Lexical stress and focus distribution as determinants of temporal structure

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0. Introduction

Neijt (1990) proposes two independent representations for prosodic prominence.[1] A non-culminative autosegmental structure with high and low tones that accounts for pitch accents in focused constituents, and a culminative metrical structure that accounts for the lexical stress position in a word and which is expressed by relative duration. The most far reaching consequence following from this proposal is that relative temporal structure of a word does not change if a pitch accent is shifted to an unstressed syllable.

This paper describes a production experiment in which we varied accent position in words by placing different parts of the same word in focus. Duration measurements show that if we shift a pitch accent, duration largely behaves as if the stress position shifts. The assumption of completely independent representations of prosodic prominence is therefore untenable.

1. Theoretical background

Pitch is generally accepted as the most important cue in the production and the perception of accents (Fry 1958, Van Katwijk 1974, Beckman 1986). Because in most cases an accent is realized on the lexically stressed syllable of a word, pitch has also been advanced as the most important cue for stress. Duration, intensity and spectral quality were universally found to be weaker cues to stress position than pitch movements (Lehiste 1970, Beckman 1986).

There is strong evidence that accent and stress in Dutch independently influence the absolute duration of syllables and segments. Nooteboom (1972) varied stress positions in unaccented Dutch three-syllable nonsense words like *pa:pa:pa:p*. A stressed syllable was always longer than an unstressed version of that syllable in the same position. Moreover, when the same words were accented all its syllables were linearly expanded in time. Recent analysis of the data revealed that the relative duration structure (syllable duration

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expressed in percentage of the word duration) was almost identical in the condition with and without an accent (cf. Martens 1992).

Slootweg (1988) showed that metrical structure (the prominence relations among syllables expressed as strong and weak nodes in a tree structure) can be mapped on durational properties of syllable strings. Similarly to the above mentioned analysis, she showed that the temporal distribution of accent is only linear expansion. The lexically stressed syllable is the metrically most prominent syllable. This syllable has the longest duration, relatively to unstressed syllables in the same position in the word.

In summary, the conclusion seems warranted, and has in fact been advanced by Neijt (1990), that metrical structure determines relative duration of syllables within words and the temporal contribution of an accent is to linearly expand the time scale of a word. Neijt goes one step further by concluding that the contributions of metrical structure and accent to the temporal organisation are independent. However, it occurred to us that this conclusion might be premature. The literature data that were used in support of this view, were exclusively based on experiments in which pitch accents occurred on lexically stressed syllables. The conclusion that the relative duration of syllables is independent of accentuation is only valid if we also use speech material with accents on unstressed syllables, varying accent as well as stress position orthogonally. Once we know what happens when stress and accent no longer coincide, it may be possible to decide about the validity of this conclusion. This type of experiment has never been done before. However there are linguistic views that make predictions about the outcome of such an experiment. We ran an experiment in which the accent position was varied placing the words or parts of the word in focus. On the basis of linguistic theories there are three relations between duration and tone, each predicting a different outcome of the experiment:

(1) **No separate levels for metre and tone; metre determines tone.**
Pitch accents are always placed on the metrically most prominent syllable. Tone structure is not represented on a separate level, but it is just another acoustic correlate of metrical structure.

This option was put forward by Chomsky and Halle (1968). However they based their mechanism only on neutral utterances whose accents always occur in stressed positions. We will not go into this option any further. The fact that there are constructions in which the tone accent is realized as a contrastive accent on an unstressed syllable (cf. Bolinger 1961) makes this option unviable.

(2) **Separate levels for metre and tone; the levels do not interact.**
Duration and tone structures are represented on separate autonomous prosodic levels (cf. Neijt 1990, 1991). Metrical constituent structure (cf. Neijt and Zonneveld 1981) reflects the relative duration of the syllables. Tone structures are generated by rules and conventions of autosegmental phonology (cf. Gussenhoven 1988). Tonal prominence is brought about by a pitch movement on a constituent that places that constituent, or a larger constituent of which it is the prosodic head, in focus (cf. Ladd 1980, Baart 1987).

