

# THE DOMAIN OF FINAL LENGTHENING IN PRODUCTION AND PERCEPTION IN DUTCH

*Tina Cambier-Langeveld\*, Marina Nespor\* & Vincent J. van Heuven\*\**

*\*University of Amsterdam, Dept. Italian*

*\*\*Leiden University, Dept. Linguistics/Phonetics Laboratory  
and*

*Holland Institute of Generative Linguistics, The Netherlands*

*e-mail: g.m.langeveld@let.uva.nl*

## ABSTRACT

Two production experiments investigating possible factors influencing the domain of final lengthening are described. Results indicate that final lengthening is generally confined to the final syllable, except when its rhyme contains only a schwa, in which case the penultimate rhyme is lengthened as well. Apparently, only the weight of the final syllable influences the size of the domain which is lengthened.

Next, a perceptual acceptability experiment was run. Results indicate that while listeners are sensitive to differences in the amount of final lengthening, they are not very sensitive to the way this is distributed over the preboundary segments. Apparently, the specific distribution of final lengthening in production has no communicative function, but is the result of the human speech mechanism, together with restrictions on the expandability of segments.

## 1. INTRODUCTION

Speakers have numerous ways at their disposal to mark the prosodic structure of their speech. The cues signalling this structure are potentially useful to the listener. Lengthening of preboundary segments, generally referred to as final lengthening, is one way of signalling prosodic boundaries in the typically continuous flow of speech.

A final lengthening effect at utterance boundaries has been firmly established ([1]). Other prosodic boundaries are marked by lengthening of the pre-boundary segments as well ([2]). There is a positive correlation between the depth of the boundary and the amount of lengthening produced by the speaker, as shown in [3]. This American-English data-base study also seems to indicate that in speech production final lengthening is confined to the rhyme of the final syllable. However, this study does not consider all possible domains, but only four: the final coda consonants, the final vowel, any segments between the last stressed vowel and the final vowel, and the last stressed vowel. Furthermore, data-base studies may overlook factors which influence the effect under observation, such as word structure, (final) syllable weight, word stress etc. The controlled material in the present research

will allow us to answer the following question:

- (1) Do boundary depth, stress and/or the structure of the final syllable/word have an effect on the domain of final lengthening?

The results of a recent production experiment on Dutch ([4]) indicate that the structure of the final syllable indeed influences the size of the lengthened unit. Not only the final syllable, but also the penultimate syllable of schwa-final words showed an effect of boundary depth on segment duration. However, since [4] considers only schwa-final disyllabic words, it is impossible to differentiate between foot structure and vowel quality as the relevant factor determining the domain of final lengthening. Furthermore, the lengthening of both syllables in these disyllabic words can also be interpreted as a lengthening of the whole word, or of the unit starting with the last stressed syllable.

In order to answer the question in (1), two production experiments were run. A pilot study contained only one target word; a second experiment involved five more words with segmentally varying final syllables and different stress patterns, so that the effect of stress and the structure of the final syllable may be investigated.

Final lengthening is not only found in production, but is important for the perception of boundaries as well. Listeners require longer preboundary durations at deeper prosodic boundaries ([5]). For Dutch, the depth of a following boundary has been shown to shift the internal criterion for phonemic vowel length identification from 76 ms for shallow boundaries to 100 ms for deep boundaries ([6]). Again, only a relation between boundary strength and the *amount* of required final lengthening was established. As far as we know, the required length of the final rhyme is correlated to boundary depth. This leaves other questions unanswered, such as:

- (2) Are listeners sensitive to differences in the distribution of a certain amount of final lengthening over the domain-final segments?

At the end of this paper, a pilot perception study will be described which gives some indication as to the sensitivity of listeners to different distributions of final lengthening.

## 2. THE PRODUCTION EXPERIMENTS

To answer the research question in (1), sentences were constructed which differ only minimally, except for the type of boundary following the target word. To ensure constant intonation (F0) patterns across speakers, subjects repeated resynthesized utterances with constant intonation contours (for details, see [7]). For this input speech, diphone synthesis was used from which all temporal markers had been eliminated, so that any temporal boundary markers in the subjects' reproduction must have been 'implemented' by the speakers themselves, thus reflecting natural lengthening effects in speech. All utterances were preceded by a precursor question, which put focus on the target word. The material was presented to the subjects both auditorily and visually (i.e. printed on paper).

