

WORD BOUNDARIES AND Fo PATTERNS IN ADVANCED STANDARD COPENHAGEN
DANISH

Nina Thorsen

Abstract: In a previous analysis word boundaries have been denied any influence upon the course of fundamental frequency in the stress groups of Advanced Standard Copenhagen Danish. A small experiment has been carried out, which supports this contention, but which also suggests that in more conservative standards, word boundaries do affect Fo patterns.

1. Introduction

In many languages linguistic stress and Fo (or pitch) are interrelated. This is true of e.g. Danish (Thorsen, 1978), Dutch ('t Hart and Cohen, 1973), English (Fry, 1958; Lieberman, 1960), and Swedish (Bruce, 1977). The nature of this relationship is language and dialect specific and so is probably also the weight which pitch has among other prosodic cues for the perception of stressed vs. unstressed syllables. Further, the domain, i.e. the specific combination of stressed and unstressed syllables, of Fo patterns may vary between languages. Thus, Esser (1978) hypothesizes that in German the word is the unit which governs Fo, whereas in English it is the foot (Halliday, 1967). Bruce (1977) implies that in Swedish the word does not seem to constitute the basis for fundamental frequency patterning, and the analysis reported in Thorsen (1978) renders support for a contention that in Advanced Standard Copenhagen (ASC) Danish, word boundaries are immaterial for the Fo patterning.

For a brief summary of the 1978 analysis, the reader is referred to Thorsen (1979 - this volume, p. 60-65). - The establishment of the stress group, i.e. a stressed syllable and all succeeding unstressed syllables, as a relevant unit for the description of ASC Danish is corroborated by Reinholt Petersen's investi-

gations on intrinsic Fo level differences between vowels (1979, this volume). Further, an analysis of utterances with emphasis for contrast also strongly suggests that word boundaries are "deleted" in the Fo course (Thorsen, forthcoming). However, none of the Danish material so far analyzed has been designed expressly with regard to an interplay between word boundaries and Fo patterns, and conclusive, unambiguous evidence seemed called for. The present experiment was intended as a pilot study.

2. Material, subjects, and registrations

2.1 Material

It is difficult to construct utterances containing stress groups which are different only in the placement of word boundaries. Still, the utterances presented below are advantageous from two points of view: The stress group under scrutiny is the first one in the sentence, thus rendering any Fo differences more noticeable than they would be in later parts of the utterance, because Fo patterns are more elaborate in initial than in final parts of declarative utterances (cf. fig. 1 on page 60, this volume). Further, the stress group contains only one unstressed syllable, and any word boundary signal would thus have only one syllable to manifest itself on, which might make it more easily detectable than in longer tails of unstressed syllables. Thus, we could expect that the extent of the (incomplete) rise-fall exhibited by a single post-tonic syllable (cf. p. 64-65, this volume) be a function of word boundary location, so that higher rises are found when the post-tonic belongs to the same word as the preceding stressed syllable, lower rises are found when the unstressed syllable is a separate word, and still lower rises (or falls) when it belongs to the next lexically stressed word.

The test sentences are:

- (1) Pipiku kukker bedre end gøgen.
 [p^hi'kʊ'kʊk^hɛ'ðɛ'ɾə'nd'gø'gɛ'n]
 (Pipiku calls better than the cuckoo.)
- (2) Pipi ku kukke bedre end gøgen.
 [p^hi'kʊ'kʊk^hɛ'ðɛ'ɾə'nd'gø'gɛ'n ...]
 (Pipi could call better than the cuckoo.)
- (3) Pipi kukkukker bedre end gøgen.
 [p^hi'kʊ'kʊk^hɛ'ðɛ'ɾə'nd'gø'gɛ'n ...]
 (Pipi calls better than the cuckoo.)

Pipi is, for the purpose of the present experiment, a French girl's name, and thus stressed on the last syllable, whereas Pipiku is an Indonesian girl's name, and stressed on the the second syllable (or so the subjects were told). To kukke is to call like a cuckoo. A cuckoo's call is a kukkuk (or a kuk) and the verb form derived from this noun would be to kukkukke. (None of the subjects protested about the unlikeliness of the sentences, but they were, admittedly, all phoneticians and therefore used to all sorts of things.)