(3) **Separate levels for metre and tone; tone determines metre.**
Pitch accents are able to change not only absolute duration, but also the relative duration structure of words. Tone and duration have separate prosodic levels but are not independent: tone structure determines metrical structure. Lexically unstressed syllables carrying a pitch accent have to be made metrically prominent (cf. Selkirk 1984).

The prediction of the second view is that contrastive accents do not affect the relative duration of the syllables no matter where an accent is placed. The prediction of the third view is that the relative duration is affected by an accent on the unstressed syllable. The main aim of this paper is to choose between these two views. Therefore, it is necessary to know what happens with the relative duration of syllables when a narrow-focus accent is realized on the lexically unstressed syllable.

Selkirk (1984:271) endorses the third view, although she explicitly excludes contrastive accent constructions from her theoretical domain. In her opinion the metrical level accounts for the rhythmical organisation of the various constituents. The assignment of a pitch accent changes the metrical structure on the level of the word and above, but not on levels below the word. Below the word level her view is compatible with that of Neijt (1990). We extended the use of Selkirks rules to below the word level. Thus our revised version of the theory differs from that of Selkirk in two respects: (i) it is extended to the levels below the word and (ii) contrastive accents are now accounted for as normal accents. The viability of this latter assumption will be examined in the present experiment as a methodological question: if we find no difference in the phonetic realization of contrastive accents and normal accents on exactly the same material, we will accept our extension of Selkirk's theory as valid.

In summary, we focused on the following research question: (i) Does the relative duration of the syllables of a word change when an accent is realized on an unstressed syllable of that word?

Also, there is a methodological question that addresses the postulated exceptional status of contrastive accents as opposed to normal accents: (ii) Is it true that speakers make no acoustical difference between a contrastive

accent on the lexically stressed syllable and a normal accent on the lexically stressed syllable placing the whole word in focus?

2. Method

2.1. Focus conditions. Accentuation is used to focus (Baart 1987), i.e., to highlight a word or a group of words. This is done by placing an accent on one of the words in that constituent. If the accent is on the prosodic head of the word group, it can highlight the whole word group ("broad focus") or just the word ("narrow focus") containing the accent. In the former case we speak of an integrative accent. Consider the following examples (syllables carrying an accent are written in capitals, lexical material in focus is underlined):

(1) Q. Are you reading a good MAgazine?
A. No, I am reading a good BOOK
(2) Q. What are you REAding?
A. I am reading a good BOOK

In (1), only the word *book* is brought into (narrow) focus expressed by the accent on that word. In (2), the whole constituent *a good book* is placed into (broad) focus by the same accent. In this case narrow and broad focus were defined on the word level (cf. Baart 1987).

In our experiment words and individual syllables were placed in focus. Therefore, we treated the notions "narrow" and "broad" focus as relative notions and defined them on the syllable level. When a whole word is placed into focus, we use the term broad focus. This broad focus is expressed by an integrative accent on the lexically stressed syllable of that word (cf. Van Heuven 1991). If only one syllable is placed in focus, expressed by a pitch accent on that syllable, we used the term narrow focus.

We needed four conditions to answer the research questions. A condition in which no accent is realized on the target word as a baseline condition. Question (ii) compares normal and contrastive accents. Therefore, we needed a condition with a normal integrative accent on the word and a condition with a narrow-focus accent on the stressed syllable. To answer the main question of this paper we need a condition in which an accent is realized on the unstressed syllable to compare it with the condition in which an accent is realized on the stressed syllable (integrative or contrastive). To realize the four focus conditions the following question-answer pairs were used.

