Establishing Prosodic Structure by Measuring Segment Duration

Elise Hofhuis
Department of Language and Speech
Nijmegen University
Erasmusplein 1, 6525 HT Nijmegen, The Netherlands

ABSTRACT

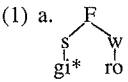
In this paper we describe two experiments which show how knowledge about segment durations can de used to decide between prosodic theories. One experiment shows us that unstressed word-final heavy syllables do not form separate feet. A second experiment demonstrates that word initial monosyllabic feet are not feet postlexically.

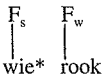
INTRODUCTION

Prosodic structure is generally motivated on the basis of its relevance to segmental phonological rules. However, it is also reflected in the durational structure of speech. For example, Gussenhoven and Rietveld (1992) found that English listeners expect the duration of preboundary syllables to increase with the rank of the prosodic boundary they precede. Many other experiments report preboundary lengthening in speech production, such as Lindblom & Rapp (1973), Klatt (1975) and Lehiste (1979). Although these experiments are concerned with morpho-syntactic boundaries, the observed lengthening can be interpreted as a reflection of prosodic structure, since higher prosodic boundaries by and large coincide with important morpho-syntactic boundaries. In this paper we will present two experiments that illustrate how knowledge about segment durations can be used to decide between theories of foot structure.

EXPERIMENT 1

Dutch treats open (VV) syllables as light and closed VC, VVC- and VCC-syllables as heavy. The Dutch stress system is left dominant, quantity sensitive and right-to-left. Heavy penultimate ,syllables attract the main stress without exception (e.g. Aláska, *álaska), while open penultimate syllables can be skipped (e.g. dóminee). As a result of this fact, final syllables without main stress are included in a binary foot with the penultimate main-stressed syllable when they are open, but closed syllables are assumed to form feet by themselves (see van der Hulst (1984), Kager (1989) and Trommelen & Zonneveld (1989), among others). This distinction is illustrated in (1a,b):

(1) a. 

b. 

For the proposals in (1) there has been no independent evidence. In fact, there are no obvious prominence distinctions between the final syllables of (1a) and (1b). Moreover, Gussenhoven's (1993) investigation of the chanted call in Dutch and several segmental foot domain rules suggests that monosyllabic feet only occur word finally in Dutch. This means that both words in (1) should be analysed as having structure (1a). It was the aim of experiment 1 to find out wether we could find phonetic evidence for the foot structure of words like (1b) as compared to (1a).

Method

It is a well documented fact that the length of stressed syllables is inversely related to the number of unstressed syllables within the foot. This was described by Nooteboom (1972) for Dutch. Thus, we assume that the stressed syllable of a monosyllabic foot is generally longer than the same syllable in a polysyllabic foot. If we generalize this assumption, we can establish the foot structure of words like (1a) and (1b) by measuring the segment durations of their first syllables. If the first syllables of words like (1b) were to have longer durations than those of words like (1a), it would be reasonable to assume that the first syllable of (1b)-type words does constitute a separate foot. However, if their first syllables are shown to be equal in duration, we must accept that both types of words should be analysed as in (1a), as Gussenhoven suggests.

Three minimal pairs of bisyllabic s/w words were selected. One had an open first syllable (2a), one a closed first syllable (2b) and one had a final syllable closed by an ambisyllabic consonant (2c). The words in each pair differed only in the weight of their second syllables. For comparative reasons we also included versions of the pairs with second syllables containing schwa.

Table 1. *Material for experiment 1.*

	2nd Light	2nd Heavy	2nd schwa
a.	Syra (si:ra)	sieraad (si:ra:t)	sieren (si:r@)
b.	basta (bɑsta)	bastaard (bɑsta:rt)	basten (bɑst@)
c.	mamma (mɑma)	mammoet (mɑmu:t)	mammen (mɑm@)

The words were embedded in a carrier sentence in postfocal position. They were spoken ten times by two male speakers of Dutch, 22 and 23 years old, who were paid a small fee for their services. The words were recorded in two sessions in a sound proof studio. Segments were measured by hand using the SESAM segmenting program of the Department of Language and Speech of Nijmegen University.

Results

We performed separate ANOVA's on the first syllable durations of the words in table 1(a), (b) and (c). The syllable durations are listed in table 2 below. Factors were speaker (2) and nature of the second syllable (light, heavy or schwa).

The nature of the second syllable had a significant effect on the duration of the first syllable for the (a) words, but only before schwa, before which it was longer (see table 2), not in the other two conditions ($F(2,53)=5.05$, $p=.010$). The lengthening effect schwa can have on preceding stressed vowels was also found by Nooteboom (1972). There was no speaker effect.

For the words in table 1(b) we found no significant difference in duration of the first syllables in any condition ($F(2,52)=1.43$, $p=.248$). No speaker effect was found.