The three sentences were mixed with 30 others that served a completely different purpose and they only occurred once each on every two pages of reading material, which further occurred in three different randomizations (each being read twice by each subject), so any direct comparison of the test items was avoided and, likewise, any list reading effect. (However, if subjects cared to think about it, the purpose of the three sentences was of course very transparent.)

2.2 Subjects

Two subjects who also served for the 1978 analysis (NRP, male, and BH, female) recorded the material, and so did the author (NT). All three speak ASC Danish. Further, a male subject (JR) who speaks a slightly more conservative variant of Standard Danish was recorded, but for technical reasons, only three recordings of each sentence were obtained from him.

2.3 Recordings

The recordings took place in a quasi-damped room with semi-professional equipment (Revox A77 tape-recorder, Sennheiser MD21 microphone, larynx microphone) in two recording sessions, spaced at least one day apart.

2.4 Registration and measurements

The recordings were processed by hard-ware intensity and pitch meters (F-J Electronics) and registered on a mingograph (Elema 800). (The intensity curves serve segmentation purposes only.) The signal from the larynx microphone was processed in the hold mode. This, in combination with adjustment of the zero-line to the lower limit of the subject's voice range and full exploitation of the record space of the mingograph galvanometer, yields a good solution of the frequency scale, generally making a measuring accuracy

Table 1

Average values of Fo (in Hz) in the first four vowels in the test sentences in the test sentences and of the distance in time (in cs) of the Fo measuring points from the first stressed vowel (negative in i). Standard deviations are given in parentheses beneath each value.

FO:	Pipiku kuk- ...				Pipi ku kuk- ...				Pipi kukkuk- ...			
	i	o	u	l u	i	o	u	l u	i	o	u	l u
NRP (N=6)	96.3 (3.82)	133.8 (7.65)	145.0 (8.37)	103.8 (1.72)	97.2 (2.40)	137.8 (4.40)	147.3 (3.61)	103.2 (2.14)	99.2 (1.33)	140.3 (3.61)	147.5 (3.15)	105.3 (1.51)
JR (N=3)	97.3 (3.21)	117.0 (4.36)	134.3 (3.79)	101.3 (2.52)	100.3 (4.16)	127.0 (3.46)	133.7 (7.64)	111.0 (6.08)	104.0 (3.00)	134.7 (4.93)	127.7 (8.33)	111.0 (1.73)
BH (N=6/6/5)	216.3 (5.85)	253.7 (4.27)	272.7 (3.27)	229.0 (3.95)	220.0 (8.67)	258.3 (6.50)	279.0 (4.86)	235.0 (6.90)	215.2 (9.12)	252.0 (12.7)	273.6 (8.41)	227.6 (11.9)
NT (N=6)	228.0 (7.38)	263.3 (11.3)	291.0 (11.7)	234.3 (9.24)	233.3 (10.6)	269.0 (10.9)	290.3 (7.53)	239.3 (6.89)	231.7 (9.75)	268.7 (7.45)	292.0 (10.7)	237.3 (7.76)
Time:												
NRP (N=6)	-18.7 (1.21)	0	14.0 (1.41)	35.8 (0.75)	-18.8 (1.72)	0	15.0 (1.26)	37.7 (1.21)	-17.8 (0.98)	0	14.5 (0.55)	36.5 (0.55)
JR (N=3)	-16.0 (2.00)	0	13.0 (1.00)	36.7 (2.52)	-12.7 (1.53)	0	15.7 (3.79)	36.0 (5.29)	-14.3 (0.58)	0	16.0 (1.00)	35.3 (2.08)
BH (N=6/6/5)	-16.2 (1.72)	0	12.8 (1.94)	34.2 (2.71)	-16.0 (2.10)	0	13.3 (1.21)	33.2 (2.04)	-14.8 (1.48)	0	13.8 (1.30)	33.2 (2.39)
NT (N=6)	-16.8 (2.14)	0	16.3 (2.42)	37.3 (3.39)	-16.3 (1.21)	0	14.8 (1.33)	36.0 (0.89)	-17.2 (0.75)	0	14.7 (0.52)	35.7 (0.82)