### 2.1. Method

The material of the pilot study and the main experiment together consisted of six Dutch words occurring in four contexts: before a Prosodic Word (PW), a Phonological Phrase (PhP), an Intonational Phrase (IP) or an Utterance (U) boundary ([8]). The words are *rodoDENdron* ('rhododendron'; pilot study), *MARathon* (id.), *harMONika* ('concertina'), *YUcca* (id), *TANdem* (id.) and *MOde* ('fashion'), with capitals indicating main word stress. These words differ in word length (2 to 4 syllables), in stress pattern and in the structure of the final syllable: this syllable may or may not have a coda consonant and the vowel quality of the final nucleus may be full or reduced (i.e. a schwa, spelled as [e]).

The four sentences for each word are equally long and differ only minimally to allow for the different boundary depths to follow the target word. An example is given in (3):

(3) *yucca* sentences

*PW boundary*

Piet wil die rare yuccaplanten, gek als hij is.

'Piet wants those strange yucca plants, crazy as he is'

*PhP boundary*

Piet wil die rare yucca planten, gek als hij is.

'Piet wants to plant that strange yucca, crazy as he is'

*IP boundary*

Piet wil die rare yucca, plantengek als hij is.

'Piet wants that strange yucca, plant crazy as he is'

*U boundary*

Plantengek als hij is, wil Piet die rare yucca.

'Plant crazy as he is, wants Piet that strange yucca'

Three male and two female speakers participated in the pilot study. Three of these are phonetically trained. In the main experiment, three male and three female subjects participated. Four of these are phonetically trained. Two of the subjects took part in both experiments. All speakers (ages 34 to 55) were native speakers of standard Dutch, as judged by a two-member panel of native Dutch phone-

ticians.

Each sentence was repeated three times by every speaker in the pilot study and two times in the main experiment. The subjects' speech was recorded directly onto computer disk and analysed with GIPOS, a high resolution waveform editor.

### 2.2. Results

Oneway ANOVA's were run for each target word with segment duration as the dependent variable, boundary depth as a fixed factor and with repeated measurements over subjects and repetitions. Separate statistical analyses were done for the pilot study (*rododendron*). In Figure 1, the segment durations for the word *rododendron* are shown for each boundary depth.

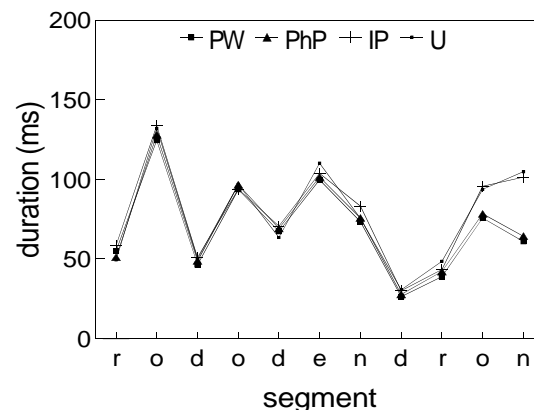


Figure 1. Segment durations for each boundary depth, for the target word 'rododendron'.

Not all boundaries in our material are lengthened with respect to the next shallower boundary. Only the IP boundary is clearly and consistently lengthened with respect to the PhP boundary. Two homogeneous subsets are formed (Newman-Keuls procedure with  $\alpha=5\%$ ): PW and PhP do not differ from each other, nor does IP differ from U. The same was found for the words in the main experiment.

The effect of boundary depth on segment duration in the word *rododendron* is only significant in the final rhyme ( $F[3,56]=4.7$ ,  $p=.006$  for the nucleus;  $F[3,56]=28.7$ ,  $p<<.001$  for the coda consonant). There is no effect in the onset, nor in any of the other preceding segments.

Also in the five words of the main experiment, there is a significant effect of boundary type on the duration of the final rhyme ( $F[3,236]=15.6$ ,  $p<<.001$  for the vowel;  $F[3,92]=21.2$ ,  $p<<.001$  for the coda consonant). The effect of boundary depth on the duration of the final onset only reaches significance in some cases (in *marathon*, *tandem* and *yucca*). In general, the effect is strongly progressive: it is weak in the final onset and becomes stronger towards the end of the syllable.

