WORD STRESS IN PROSODIC CONTEXT

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SUMMARY*

This contribution deals with the acoustic realisation of 'primary' versus 'secondary' stress in monomorphemic and compound words in Dutch, and with the effect of sentence accent on the acoustic realisation of syllables carrying lexical stress in simplex words. Measurements show a linear phonetic factor interacting with phonological variables to determine the acoustic realisation of lexical stress. Also, the important acoustic correlates of stress turn out to react differently to phonological prominence on higher prosodic levels. The unit under investigation is the syllable with 'main' stress; we believe the syllable to be the domain in which stress is manifested.

INTRODUCTION

Most phonetic work on stress has involved the search for the acoustic manifestations of lexical stress, and the question of the perceptual 'cue value' of each of a number of acoustic parameters which have come to be associated with stress. Stressed syllables differ from unstressed ones in that they show longer duration, specific pitch movements and more intensity. The difference between stressed and unstressed syllables within one word has been studied extensively (see Niemi (1984) for an overview). However, we know of no systematic investigation as to the influence of prosodic levels higher than the word on the realisation of lexical stress.

In phonological theory, the prominence relations on these higher levels have been specified, albeit in non-acoustic terms. Pertinent to the present study are such relations on the word-formation level, the level of the phonological phrase, and sentence level.

Whenever two words are joined to form a compound, one turns out to be stronger, and the other less prominent. The recently developed 'metrical' framework in phonology captures this generalization by always grouping constituents into binary pairs, within which the strong-weak relation is formally defined. Thus, it is impossible to end up with two 'primary' stresses.

Under the shorthand name of 'status', we studied the acoustic difference between identical syllables in the weak parts of compounds or as the stressed syllable of simplex words.

This material was embedded in the higher-level prosodic structure known as the phonological phrase. Within this type of word group, there also exists a strong-weak relation between constituents. In accord with Liberman & Prince (1977)'s Lexical Category Prominence Rule, the second part of Dutch phrases is more prominent than the first. The rule operates without regard to the internal structure of the constituents, so that the weak element in the compound retains its status of being weaker than the first element. In the experiment reported on here, the phonological phrase is the context in which compounds and simplex words appear and within which phonetic conditions were rigidly controlled.

The highest level where prosodic prominence relations occur is that of the sentence. Sentence accent distinguishes strong and weak (more prominent or less so) intonational phrases, on pragmatic and contextual bases. The effect of sentence accent on syllables of either status is the second issue that was studied. Traditionally, sentence accent is primarily associated with specific prominence lending pitch movements, while acoustic features like intensity and syllable duration are affected to a lesser degree. In the context of the present experiment, there were two questions to be answered:

1) What is the difference, in acoustic terms, between a syllable assigned phonological main stress and the same syllable bearing 'secondary' stress in the weaker phonological environment formed by the second part of a compound?

2) How does the presence or absence of sentence accent affect these characteristics?

To answer these questions, acoustic measurements were performed on some 500 syllables, pronounced in controlled phonological and phonetic contexts. Along with providing insights into the acoustic effects of both status and sentence accent, this setting disclosed the influence of a linear phonetic parameter, namely the position of the syllable within the word.

THE EXPERIMENT

Material

Speech material was devised to study the influence of status and accent, and to introduce a third independent variable, the position of the lexical stress within the word. The material was based on fifteen tri-syllabic target words with lexical stress on the first, middle or last syllable, five times each. The phonetic variable of position of the target syllable in the word shall be called 'type n', the numeral indicating first, second or third position. To minimize acoustic differences caused by syllable make-up, we strove for uniformity in the consonant-vowel structures. Accordingly, (almost) all syllables consisted of one consonant and one long vowel. Five vowels occurred, balanced across word position types. The words are listed at the end of this paper.

To form two kinds of word groups in which the target word would be either strong or weak, we embedded that word in an adjective-noun phrase, where the target would be strong, and in a nominal compound, where it was the second element and, thus, weak. So, the syllable could end up in a monomorphemic word ('main stress') or in the weaker part of a compound ('secondary stress'). For example, (the target syllable is the middle syllable of 'kimono'):

(main stress): 'die rode kimono'(that red kimono)
(secondary stress): 'die mode-kimono'(that fashion-kimono)

As the examples show, the phonetic context within the phrases was kept as similar as possible. The number of syllables preceding the stressed one was kept constant, through the introduction of the adjective. The CV-structure of all syllables within the phrase was the same, with identical vocalic segments.