of 1 Hz possible for males and 2 Hz for females. - The first four vowels in the sentences were measured, as follows: Monotonously falling or rising F_0 movements (and this description covers most of the vowels) were measured at a point in time $2/3$ of the distance from vowel onset, because this point corresponds to the perceived level pitch of the vowel, if its movement is not perceived (cf. Rossi, 1971 and 1978). The post-tonic vowel is often rising-falling and is then measured at its peak. - The distance in time of each measuring point from the first stressed vowel was also measured.

3. Results

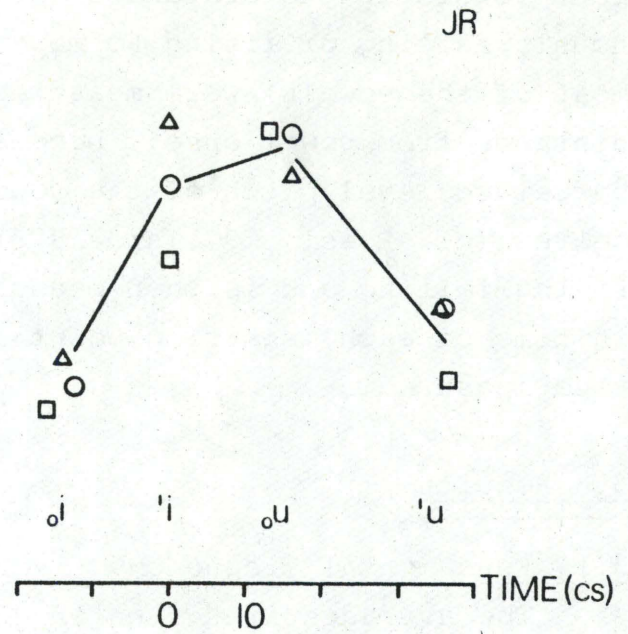
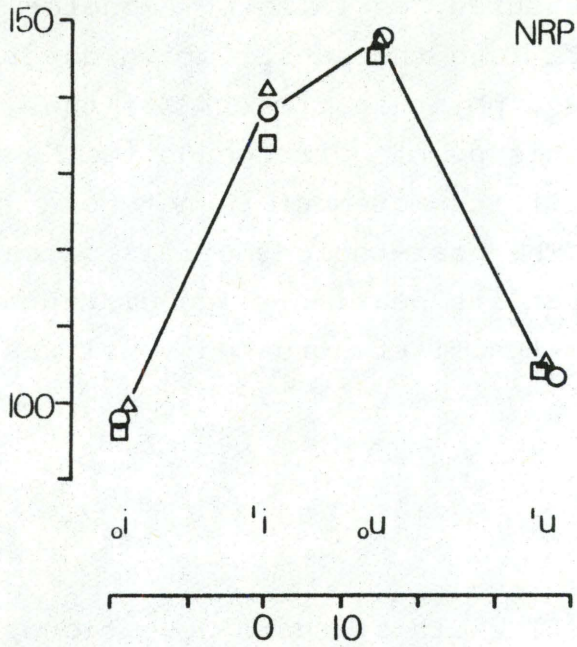
3.1 Fundamental frequency

The averages are given in table 1 (with standard deviations), and in fig. 1 stylized tracings of the F_0 course in the first four syllables of the test sentences are depicted. To facilitate the comparison between stress group types and between subjects, the F_0 averages were converted to semitones (re 100 Hz) which values were then weighted (by simple multiplication) to make all intervals between the two stressed vowels equal (3 semitones) and then they were normalized (by addition or subtraction) to have the stressed vowels coincide at 6 and 3 semitones, respectively; the durations were normalized to a stressed vowel distance of 38 cs, cf. fig. 2.