In Figure 2, the lengthening of the penultimate and of the final syllable are shown for each target word, with the duration at the shallowest boundary (PW) taken as 'zero

duration'. When the final vowel is full (in *marathon*, *harmonika* and *yucca*), there is no lengthening effect before the final syllable. However, in the word *mode*, a large effect (of 30 ms) is found in the penultimate nucleus ( $F[3,44]=9.6$ ,  $p<.001$ ). Moreover, the penultimate nucleus of the word *tandem* is not significantly lengthened at the .05 level ( $F[3,44]=2.5$ ,  $p=.073$ ), but does show a tendency to lengthen (+15 ms), which is not found in the words having a final full vowel.

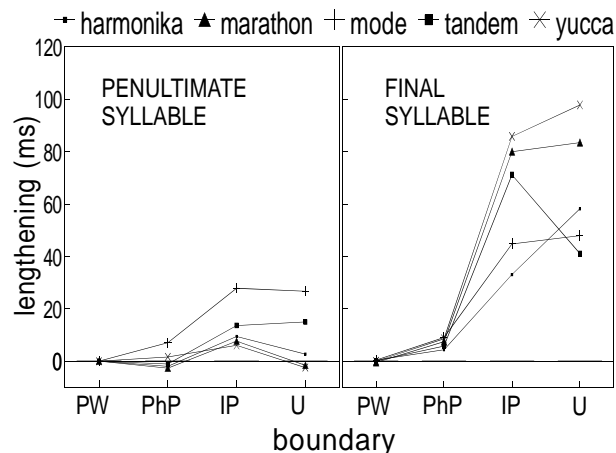


Figure 2. Lengthening of the final two syllables of the five target words in the main production experiment.

### 2.3 Discussion

In general, the final lengthening effect is confined to the final syllable. The rhyme is always lengthened, while the onset is not systematically affected. There is one exception to this generalization, which is the lengthening in the penultimate syllable of the word *mode*. Apparently, when the rhyme of the final syllable contains only a schwa (i.e. a final ultra-light syllable), final lengthening begins in the penultimate syllable. This effect can also be found, but does not reach significance, in words ending with a schwa plus a coda consonant, i.e., in the next lightest type of rhyme. The domain of final lengthening cannot be the final foot, since *yucca* is also one disyllabic foot, but does not show any lengthening in the penultimate syllable.

The effect of syllable weight on the domain of final lengthening may be explained by the fact that in general, light syllables are phonetically shorter than heavy syllables. A final schwa, being shorter than a final long vowel, may not be stretched to the degree that is required by the boundary depth. Thus, segments preceding a short final segment will have to participate in the final lengthening, resulting in a larger lengthened domain. The domain of final lengthening is then determined by phonetic considerations such as inherent duration of segments and their expandability ([9]).

## 3. PERCEPTION - THE PILOT STUDY

To find out whether listeners are sensitive to the distribution of final lengthening over the final segments, an acceptability experiment was run. The segment durations found in production were taken as a starting point. To reduce the amount of material, only the sentences uttered by the best speaker were used (i.e. the speaker who obtained the best results in a separate identification experiment). Only the PhP and IP boundaries are included, since an IP boundary is most clearly marked by final lengthening and the PhP boundary counts as the baseline condition. The PhP rather than the PW sentences were used because the PhP sentences structurally resemble the IP sentences more closely.

### 3.1. Method

For each word, an IP sentence and a PhP sentence were used. As a starting point, the mean segment duration was calculated from the segment durations in the two utterances. This gives the first temporal word structure presented both in the PhP and in the IP sentence.

Portions of 50 ms and 100 ms were added to the mean duration in the IP sentence, and subtracted from the mean duration in the PhP sentence. These increments were spread over either the final rhyme (domain i), the final syllable (domain ii), or the penultimate rhyme plus the final syllable (domain iii). To give an impression of the resulting segment durations, the durational structures for the word *yucca* are shown in Figure 3.

