", *Phonetica 41*, 1984. (A more extensive version published under the title "Two experiments in the perception of Fø timing in Danish" in *Ann. Rep. Inst. Phon., Univ. Cph. 17*, 1983, 1-20.)

Thorsen, N. and Nielsen, B. Jul 1981: "Fundamental frequency patterning and sentence intonation in two Jutlandish dialects - A first approach", *Ann. Rep. Inst. Phon., Univ. Cph. 15*, 1-12

APPENDIX I

The test words and sequences (underlined) in their carrier sentences with translations. The stressed vowels are indicated orthographically here with acute accents.

A. Fø pattern truncation

Nýt kít bínder bédst.
New putty holds better.

Den ný Kéats kénder han íkke.
He does not know the new (edition of) Keats.

Séks bít rǽkker íkke.
Six bits are not enough.

Den ný béat kénder han íkke.
He does not know the new beat (music).

Nýt gúld glímter mést.
New gold glistens more.

Lýs Kóol slúkker tǿrsten.
Light Kool quenches your thirst.

Nýt tín íltes húrtigt.
New pewter is quickly oxidized.

Et nýt téam ǽldes húrtigt.
A new team grows quickly old.

B. Fø peak location

Glássene og kánderne var méget gámle.
The glasses and the jugs were very old.

Nǽsen og kínderne var méget vármе.
The nose and cheeks were very hot.

Téksten til sálmerne var méget gámmel.
The lyrics of the psalms was very old.

De fléste af skýldnerne var méget gámle.
Most of the debtors were very old.

Trénserne og sádlerne var méget gamle.
The bridles and the saddles were very old.

Fórsvareren og vídnerne var méget gámle.
The counsel and the witnesses were very old.

Bílledet af dámerne var méget gámmelt.
The picture of the ladies was very old.

Óptagelsen af tálerne var méget gammel.
The recording of the speeches was very old.

Púden og dýnerne var méget gámle.
The pillow and the eiderdowns were very old.

Køllen og kúglerne var méget gámle.
The club and the balls were very old.

Slágterne og bágerne var méget gámle.
The butchers and the bakers were very old.

Kárlene og pígerne var méget gámle.
The grooms and the maids were very old.

C. Long prosodic stress groups

Knúdsen er journalíst på Politíken. (3)
Knudsen is a journalist for Politiken.

Péter blev ánsat på Politíken. (4)
Peter was employed by Politiken.

Han stártede som árbejdsmànd på Politíken. (5)
He began as a labourer at Politiken.

Lársen er spórtsredaktør på Politíken. (6)
Larsen is a sports editor with Politiken.

Líssi er móderedaktør på Politíken. (7)
Lissi is a fashion editor with Politiken.

Han éndte som údenrigsredaktør på Politíken. (8)
He ended up as editor of foreign affairs with Politiken.

Han begýndte som údenrigskorrespondènt på Politíken.
He began as a foreign correspondent to Politiken.

The number in parentheses indicates the number of unstressed syllables in the prosodic stress group.

APPENDIX II

Average values of Fø (in Hz) and time (in cs) coordinates of the Fø minimum, the Fø maximum, and the difference between maximum and minimum in 12 words. Standard deviation of Fø means are generally well below 5% of the mean, whereas standard deviations of time values range between 10 and 15%.

	Fø minimum		Fø maximum		Fø max-min	
	Hz	cs	Hz	cs	Hz	cs
Subject NRP						
kanderne	79.3	12.0	103.8	26.7	24.5	14.7
kinderne	84.3	10.7	106.0	23.5	21.7	12.8
salmerne	78.3	13.7	105.3	30.8	27.0	17.1
skyldnerne	85.2	10.2	107.8	26.8	22.6	16.6
sadlerne	77.3	13.7	102.2	30.0	24.9	16.3
vidnerne	83.8	13.8	105.3	29.2	21.5	15.4
damerne	78.2	13.8	103.5	29.7	25.3	15.9
dynerne	83.8	10.0	107.5	28.3	23.7	18.3
talerne	76.0	11.7	100.2	30.5	24.2	18.8
kuglerne	81.8	13.5	106.3	28.5	24.5	15.0
bagerne	77.3	13.7	100.3	32.2	23.0	18.5
pigerne	87.2	7.7	106.3	20.8	19.1	13.1
Subject JBC						
kanderne	94.2	9.5	113.5	26.7	19.3	17.2
kinderne	100.8	8.3	112.5	23.7	11.7	15.4
salmerne	95.7	10.5	112.2	30.2	16.5	19.7
skyldnerne	104.3	11.0	115.0	26.5	10.7	15.5
sadlerne	94.8	9.7	111.3	30.0	16.5	20.3
vidnerne	101.3	11.8	113.3	26.8	12.0	15.0
damerne	95.0	11.3	113.5	31.3	18.5	20.0
dynerne	101.5	10.0	114.7	26.2	13.2	16.2
talerne	92.8	9.2	110.3	28.3	17.5	19.1
kuglerne	103.8	11.8	116.8	26.5	13.0	14.7
bagerne	92.8	11.2	111.0	29.3	18.2	18.1
pigerne	103.0	8.2	117.5	23.8	14.5	15.6