It seems clear (particularly from fig. 2) that the three ASC speakers (NRP, BH, and NT) do not distinguish the three stress group types in the F_0 course, except that NT has the post-tonic slightly higher in Pipiku kukker ... than in the other two sentences. JR is evidently different, and he follows the pattern outlined in section 2.1: the highest rise to the post-tonic is found in Pipiku kukker ... where the post-tonic belongs to the same word as the preceding stressed syllable, lower in Pipi ku kukke ... where the post-tonic constitutes a separate word, and lowest in Pipi kukkukker ... where the post-tonic belongs to the next stressed word.

Fig. 2 is informative, but the normalization and weighting that it took to produce it may blur some differences of a fundamental kind (at least as far as JR is concerned): It appears from

FREQUENCY (Hz)



FREQUENCY (Hz)

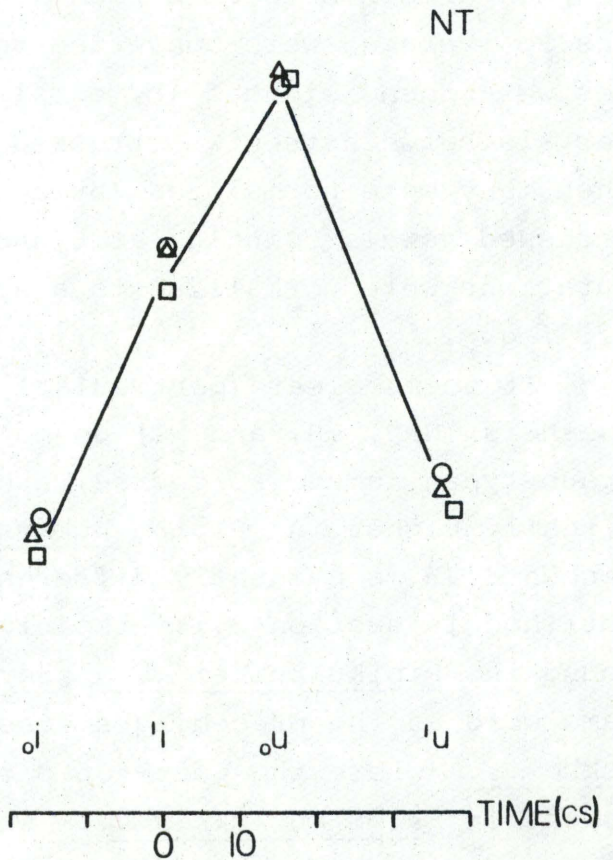
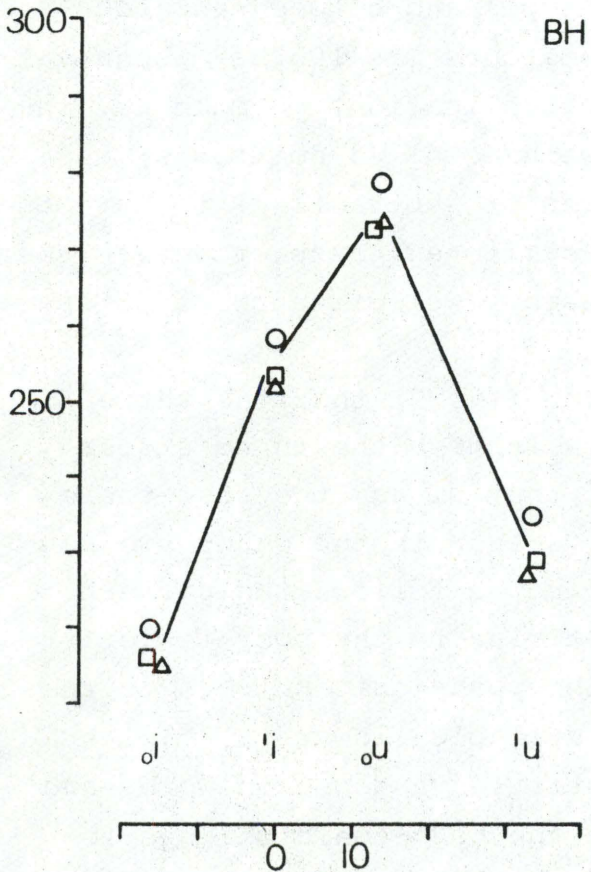


Figure 1

Stylized tracings of the course of fundamental frequency in the first four syllables of the test sentences.