I. NO FOCUS (NF): Focus on a word other than the target words (target word: versie 'version').

Q. Heb je versie GEZEGD of OPGESCHREVEN?
'Have you version said or written?'
A. Ik heb versie geZEGD
'I have version said'

II. BROAD FOCUS on the word (BF), expressed by an integrative accent on the lexical stressed syllable of the target word (target word: versie 'version'). The word was contrasted with a word from the same semantical field.

Q. Heb je VERSIE of DEELgezegd?
'Have you version or part said?'
A. Ik heb VERsie gezegd.
'I have version said'

III. NARROW FOCUS on the lexical stressed syllable (SF), expressed by a narrow-focus accent on that syllable (target word: versie 'version'). The word was contrasted with a word with an identical unstressed syllable and a different stressed syllable.

Q. Heb je VERsie of FUsie gezegd?
'Have you version or fusion said?'
A. Ik heb VERsie gezegd.
'I have version said'

IV. NARROW FOCUS on the unstressed syllable (UF), expressed by a narrow-focus accent on that syllable (target word: versie 'version'). The word was contrasted with a word with an identical stressed syllable and a different unstressed syllable.

Q. Heb je verSIE of verBUMgezegd?
'Have you version or verbumsaid?'
A. Ik heb verSIE gezegd.
'I have version said'

2.2. Stress position and rhyme structure. The position of the stressed syllable in Dutch di-syllabic simplex words depends on the weight of the final syllable. If the final syllable contains a long vowel and at least one final consonant it is regularly stressed. If the final syllable is open, stress regularly falls on the first syllable. As a consequence it is impossible to come up with segmentally identical structures differing in regular stress position. In such minimal stress pairs, one stress position will have to be marked as an exception. However,

we also want to compare different stress positions across identical syllable structures. Therefore we need a 2*2 factorial design for our lexical material, as exemplified in the table below:

	INITIAL STRESS		FINAL STRESS	
VC-VV	versie	(regular)	pigmee	(exception)
VC-VVC	potlood	(exception)	portiek	(regular)

Each cell in this stimulus matrix was filled with 2 or 3 instances. In the appendix a list of the stimulus words is presented.

2.3. Subjects and recording procedures. The subjects for this study were two native Dutch phoneticians (one male and one female) at the Dept. Linguistics/Phonetics of Leyden University. The speakers were recorded individually in a sound insulated recording booth, using semi-professional equipment. The total set consisted of 44 question-answer stimuli (4 focus conditions x 11 words). The stimuli were randomized and presented on six sheets of paper. Focus positions were underlined and had to be realized as a so-called 'pointed hat' pitch accent (configuration 1&A in the intonation grammar of Dutch, cf. 't Hart, Collier, and Cohen 1990). Speakers read all the question-answer pairs twice. Two phonetically trained listeners then verified the locations and the realization of the accents. There was no disagreement on this point and every utterance could be used for further analysis.

2.4. Acoustical analysis. The 176 target sentences (11 target words x 4 focus conditions x 2 speakers x 2 repetitions) were digitized (10 kHz, 12 bits, 0,3-4,5 KHz BP). Syllable durations were then measured by hand using the high resolution waveform editor SESAM (Broeder 1990). Syllable boundaries were determined by the visual criteria described in Van Zanten, Damen and Van Houten (1991). Relative syllable duration was expressed in per cent by dividing the absolute syllable duration by the absolute word duration and then multiplying the result by 100.

3. Results

3.1. Main effects and interactions. A three-way analysis of variance was performed on both absolute and relative syllable duration with focus and word type as fixed factors and speaker as a random factor. In table 1 mean absolute and relative syllable durations are broken down for the three independent variables speaker, word type and focus condition.

Table 1 shows that speaker 1, in general, has somewhat longer initial syllables with an average duration of 252 ms for speaker 1 and of 243 ms for speaker 2 [$F(1,174)=6.0$, $p=.015$]. On the other hand, speaker 2 has somewhat longer second syllables [$F(1,174)=8.6$, $p=.004$]. This difference is also found for the relative duration of the syllables. The mean relative duration of the first syllable of speaker 1 is 55% and of speaker 2 it is 52 % [$F(1,174)=15.5$, $p<.001$]. Crucially, however, there are no significant interactions involving speaker. Therefore, we decided to collapse the results over both speakers in our subsequent analyses.