	Fø minimum		Fø maximum		Fø max-min.	
	Hz	cs	Hz	cs	Hz	cs
Subject GB						
kanderne	170.7	7.7	198.3	23.2	27.6	15.5
kinderne	189.0	5.7	204.0	19.2	15.0	13.5
salmerne	169.0	7.3	200.0	25.0	31.0	17.7
skyldnerne	185.3	6.7	204.7	18.3	19.4	11.6
sadlerne	164.7	7.3	196.3	22.0	31.6	14.7
vidnerne	174.3	5.5	202.0	20.7	27.7	15.2
damerne	163.6	7.8	201.3	25.7	37.7	17.9
dynerne	194.0	7.3	216.0	19.5	22.0	12.2
talerne	170.7	8.3	197.0	23.5	26.3	15.2
kuglerne	182.3	9.0	210.0	19.3	27.7	10.3
bagerne	168.3	7.3	199.0	27.5	30.7	20.2
pigerne	190.3	5.8	217.7	17.5	27.4	11.7
Subject NT						
kanderne	185.3	9.2	221.7	23.3	36.4	14.1
kinderne	205.7	7.1	229.3	20.8	23.6	13.7
salmerne	178.7	10.3	215.0	28.7	36.3	18.4
skyldnerne	195.0	9.7	232.0	24.0	37.0	14.3
sadlerne	178.3	11.2	212.7	25.1	34.4	13.9
vidnerne	191.0	9.8	222.3	22.8	31.3	13.0
damerne	178.0	10.4	216.3	27.2	38.3	16.8
dynerne	205.6	9.8	230.0	21.8	24.4	12.0
talerne	176.3	11.7	207.7	24.4	31.4	12.7
kuglerne	194.7	9.8	231.7	21.7	37.0	11.9
bagerne	170.3	9.3	211.0	25.2	40.7	15.9
pigerne	197.7	6.9	230.7	20.7	33.0	13.8

APPENDIX IIIA

Average time (cs) and frequency (semitones re 100 Hz) coordinates to two stressed vowels (V_1 and V_2) surrounding a varying number of unstressed syllables (from three to nine). The slope of a straight line connecting V_1 and V_2 is given in semitones/second. V_2 was an [i] in all utterances, whereas V_1 varied as indicated to the left. Two male subjects (NRP and JBC) and two females (GB and NT).

number of unstressed syllables	V_1	NRP V_1	NRP V_2	NRP Slope	JBC V_1	JBC V_2	JBC Slope
3	[i]	-2.6/5	-4.2/75	-2.3	1.1/5	-0.2/75	-1.9
4	[a]	-4.7/4	-4.3/91	0.5	-0.3/5	-0.3/92	0
5	[ɑ·]	-4.2/9	-4.0/107	0.2	-0.6/6	-0.3/106	0.3
6	[ɒ·]	-3.8/6	-4.1/124	-0.3	0.2/6	-0.5/123	-0.6
7	[o·]	-2.1/7	-4.4/127	-1.9	0.6/5	-0.3/121	-0.8
8	[u·]	-2.0/7	-4.2/142	-1.6	1.7/5	-0.5/141	-1.6
9	[u·]	-1.9/6	-4.1/150	-1.5	1.4/5	-0.6/154	-1.3

number of unstressed syllables	V_1	GB V_1	GB V_2	GB Slope	NT V_1	NT V_2	NT Slope
3	[i]	10.6/4	7.2/56	-6.5	11.4/6	6.2/76	-7.4
4	[a]	10.0/3	6.8/76	-4.4	9.8/8	5.6/101	-4.5
5	[ɑ·]	9.2/6	7.0/93	-2.5	7.8/6	5.4/111	-2.3
6	[ɒ·]	9.8/4	6.4/106	-3.3	11.0/5	6.2/124	-4.0
7	[o·]	10.0/3	6.8/111	-3.0	11.1/6	5.2/130	-4.8
8	[u·]	12.6/5	6.8/125	-4.8	11.8/7	5.8/144	-4.4
9	[u·]	12.4/5	7.0/141	-4.0	12.2/6	5.7/155	-4.4

APPENDIX IIIb

As Appendix IIIa, except that a rough compensation for intrinsic Fø level differences between vowels of different tongue height (V_1) has been performed by adding 0.5 semitones to the values of [i] and [o·], and 2.0 semitones to [a], [ɑ·], and [ɒ·].

number of unstressed syllables	V_1	NRP V_1	NRP V_2	NRP Slope	JBC V_1	JBC V_2	JBC Slope
3	([i])	-2.1/5	-4.2/75	-3.0	1.6/5	-0.2/75	-2.6
4	([a])	-2.7/4	-4.3/91	-1.8	1.7/5	-0.3/92	-2.3
5	([ɑ·])	-2.2/9	-4.0/107	-1.8	1.4/6	-0.3/106	-1.7
6	([ɒ·])	-1.8/6	-4.1/124	-1.9	2.2/6	-0.5/123	-2.3
7	([o·])	-1.6/7	-4.4/127	-2.3	2.6/5	-0.3/121	-2.5
8	([u·])	-2.0/7	-4.2/142	-1.6	1.7/5	-0.5/141	-1.6
9	([u·])	-1.9/6	-4.1/150	-1.5	1.4/5	-0.6/154	-1.3

number of unstressed syllables	V_1	GB V_1	GB V_2	GB Slope	NT V_1	NT V_2	NT Slope
3	([i])	11.1/4	7.2/56	-7.5	11.9/6	6.2/76	-8.1
4	([a])	12.0/3	6.8/76	-7.1	11.8/8	5.6/101	-6.7
5	([ɑ·])	11.2/6	7.0/93	-4.8	9.8/6	5.4/111	-4.2
6	([ɒ·])	11.8/4	6.4/106	-5.3	13.0/5	6.2/124	-5.7
7	([o·])	10.5/3	6.8/111	-3.4	11.6/6	5.2/130	-5.2
8	([u·])	12.6/5	6.8/125	-4.8	11.8/7	5.8/144	-4.4
9	([u·])	12.4/5	7.0/141	-4.0	12.2/6	5.7/155	-4.4