□ : Pipiku kukker bedre end gøgen. O : Pipi ku kukke bedre end gøgen.
 Δ : Pipi kukkukker bedre end gøgen.

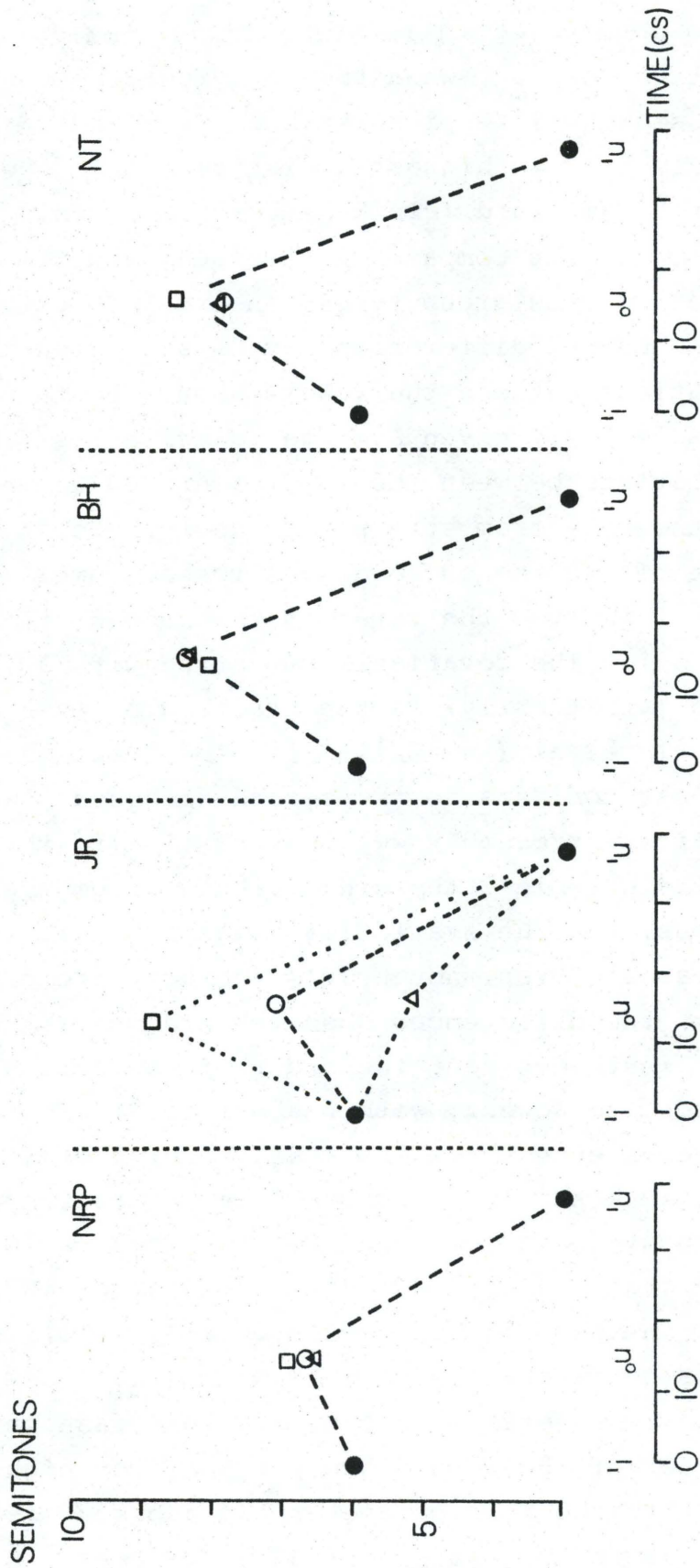


Figure 2

Stylized, normalized, and weighted tracings of the course of fundamental frequency in the first stressed, the post-tonic, and the second stressed syllables of the test sentences. Filled circles pertain to the stressed syllables.

□: Pipiku kukker bedre end gøgen. O: Pipi ku kukke bedre end gøgen.