Table 1. Mean duration in ms of syllable 1 and 2 (syl1 and syl2) and relative duration of syllable 1 in % of the word duration (%syl1) per **speaker**, **word type**, and **focus condition** (NF, BF, SF, UF). Standard deviations are presented in parentheses.

		syl1	**syl2**	**%syl1**
SPEAKER	1	252 (49)	209 (45)	55% (8)
	2	243 (56)	223 (51)	52% (9)
WORD-TYPE	VC-vv	266 (39)	183 (50)	60% (7)
	vc-VV	254 (46)	218 (35)	54% (6)
	VC-vvc	281 (42)	208 (34)	57% (5)
	vc-VVC	201 (47)	251 (44)	44% (7)
FOCUS-CONDITION	NF	215 (42)	176 (40)	55% (9)
	BF	253 (54)	224 (44)	53% (9)
	SF	251 (57)	228 (48)	52% (10)
	UF	273 (37)	236 (38)	54% (7)

Table 1 also shows that there is a difference between the four word types. The unstressed versions of the first and the second syllables are shorter than their stressed counterparts. The stressed VC-syllables are 266 and 281 ms, respectively, whereas their unstressed version are 254 and 201 ms. This difference also holds for the relative duration of the first syllable: 60% and 57% versus 54% and 44%. Furthermore, it is clear that a VV syllable is shorter than a VVC syllable: 183 and 218 ms versus 208 and 251 ms. The differences in duration are statistically significant both for the duration of the first syllable [$F(3,172)=37.0$, $p=.001$], and the duration of the second syllable [$F(3,172)=22.6$, $p=.015$] and the relative duration of the first syllable [$F(3,172)=33.6$, $p=.008$].

Focus condition also affects the absolute duration of the syllables. Syllables in the condition NF are about 40 ms shorter than the same syllables in condition BF and SF. These latter two focus conditions have virtually the same syllable durations: 253 ms versus 251 ms for the first syllable and 224 ms versus 228 ms for the second syllable. For each dependent variable, the

difference in duration between the focus conditions is significant [first syllable: $F(3,172)=22.4$, $p=.015$; second syllable: $F(3,172)=170.7$, $p=.001$; relative syllable duration [$F(3,172)=10.6$, $p=.042$]. The interaction between focus and word type was significant for the first syllable [$F(9,160)=11.2$, $p=.001$], the second syllable [$F(9,160)=34.3$, $p<.001$] and the relative duration of the first syllable [$F(9,160)=34.0$, $p<.001$]. The significance of these interactions is caused by a difference in stress position among the four word types. Given these interactions between focus and type we decided to examine the influence of focus on the duration structure of words for each word type separately, by an one-way analysis of variance performed on both absolute and relative syllable duration with focus condition as the fixed effect.

3.2. Focus and word type. In table 2 syllable durations are presented for each focus condition per word type.

Table 2. Absolute syllable durations in ms and relative duration of the stressed syllable in % of the word duration for each word type separately in the different focus conditions (NF, BF, SF, UF).

VC-vv	(VERsie)			**VC**-vvc	(POTlood)		
	syl1	syl2	%syl1		**syl1**	syl2	%syl1
1. NF	**240**	131	65	1. NF	**251**	166	60
2. BF	**291**	179	62	2. BF	**309**	207	60
3. SF	**291**	178	62	3. SF	**307**	207	60
4. UF	**243**	247	50	4. UF	**256**	254	50
vc-**VV**	(pigMEE)			vc-**VVC**	(porTIEK)		
	syl1	**syl2**	%syl2		syl1	**syl2**	%syl2
1. NF	210	**182**	46	1. NF	170	**220**	56
2. BF	243	**241**	50	2. BF	187	**264**	59
3. SF	247	**247**	50	3. SF	177	**274**	61
4. UF	317	**209**	40	4. UF	269	**247**	48

Focus condition caused a significant effect on syllable duration, both absolute and relative, for all word types (all cases: $p<.001$).