In order to study the effect of the presence or absence of sentence accent, we used two different sentences of which the phonological phrase could be a part. One sentence prompted a reading with sentence accent on the phrase in question. In the other sentence the phrase was relatively unimportant; it was easy to pronounce it without sentence accent. The sentences were:

(accent): 'Vergeet niet die ..... in je toespraak te noemen.'
(Don't forget to mention that ..... in your speech.)
(no accent): 'Ik geef NIKS om die ..... die ze daar aanprijzen.'
(I don't care AT ALL for that ..... they're selling there.)

Both sentences were to be pronounced as one intonational block.

Speakers, instructions and the recording session

Speakers were 8 males, who pronounced the set of sentences presented to them in random order. Each speaker produced 60 utterances: the product of 15 words x 2 status possibilities x 2 sentence accent conditions. After some training, they were all able to produce the accent patterns desired. This does not mean they delivered exact replicas of an example: performance was checked on the basis of perceptual equivalence. Recordings were made in a soundproofed studio with semi-professional equipment, the sessions led by the experimenter.

Measurements and computed values

Acoustic measurements were performed on the syllables with lexical stress with and without accent, both in compounds and phrases. 1) For each syllable, a number of values to capture pitch, duration and intensity features were obtained. From these, three new variables were computed, taking into account speakers' speech rate, and melodic and dynamic speech characteristics.

-The new duration variable expressed syllable duration as a proportion of the sum of the four unreduced syllabes in the compound or comparable phrase.

-Syllable intensity was expressed in dB above the intensity baseline. This was defined as the lowest mean value observed on unstressed syllables, for each speaker and condition separately.

-To arrive at a new pitch variable, the aim was to express pitch changes rather than absolute values. These changes were then to be related to speakers' melodic ranges. Pitch range was defined as the difference between highest pitch observed on stressed accented syllables and lowest pitch as found on unstressed syllables in a condition without accent, both mean values for each speaker and condition separately. The pitch change was chosen as the largest pitch movement occurring on a given syllable, and expressed as a percentage of the pitch range. 2) While using the variable names of 'pitch', 'duration' and 'intensity', reference is made to the variables defined as above.

Mean values were computed for these new variables, to gain an overview of the acoustic differences in each linguistic condition. Analyses of variance served to determine which of the independent linguistic variables (status, accent and the linear phonetic factor described above) most influenced the dependent acoustic variables.

RESULTS

The results for the three variables are presented separately. An overview of the results of the analyses of variance is in the Summary Table of Effects, given in the final section.

Intensity

As Figure 1 shows, there is an effect of word type on the values of the intensity variable. They range from means of 7.7 to 7.5 to 4.7 dB above the baseline for types 1 to 3: $F(2,384)=3.08, p<.001$. It is clear that the final position in the word leads to low intensities. This tallies with suggestions made in Pierrehumbert (1979), where the phenomenon of amplitude downdrift in sentences is described.

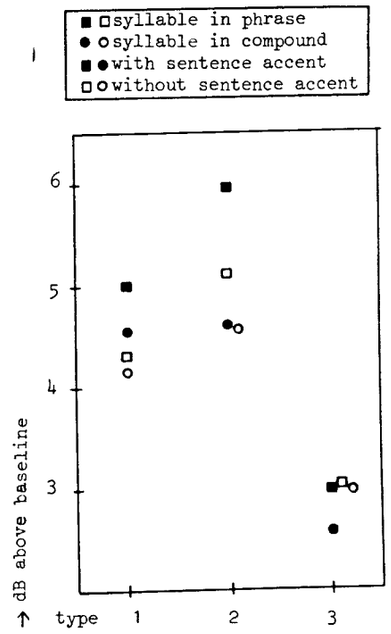

Figure 1: Mean intensity, expressed as distance from speaker's intensity baseline, of stressed syllables in various positions, in compounds and phrases, with and without sentence accent.