△: Pipi kukkukker bedre end gøgen.

fig. 1 (and table 1) that the post-tonic is not the only vowel which varies - so does the level of the first stressed vowel and (to a smaller degree) the second stressed vowel. In particular, JR's patterns in fig. 1 make one suspect that the level of [^li] and that of [_ou] covary: [^li] is highest and simultaneously [_ou] is lowest (relative to [^lu]) when the post-tonic belongs to the succeeding stressed vowel (Pipi kukkukker ...), and [^li] is lowest and simultaneously [_ou] is highest (relative to [^lu]) when [^li] and [_ou] belong to the same word (Pipiku kukker ...). This means that it is not sufficient to just compare the average values of the post-tonic vowel across stress group types, in order to establish to what extent the observed differences may be statistically significant: the relations between the vowels should be taken into account. - In table 2 are given average values and standard deviations of the relations between the vowels (excluding the sentence initial one): the rise from stressed to post-tonic (^li-_ou), the fall from post-tonic to the succeeding stressed vowel, numerically (_ou-^lu), and the fall from the first to the second stressed vowel, numerically (^li-^lu). The covariation observed with JR, cf. above, may be expressed (arbitrarily) as the fraction of the _ou-^lu-interval to the ^li-^lu-interval (_ou-^lu/^li-^lu): the fraction decreases the closer the post-tonic is to the second stressed vowel and/or the higher the first stressed vowel is (relative to the second stressed vowel). In table 3 these entities are compared across stress group types, and the statistical significance, if 10% or better, is indicated. Even though JR's averages are based on only three recordings, the differences observed are statistically significant in most instances, and the order of the stress group types, from highest to lowest, with respect to the four parameters is as expected: Sentence 1 (Pipiku kukker ...) scores highest and sentence 3 (Pipi kukkukker ...) scores lowest with respect to the rise to the post-tonic (^li-_ou), the fall from the post-tonic (_ou-^lu), and the fraction (_ou-^lu/^li-^lu). The order is reversed, as it should be, in the inter-stress interval (^li-^lu), except that the difference is nearly nil between Pipi ku ... and Pipiku - The other subjects do not behave in a fashion uniform with JR: the order of the stress group types from highest to lowest, with respect to the four parameters in table 3, is only identical to that of JR in two instances (NRP: ^li-_ou and _ou-^lu/^li-^lu).

Table 2

Average values of the F_0 relationships between the first stressed, the post-tonic and the second stressed vowel in the test sentences, i.e. the rise to the post-tonic ($'i-u$), the fall from the post-tonic to the succeeding stressed vowel, numerically ($u-lu$), the fall from the first to the second stressed vowel, numerically ($'i-lu$), and the ratio between $u-lu$ and $'i-lu$. Standard deviations are given in parentheses beneath each value. Note that the fraction is not calculated from the average values of its nominator and denominator but from the raw data, which is why there are apparent discrepancies between this fraction and one calculated from $u-lu$ and $'i-lu$ as they appear in the table.

	Pipiku kuk-			Pipi ku kuk-			Pipi kukkuk-		
	$'i-u$	$u-lu$	$\frac{u-lu}{'i-lu}$	$'i-u$	$u-lu$	$\frac{u-lu}{'i-lu}$	$'i-u$	$u-lu$	$\frac{u-lu}{'i-lu}$
NRP (N=6)	11.2 (7.44)	41.2 (6.97)	1.43 (0.391)	9.5 (3.99)	44.2 (3.31)	1.29 (0.173)	7.2 (2.71)	42.2 (3.31)	1.21 (0.090)
JR (N=3)	17.3 (6.51)	33.0 (2.65)	2.48 (1.33)	6.7 (7.77)	22.7 (3.21)	1.55 (0.639)	-7.0 (8.89)	16.7 (6.66)	0.755 (0.347)
BH (N=6/6/5)	19.0 (4.69)	43.7 (4.80)	1.82 (0.327)	20.7 (6.28)	44.0 (3.10)	1.98 (0.523)	21.6 (5.55)	46.0 (9.49)	2.12 (0.787)
NT (N=6)	27.7 (5.72)	56.7 (8.45)	2.01 (0.403)	21.3 (9.00)	51.0 (8.17)	1.80 (0.454)	23.3 (7.66)	54.7 (12.37)	1.81 (0.377)

Table 3

A comparison across stress group types of the Fo relationships tabulated in table 2. The stress group types are designated "1" (Pipiku kukker ...), "2" (Pipi ku kukke ...), and "3" (Pipi kukkukker ...). They are listed in decreasing order of magnitude, from left to right, and the statistical significance, if 10% or better, is indicated in parentheses.