For both absolute and relative duration Newman-Keuls range tests ($\alpha<.05$) were used to make pairwise post hoc comparisons between the means. The results will be discussed in separate sections according to the research questions.

3.3. The influence of normal accentuation. The presence or absence of accent affects the durational behavior of stressed and unstressed syllables. Accented words have significantly longer syllables than unaccented words (table 2, con-

dition NF versus BF). Stressed syllables are 44 to 59 ms longer if the word is accented. Unstressed syllables are 33 to 48 ms longer, except for word type vc-VVC (portiek). Although the relative differences are not exactly the same for the stressed and the unstressed syllable, relative duration is preserved between condition NF and BF, as we can also see in table 2. Thus the influence of accentuation on duration is restricted to the absolute duration. Relative duration is preserved under normal accentuation. These results are in full agreement with earlier results reported by Nooteboom (1972) and Slootweg (1987).

3.4. Contrastive accents versus normal accents. We did not find any difference in temporal organisation of the syllables between the condition in which a narrow-focus accent is realized on the stressed syllable and the condition in which an integrative accent is realized on the same stressed syllable (table 2, condition BF versus SF).[2] Thus the narrow focus that a listener wants to express on the stressed syllable in the narrow focus condition is not realized by lengthening that syllable relative to the same syllable with an integrative broad-focus accent. Obviously, the temporal structure is identical in both conditions. In answer to our methodological question (ii), we therefore conclude that there is no need to treat contrastive accents different from normal accents.

3.5. Narrow focus on the stressed syllable versus narrow focus on the unstressed syllable. Our crucial research question concerned the status of the hypothesis, viz. that duration structure will not be influenced by any type of accentuation. Based on the results presented in table 2 (condition SF versus UF) we can conclude that this question has to be answered in the negative. Accentuation of the unstressed syllable causes a considerable increase of the duration of that syllable. Also the relative duration structure changes if a contrastive accent is placed on the unstressed syllable. In all cases the relative duration of the stressed syllable decreases by ten percent relative to the stressed syllable in the other focus conditions. We conclude from these results that duration structure changes under the influence of an contrastive accent. However, it would be premature to conclude that metrical structure changes as well, as will be explained below.

Let us now compare the relative duration structure of words with a narrow-focus accent on the stressed syllable and words with a narrow-focus

[2] A detailed F0 analysis of the data revealed that the conditions also had exactly the same location, duration and height of the pitch accent.

accent on the unstressed syllable. We derive different expectations from the different theories described. If it is true that the placement of an accent on the unstressed syllable leads to a shift of the metrical prominence onto that syllable, we expect the following. The relative duration structure of a VC-vv(c) word with a narrow-focus accent on the stressed syllable has the same relative duration structure as a vc-VV(C) word with a narrow focus accent on the unstressed syllable. In both cases an accent is placed on the first syllable making that syllable metrical prominent. If metrical structure is preserved we should at least find a remnant of the original duration structure.

We found the following pattern in our data (the stress position is bold, the accent position is underlined):

VC-VV	**VER**-sie	**62%** 38%	**ver**-SIE	**50%** 50%
	PIG-**mee**	61% **39%**	pig-**MEE**	50% **50%**
VC-VVC	**POT**-lood	**60%** 40%	**pot**-LOOD	**50%** 50%
	POR-**tiek**	52% **48%**	por-**TIEK**	39% **61%**

These results for the VC-VV words clearly suggest that metrical structure adapts to the location of the accent and that it is no longer dependent on the lexical stress location.