The first syllables of the (c) words in were not significantly different in any of the three conditions ($F(2,54)=1.068$, $p=.351$). There was a significant speaker effect: the syllables of one speaker were on average 10 ms longer ($F(1,54)=7.31$, $p=.009$). However, there was no interaction involving the speakers.

Table 2. *Results of experiment 1: first syllable durations in ms.*

	2nd light	2nd heavy	2nd schwa
1st syll. open	261	260	274
1st syll. closed	269	271	277
1st syll. ambi.	226	231	226

EXPERIMENT 2

Another implication of Gussenhoven's (1993) findings concerns words with w/s stress patterns. They are usually analysed as consisting of a stressless monosyllabic foot followed by a foot bearing main stress. If monosyllabic feet cannot occur word initially this analysis cannot be maintained. Gussenhoven suggests that these word initial feet should be analysed as appendices to the word, and do not receive foot structure. The phonological data seem to corroborate this analysis. One way of finding additional phonetic evidence for the analysis is to look at the neutralisation of vowel duration in the appendix. It is a distributional fact of Dutch that the opposition between long and short vowels is only maintained in foot-initial and word-final position, which suggests that no VV-V opposition exists outside these contexts. Therefore, a lack of durational opposition between tense and lax vowels in word-initial position may be interpreted as indicating the absence of foot structure. The experiment was designed to find out whether this neutralization is an acoustically relevant process.

Method and results

The only minimal pair we could find for this experiment was the pair *anale* (ana:l@) 'anal', with a long first vowel, versus *annalen* (ɑna:l@) 'annals', with a short vowel and ambisyllabic consonant. The two words were embedded in the same carrier sentence as the one in experiment 1, and spoken 10 times by the same speakers.

We carried out separate ANOVA's on the vowel and on the following /n/. Factors were speaker (2) and vowel type (long or short). We found no significant difference in duration between the long and short vowels ($F(1,36)=.051$, $p=.823$). There was no significant difference between the speakers either. In the second analysis the /n/ was found to have nearly equal durations in both words (2 ms difference) but one speaker's /n/'s were significantly longer ($F(1,36)=55$, $p<.001$). We also found some interaction between the two factors ($F(1,36)=5.83$, $p=.021$) due to the fact that for one speaker the /n/ was longer after the "long" vowel (7 ms) while it was longer after the short vowel (3 ms) for the other speaker. This was not a substantial difference, however. The segment durations are listed in Table 3 below.

Table 3. *Results of experiment 2: durations in ms.*

	duration of vowel	duration of /n/
'anale'	73 ms	68 ms
'annalen'	72 ms	66 ms

CONCLUSION

The results of experiment 1 clearly show that the weight of an unstressed syllable does not influence the duration of a preceding main-stressed syllable. Thus, we must conclude that the words in table 1 have the same binary foot structure. As was mentioned above, the foot-domain rules that are described in Gussenhoven (1993) independently motivate this analysis.

Experiment 2 demonstrates the total neutralisation of durational differences between long and short vowels in word-initial unstressed syllables. We think this can be explained by the absence of foot structure above these syllables, and that these syllables should be analysed as appendices to the foot. We assume that this can cause VV-syllables to drop a V-slot. This analysis was argued for independently by Gussenhoven (1993) on the basis of observations about the chanted call in Dutch, and segmental phonological rules.

Both experiments indicate that it is possible to corroborate phonological theories using phonetic evidence. It is our intention to explore this possibility further in future experiments.

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REFERENCES

C. Gussenhoven and A. Rietveld (1992), "Intonation contours, prosodic structure and preboundary lengthening", *Journal of Phonetics,* Vol. 20, pp. 283-303.

C. Gussenhoven (1993), "The Dutch foot and the chanted call", to appear in *Journal of Phonetics.*

H. van der Hulst (1984), *Syllable structure and stress in Dutch* (Foris, Dordrecht).

R. Kager (1989), *A metrical theory of stress and destressing in English and Dutch* (Foris, Dordrecht).

D. Klatt (1975), "Vowel lengthening is syntactically determined in connected discourse", *Journal of Phonetics,* Vol. 3, pp. 161-172.

I. Lehiste (1972), "The timing of utterances and linguistic boundaries", *Journal of the Acoustic Society of America,* Vol. 51, pp. 2018-2024.

B. Lindblom and K. Rapp (1973), "Some temporal regularities of spoken Swedish", *Papers from the Institute of Linguistics,* Vol. 21 (University of Stockholm).

S. G. Nooteboom (1972), *Production and perception of vowel duration* (University of Utrecht, Utrecht).

M. Trommelen and W. Zonneveld (1989), *Klemtoon en metrische fonologie* (Coutinho, Muiden).