	${}^l i - {}^o u$
NRP	1 > 2 > 3
JR	1 > 2 > 3: 1>2 (10%); 2>3 (10%); 1>3 (1%)
BH	3 > 2 > 1
NT	1 > 3 > 2: 1>2 (10%)

	${}^o u - {}^l u$
NRP	2 > 3 > 1
JR	1 > 2 > 3: 1>2 (5%); 1>3 (5%)
BH	3 > 2 ≈ 1
NT	1 > 3 > 2

	${}^l i - {}^l u$
NRP	2 ≈ 3 > 1: 3>1 (10%)
JR	3 > 2 ≈ 1: 3>2 (10%); 3>1 (10%)
BH	1 ≈ 3 > 2
NT	3 > 2 ≈ 1

	$\frac{{}^o u - {}^l u}{{}^l i - {}^l u}$
NRP	1 > 2 > 3
JR	1 > 2 > 3: 1>3 (5%); 2>3 (10%)
BH	3 > 2 > 1
NT	1 > 3 ≈ 2

We may regard the sentence numbers as ranks (and reverse them for the inter-stress interval, ${}^1i-{}^1u$) and calculate the Kendall coefficient of concordance (W) between the "rankings" of NRP, BH, and NT across the four parameters: $W = 0.007$, i.e. the concordance is nil.

The statistical analysis confirmed the initial observation, that the location of word boundaries is not reflected in the Fo patterns of the ASC speaking subjects, but they are very manifest with JR. JR was brought up on Funen but the word boundary/Fo relations found with him are hardly a Danish influence, because this is not otherwise perceptible, but they may be a characteristic of the conservative variant of Standard Danish. - To resolve this issue would take a separate investigation. (On the other hand, if different varieties of Danish turn out to be fundamentally different with respect to a relation between word boundaries and Fo patterns, then this difference may be confined to neutral speech: When emphasis for contrast occurs on a word in the utterance, JR seems to delete the word boundaries in much the same fashion as do ASC speakers, cf. Thorsen, forthcoming.)

3.2 Duration

Differences in timing may of course exist independently of the lack of differences in fundamental frequency (co-exist in JR's case). In table 4 the durational differences tabulated in table 1 are compared across the three stress group types. Hypotheses about these differences might run as follows: (1): The inter-stress interval (${}^1i-{}^1u$) should be longer in Pipi ku kukke ... where two word boundaries intervene, than in the other two types.

(2): The distance from stressed to post-tonic (${}^1i-{}_0u$) should be smaller in Pipiku kukker ... where no word boundary intervenes, than in the other two types. (3): The distance from post-tonic to the succeeding stressed vowel (${}_0u-{}^1u$) should be smaller in Pipi kukkukker ... where no boundary intervenes, than in the other two types.

Ad (1): NRP is the only one who has a longer inter-stress distance in Pipi ku kukke ..., but with him this distance is also significantly longer in Pipi kukkukker ... than in Pipiku kukker ... for which it is hard to find an explanation. Ad (2): Three subjects have a shorter distance to the post-tonic in Pipiku kukker ..., but only significantly so with JR; with NT

Table 4

A comparison across stress group types of the durational differences tabulated in table 1. The stress group types are designated "1" (Pipiku kukker ...), "2" (Pipi ku kukke ...), and "3" (Pipi kukkukker ...). They are listed in decreasing order of magnitude, from left to right, and the statistical significance, if 10% or better, is indicated in parentheses.