The status of the stressed syllable also produces a clear difference in intensities: means of 7.1 dB for syllables with primary stress, against 6.2 dB for syllables with 'secondary' stress in compounds. This difference, too, was statistically significant: $F(1,384)=17.77, p<.001$.
The presence of sentence accent resulted in higher intensities. The mean values are 7.5 dB for accented and 5.8 dB for unaccented items. Again, this difference was significant: $F(1,384)=72.50, p<.001$.
There were no interactions at the significance level employed in this study.

Proportional syllable duration

The results for the duration parameter are presented in Figure 2.
The most striking effect on the durational parameter can be seen on the horizontal axis. As the stressed syllable is situated further back in the target word, its proportional duration increases from 25% via 29% to 30%. This fully agrees with the observations in Nooteboom (1972), where vowel duration is a function of the number of syllables to follow in the word. The results show that the same holds for proportional duration of non-identical syllables: $F(2,384)=63.73, p<.001$.
The factor status also causes a significant effect: $F(1,384)=24.91, p<.001$. If the stressed syllable forms part of a simplex strong element in the phrase, its duration is longer than if it is in the weak part of a compound: 29% and 27%, respectively.
Remarkably, the presence or absence of sentence accent had no influence on the proportional duration. In the analysis of variance the effect of accent was not significant.
There were no significant interactions between the independent variables. This means that the actual increase of the proportional duration across word types is independent of the status of the word. The two factors of type and status operate separately.

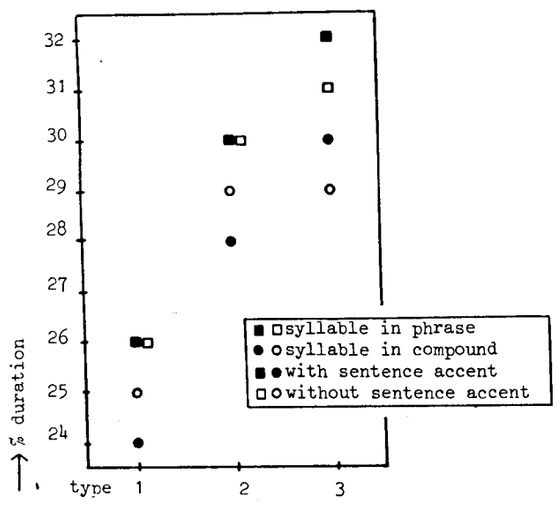

Figure 2: Mean proportional syllable duration of stressed syllables in various positions, in compounds and phrases, with and without sentence accents.

Pitch movements

The mean values for the proportional pitch movements are presented below. Figure 3 shows that word type has an effect on the size of the pitch movements. Disregarding the direction of the movements, (and the important effects of status and accent) they take up 23%, 15% and 8% of the speaker's pitch range for types 1, 2, 3, respectively. This effect was found to be significant $F(2,384)=12.78, p<.001$. 4)
A strong effect was caused by the factor status: if the word was itself the head of the phrase, the mean pitch movement on the stressed syllable was 16% of the pitch range, while it was only 8% on the syllables in the second elements of compounds. Also, in the latter case, the direction of the change was falling rather than rising, as in the former. The analysis of variance yielded a significant effect: $F(1,384)=90.05, p<.001$.
Accentuation within the sentence causes clear pitch movements, both rising and falling, with an overall mean of 11% of the pitch range. Syllables in unaccented words showed falling pitch through 3% (mean) of the pitch range. The effect of accent was, of course, significant: $F(1,384)=28.04, p<.001$.
First order interactions play a part in the variance of this variable. The values for status depend on the word type, as figure 3 shows: from type 1 to 3, the difference between 'secondary' and 'primary' stressed elements diminishes. This is a significant effect: $F(2,384)=10.19, p<.001$.
Also, status and accent cooperate to produce significant differences: $F(3.384)=84.52, p<.0001$. The effect of accent on pitch changes is much more marked on syllables in simplex words, than on the 'secondary' stresses.
The second order interaction of type and status and accent yielded significant results as well: $F(8,384)=11.61, p<.001$.)