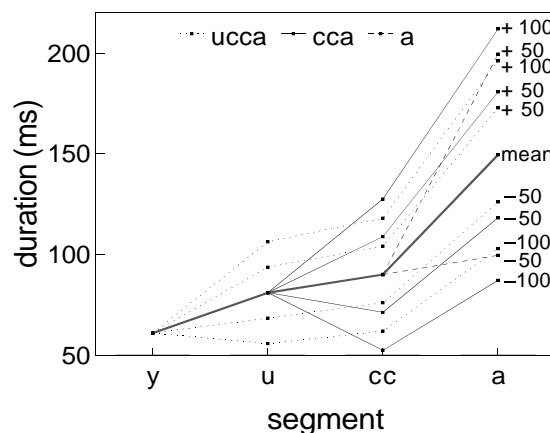


Figure 3. Durational structures for the word 'yucca' in the acceptability experiment.

Segment lengthening or shortening within any domain was proportional to its neutral (mean) duration. A short segment is thus lengthened by fewer milliseconds than a long segment.

28 native Dutch listeners, aged 18 to 67, participated in the experiment. They had no known hearing impairments.

All utterances were presented twice over high-quality headphones. Each utterance was given on paper, with the

target word underlined. Subjects were instructed to pay close attention to the durational build-up of the target word, as well as to its position in the sentence. They then had to indicate the acceptability of this durational structure on a scale from 1 (unacceptable) to 10 (perfect).

### 3.2. Results

An ANOVA was run with boundary type, total word duration and domain as fixed factors, with repeated measurements over subjects, words and repetitions and with acceptability as the dependent variable. In general, only the total word length has an effect on the acceptability ( $F[2,3525]=7.2$ ;  $p=.001$ ). Separate ANOVA's for each individual word show that only the boundary involved and the word length affect acceptability, while the domain never does; these results are the same for each target word. In Figure 4, the mean responses for each durational structure is given at a PhP boundary (left) and at an IP boundary (right). On the x-axis, the total word durations are given (mean,  $\pm 50$  ms,  $\pm 100$  ms), while the three bars give the results for the three domains over which the 50 or 100 ms are spread (domain i = final rhyme, domain ii = final syllable, domain iii = penultimate rhyme plus the final syllable).

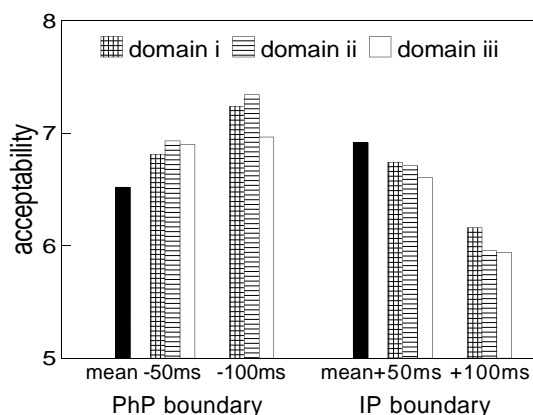


Figure 4. Mean acceptability of each durational structure for all words taken together.

As can be concluded from Figure 4, the mean durations were actually fairly long, thus giving a high score when implemented at an IP boundary, and lower scores when placed at a PhP boundary. In fact, any further lengthening at an IP boundary sounds worse than the mean duration, while shortening at a PhP boundary increases acceptability. Still, it is clear that only the total word length affects acceptability, but not the way this duration is built up; in fact, the difference between any of the three domains is generally as little as 0.2 on a 10-point scale.

## 4. CONCLUSION

The production experiments revealed that the effect of final lengthening is generally restricted to the final syllable, except when the final rhyme contains only a schwa, in which case some of the lengthening spills over to the preceding vowel. Furthermore, the effect is strongly progressive, getting smaller as the distance from the prosodic break gets larger. However, the exact domain over which final lengthening is distributed does not seem to influence the acceptability of the durational build-up of a word. We conclude that only the amount of final lengthening is perceptually important, whereas the distribution of the increment is not. The distribution of final lengthening thus has no communicative function. The progressive nature of final lengthening is rather due to the fact that the speaker is approaching a break, slowing down more towards the end of the phrase in a way analogous to coming to a stop after any mechanical movement. Furthermore, the number of affected segments seems to depend solely on the expandability of the final segments, thus only exceeding the final syllable when this syllable has an ultra-light rhyme.

## 5. REFERENCES

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