	${}^i i - {}^o u$	
NRP	2 > 3 > 1	
JR	3 > 2 > 1:	3>1 (2.5%)
BH	3 > 2 > 1	
NT	1 > 2 > 3:	1>3 (10%)
	${}^o u - {}^i u$	
NRP	2 > 3 > 1	
JR	1 > 2 > 3:	1>2 (5%); 1>3 (2.5%)
BH	1 > 2 > 3:	1>2 (5%); 1>3 (2.5%)
NT	2 > 1 = 3	
	${}^i i - {}^i u$	
NRP	2 > 3 > 1:	2>3 (5%); 2>1 (0.5%); 3>1 (5%)
JR	1 > 2 > 3	
BH	1 > 2 = 3	
NT	1 > 2 > 3:	1>3 (10%)

the order is reversed and, further, this distance is significantly longer in in Pipiku kukker ... than in Pipi kukkukker ..., which seems counter-intuitive. Ad (3): BH and JR have significantly shorter distances from post-tonic to the succeeding stressed vowel in Pipi kukkukker ... but it is also significantly shorter in Pipi ku kukke ... than in Pipiku kukker ..., for which it is hard to find an explanation. NRP and NT differ from this pattern.

On the whole, the durational differences cannot be said to reflect word boundary location in any succinct way, except maybe with JR who has a shorter distance from stressed to post-tonic in Pipiku kukker ... and a shorter distance from post-tonic to the succeeding stressed vowel in Pipi kukkukker

4. Conclusion

The results of the present experiment confirm the results of the 1978 analysis, that in Advanced Standard Copenhagen Danish word boundaries leave no trace in the course of fundamental frequency in the stress group - but they also suggest that this may not be generalizable to all varieties of Danish. If this suggestion is corroborated by further analyses, then the definition of the stress group, as it applies to ASC Danish, namely 'a stressed syllable plus all succeeding unstressed syllables, irrespective of intervening word boundaries' may not be entirely adequate, because it cannot be said to be the unit which governs the predictable, recurrent, and in certain respects invariant, Fo patterns (as is the case in ASC). (But then again, there may be other reasons to stick with the stress group: Peter Holtse (personal communication) has performed an analysis on the variation of vowel duration, with speakers from various dialects, and found that this variation seems to be determined by the stress group - in the ASC-sense.)

The investigation was intended as a pilot study. However, I think that the results are clear enough for the ASC speakers to be conclusive - but they may serve as a basis for further analyses of other kinds of Danish.

References

- Bruce, G. 1977: "Swedish word accents in sentence perspective", Travaux de l'Institut de Linguistique de Lund 12, p. 1-155
- Esser, J. 1978: "Contrastive intonation of German and English. Problems and some results", Phonetica 35, p. 41-55
- Fry, D.B. 1958: "Experiments in the perception of stress", L&S 1, p. 126-152
- Halliday, M.A.K. 1967: Intonation and Grammar in British English, Mouton, The Hague
- 't Hart, J. & A. Cohen 1973: "Intonation by rule: a perceptual quest", JPh 1, p. 309-327
- Lieberman, P. 1960: "Some acoustic correlates of word stress in American English", JASA 32, p. 451-454
- Reinholt Petersen, N. 1979: "Variation in inherent Fo level differences between vowels as a function of position in the utterance and in the stress group", ARIPUC 13, p. 27-57 (this volume)
- Rossi, M. 1971: "Le seuil de glissando ou seuil de perception des variations tonales pour les sons de la parole", Phonetica 23, p. 1-33
- Rossi, M. 1978: "La perception des glissandos descendants dans les contours prosodiques", Phonetica 35, p. 11-40
- Thorsen, N. 1978: "An acoustical investigation of Danish intonation", JPh 6, p. 151-175
- Thorsen, N. 1979: "Lexical stress, emphasis for contrast, and sentence intonation in Advanced Standard Copenhagen Danish", ARIPUC 13, p. 59-85 (this volume)
- Thorsen, N. (forthcoming) "Lexical stress, emphasis for contrast, and sentence intonation in Advanced Standard Copenhagen Danish" (an enlarged version of Thorsen, 1979), in preparation.