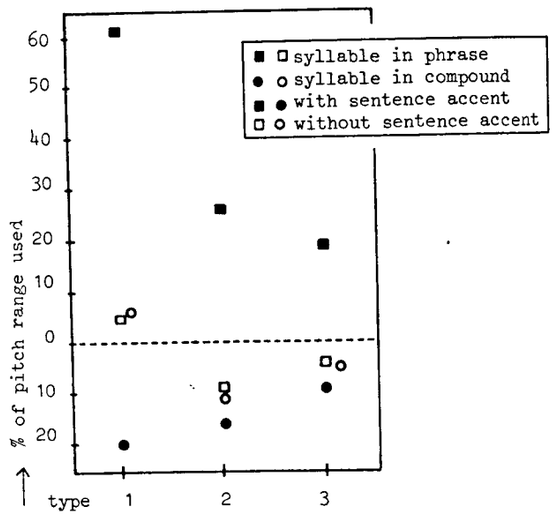

Figure 3: Mean pitch movement, expressed as a proportion of the speaker's pitch range, for stressed syllables in various positions, in compounds and phrases, with and without sentence accent.

DISCUSSION

Table 1 below gives the results of the analyses of variance, with a significance level of $p<.001$. 4)
Position of the target syllable within the word had a significant effect on all three variables studied. As the figures showed, this effect was not the same for the three variables; duration increased towards the end of the word, pitch movements got smaller, while intensity was negatively affected by the final position in the word. The status of the syllable had an effect as well. If a syllable was embedded in a compound, as the least prominent element, its intensity was lower, its duration is (generally) shorter and its pitch movements were smaller than in a simplex word. As to sentence accent, notice how this increased syllable pitch and intensity, but not duration. Higher order interactions occured with the pitch variable only.
Of the three variables studied, duration is the most 'straightforward'. Only type and status play a role in the values obtained. Intensity is also affected by sentence accent. The pitch movements constitute the most complex variable; not only are status, accent and the linear phonetic factor important as such, interactions of these variables further determine the behavior of the pitch variable.

effect	p	d	i
type	*	*	*
status	*	*	*
accent	*	ns	*
type x status	*	ns	ns
statusxaccent	*	ns	ns
typexaccent	ns	ns	ns
typexstatusxaccent	*	ns	ns

Table 1: Summary of the analyses of variance performed on the P(itch), D(uration) and I(ntensity) data.

The results of the present study show unequivocally that what is loosely referred to as (relative) prominence in prosodic literature, can be specified in a precise and insightful fashion when dealing with production aspects of prosodic structures. The cover-all term prominence can be split up into a number of separate acoustic correlates of stress and accent, each of which reacts differently to another phonetic parameter, namely that of position in the word.
The strategy to tackle this wealth of subtleties produced in speech would be to find out which of the observed regularities are also perceptually relevant, and to what extent. Currently, we are investigating the interaction of syllable position and size of preferred pitch movements, in a pitch adjustment experiment with naive listeners. It is only on the basis of results in the perceptual realm that we can realistically assess what is essential in higher level prosodics.

NOTES

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1) Measurements were performed by means of a speech editing system and the ILS speech analysis system.
2) No claim is made as to the perceptual relevance of this variable's definition. It could be argued that conferring Hz to semitone values would be a way to arrive at a direct coupling of measured acoustic differences and perceived stress differences. In this paper, we leave the matter undecided.
3) We have compared the behavior of the pitch movement variable to that of the absolute pitch reached in he syllable. Effects of type, status and accent were present, with this difference: from types 1 to 3, the pitch peak was somewhat lowered, while the pitch movement diminished considerably. Examination of the measurements revealed no inconsistency: in final positions, the pitch peak was reached via earlier steps on preceding syllables, so that the final step was indeed the smallest.
4)In spite of our efforts to rule out speaker-related variation in the variables computed, the factor of 'speaker' still caused significant effects on duration and intensity. Also, two-factor interactions of 'speaker' and other independent variables occurred in the values of both pitch variables.

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LIST OF WORDS USED

Stress on first syllable: bariton, risico, dominee, genius, junior.
Stress on second syllable: dynamo, familie, kimono, komedie, illusie.
Stress on third syllable: chocola, melodie, mirabeau, defilé, residu.