However, the results of the vc-VVC and the VC-vvc words give a different picture. These results suggest that stressed syllables preserve some of their original duration. The unaccented, stressed syllable *pot* becomes 50% instead of 39%; *por* becomes 48% instead of 40%.

Martens (1992) gives additional evidence to support the view that some of the extra duration of a stressed syllable is preserved when its unstressed neighbour is accented. He was able to compare segmentally identical syllables in the following conditions [+stress, -accent], [+stress, +accent], [-stress,-accent], and [-stress, +accent]. His data show that a [+stress, -accent] syllable is 13 to 18 ms longer than a [-stress, -accent] syllable and also that a [+stress, +accent] syllable is 5 to 14 ms longer than a [-stress, +accent] syllable. Thus there is a considerable effect of accent on duration, but there is also a slight residual effect of stress. Undoubtedly, the effect of accentuation is perceptually relevant, while the effect of stress is probably not (this has therefore still to be investigated in further research).

4. General discussion

In this study we examined the contributions to the duration structure of words of lexical stress and contrastive focus as realized by a pitch accent. Neijt (1990) described this relation by assuming two independent levels for durational and tonal prominence. She claimed that durational structure, reflecting

metrical structure is fixed. The consequences of this account were investigated in the present experiment.

From the results we draw the following conclusions. It was shown that the relative duration structure of a word does not undergo a change due to word focus accent on that word. However, absolute duration is influenced by realization of an accent. The unaccented version of a word is four to six percent shorter than the accented version. These results are in agreement with results reported by Nooteboom (1972) and Slootweg (1987). Eefting (1991) also found that accentuation caused a difference in duration of about 25% and that all syllables of the word contributed to the durational changes to the same extent.

Moreover, we saw that there was absolutely no acoustic difference between a narrow-focus accent on the stressed syllable and an integrative word accent on the stressed syllable. A speaker does not place a syllable in narrow focus by changing either its absolute or relative duration. Accent placement does influence the duration but placing the stressed syllable in narrow focus does not have an extra effect on the duration change. Notice that the same effect has been reported for word groups. Placing a word in narrow focus has no consequences for the temporal organisation of the word group relative to the same word group in broad focus with an integrative accent on the same word (Eefting 1991). Thus it seems that focus domains are generally not marked by temporal means.

As for the main research question, we found the following result: the relative duration of the syllables changes in words with a narrow-focus accent on the unstressed syllable. Moving the accent from the stressed to the unstressed syllable leads to a decrease in relative duration of the stressed syllable of about ten percent which is added to the unstressed syllable. From the results we conclude that metrical structure as reflected in relative syllable duration is largely obliterated under different accent conditions.

Selkirks revised theory clearly describes the facts better than Neijt (1991): metrical structure is not preserved; accentuation determines the metrical structure. However, this theory is not able to explain the, admittedly small, residual effect of stress position in VC-VVC words. This residual (and undoubtedly perceptually irrelevant) effect reflects the original underlying metrical structure.

Such vestiges of underlying linguistic structure have also been reported on the segmental level. As a case in point, consider the claimed neutralisation of the underlying voicing contrast in word-final obstruents in German (cf. Port and O'Dell 1985, and references given there). Analysis of German words revealed that the distribution of acoustic parameters for underlying voiced and voiceless stops are significantly different, even after neutralisation of the opposition in word-final position. The generative phonological rule, describing the phenomenon only predicts a word-final voiceless obstruent, which in no

way preserves any of the original [+voice] properties. Subsequent perceptual tests revealed that the acoustical differences between the neutralised voiced and voiceless cognates could be discriminated above chance (59% correct with chance at 50%). As in our case, however, the authors were reluctant to claim communicative importance to this effect.

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Appendix

List of words used:

VC-vv	'versie	'saldo	'pasta
vc-VV	sol'dij	pig'mee	kan'dij
VC-vvc	'bloknoot	'potlood	
vc-VVC	por'tiek	par'kiet	fon'tein