

Stress and segment duration in Dutch

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1. Introduction

Wim Zonneveld and his associates have spent a major part of their early career on the word-prosodic systems of English and Dutch, where the intricacies of word stress and the differences between the Dutch and the English way of assigning stress were at the forefront of their research effort. Neijt and Zonneveld (1982) published the first analysis of the Dutch stress system in the metrical framework, to be followed later by Kager and Zonneveld (1986), Trommelen and Zonneveld (1989) and – explicitly targeting the similarities and differences between Dutch and English – Kager (1989).¹ For this reason I decided to write my contribution to Wim's festschrift on the topic of stress.

I should point out, however, that this contribution is not so much about the phonology of stress per se; that is, I will not be concerned with the question which syllable is the prosodic head at the word level. Instead, I will focus on the rather more phonetic question how the stressed position is cued by acoustic properties. Research on the acoustical correlates of stress started in the 1950s with the ground-breaking work by

¹ Our shared fascination with stress systems goes back to the publication of Chomsky and Halle's (1968) *The Sound Pattern of English*. The first part of this magnum opus laid out a new theory of stress (a unified view at both the word and sentence level), which was given a prominent position in the following years in the teaching programmes at the Departments of General Linguistics (Henk Schultink's graduate lectures) and of English (Antonie Cohen's graduate research seminar), which both Wim and I attended. Together with fellow graduate students Heleen Kost and Wout Zinkstok, Wim wrote a large and extremely time-consuming research paper on the (reliability of) intuitions of Dutch native speakers on stress and stress levels of syllables in words of various lengths. The subtitle of this paper was 'What we did on our holidays' – which betrays that Wim was never a nine-to-five worker. The research paper was named after the then popular album by folk rock band Fairport Convention. As a bit of human interest, Wim and I went to see the band together in the summer of 1972 at the Lochem open air pop festival. Those were the days...

Fry (1955, 1958, 1965). Other experimental phoneticians followed (e.g. Morton & Jassem 1965), working within the same paradigm. The upshot of this type of research was that word stress seemed to be cued by a set of four acoustical parameters, which could be arranged in order of perceptual importance as (i) pitch change falling on the stressed syllable, (ii) lengthening of the stressed syllable, (iii) more intensity on the stressed syllable and (iv) spectral expansion of the stressed vowel.²

It should be pointed out, in this connection, that the placement of the pitch-change cue at the top of the rank order of stress cues in English (and Dutch) is now generally seen as the reflex of confounding word stress and sentence stress (the latter sometimes called ‘accentuation’). Sentence stress (‘accent’) is cued by a prominence-lending pitch change, in both Dutch and English (and many other languages), which always evokes the perception of stress on the syllable that is associated with the pitch change. The effect cannot be counteracted by any combination of stress cues suggesting stress on a different syllable. As a result the pitch change is perceptually the strongest cue for stress, but it should be realised that the cue is absent if a word does not carry sentence stress. Typically, any content word will be produced in context with sentence stress on it, unless the word is out of focus (i.e., does not contribute important information to the discourse) or when it falls under the scope of another, hierarchically superior content word (so-called integrative focus or broad focus – see, for instance, Van Heuven 1994, and references therein). The absence of a pitch change on the stressed syllable of words without sentence stress was shown for Dutch and (American) English by Sluijter and Van Heuven (1995, 1996), respectively.³ Since the pitch cue is uniquely associated with

² Although this rank-ordering of stress cues was proposed as a universal property, it was based exclusively on English data. Fry himself was among the first to acknowledge that his hierarchy should be tested on data obtained from other and more diversified languages. Berinstein (1979) launched what would later be named the functional view on stress cues. Her idea was that segmental structure and (word) prosody draw on the same acoustic resources when it comes to marking phonological contrasts. If a particular cue is used in one part of the phonology, for instance to signal a segmental contrast, it cannot be used effectively to mark contrasts elsewhere in the phonology, such as stress. K’ekchi and Caqchiquel are Mayan languages spoken in Guatemala and both have fixed stress on the final syllable. The difference is that Caqchiquel has a phonemic length contrast in the vowels, which is absent from K’ekchi. According to the functional hypothesis, the duration cue, which should rank second place in the Fry hierarchy of stress cues, and which it does in K’ekchi, drops to a lower rank in Caqchiquel. Similar results were later reported in languages with more complex word-prosodic systems where the stress cues are employed simultaneously to cue stress and lexical tone (Potisuk, Harper and Gandour 1996 for Thai, Remijsen 2002 for Samate Ma’ya – a language spoken in the Indonesian archipelago).

³ This is not to say that there may be no pitch change at all on the stressed syllable of a word without sentence stress, but the magnitude of the pitch change will be so small (typically smaller than 3 semitones) that it does not impart prominence to the target word. In other languages stressed syllables in words with sentence stress may be marked with a reduced, yet clearly noticeable pitch movement, e.g. Egyptian Arabic (Hellmuth 2007).

stress at the sentence level, it is now widely held that the most important and consistent cue for stress is duration.

The question I will specifically address in this paper is whether the durations of all parts of the syllable contribute equally to the cueing of stress or whether some portions of the syllable have a greater influence than others. In the following section I will first review some literature on the role of duration in the production of stress, with emphasis on Dutch. Next, I will try to examine what is known about the perceptual effects of varying the duration of syllables as a whole as opposed to differentially varying the duration of subsyllabic units (such as onset, nucleus and coda) to the perception of syllable length and stress. It will become transparent that no experiments have been reported in the literature on Dutch (or any other stress language) in which the durations of subsyllabic units were systematically varied in synthetic or resynthesised natural speech in order to determine their possibly different contribution to the perception of stress. The experiment that is reported in section 3 will then fill the gap. The findings will be briefly discussed in section 4.

2. Stress and duration in Dutch: Some literature data

For most languages investigated it was found that a stressed syllable is consistently longer than its unstressed counterpart. Moreover, the lengthening of stressed syllables takes place whether the target word carries stress at the sentence level or only at the word level. A word carries a sentence stress if it is the prosodic head of a constituent that is 'in focus', i.e. which the speaker presents as expressing important information to the listener. In Dutch, a word with sentence stress is lengthened in its entirety by some 10 percent (and has a perceptually prominent pitch change associated with its stressed syllable). However, whether or not this additional lengthening of the word takes place, the stressed syllable differs from its unstressed counterparts by the same relative amount (e.g. Nootboom 1972, Sluijter and Van Heuven 1995).

An early study that examined the effect of stress on the durations of subsyllabic units in Dutch can be found in Nootboom (1972, appendices 11-12). Target items were non-words /pɑpɑpɑp/ and /papɑpɑp/, with short/lax /ɑ/ and long/tense /a/, respectively. These items were spoken with stress on the first, second and third syllable in turn, in carrier sentences such that they were either accented (with sentence stress) or unaccented (word stress only). A large number of tokens were produced by each of two male Dutch speakers for each of the 3 (stress positions) × 2 (accentuation) × 2 (vowel length) = 12 non-word types (between 17 and 26 tokens per type by speaker SG; between 12 and 24 by speaker IS). Duration of all plosives /p/ in positions C₁ to C₄ were measured physiologically (rather than acoustically) using electronic switches that were activated by lip contacts, as were the durations of the vowels in V₁, V₂ and V₃. A summary of the results is seen in Figure 1. This figure plots the segment durations, in milliseconds (ms), of C₁, V₁, C₂, V₂, C₃, V₃ and C₄, in this order, along the X-axis, with separate lines for

items with initial, medial and final stress. The four panels are arranged by vowel length (rows) and by accentuation (columns).

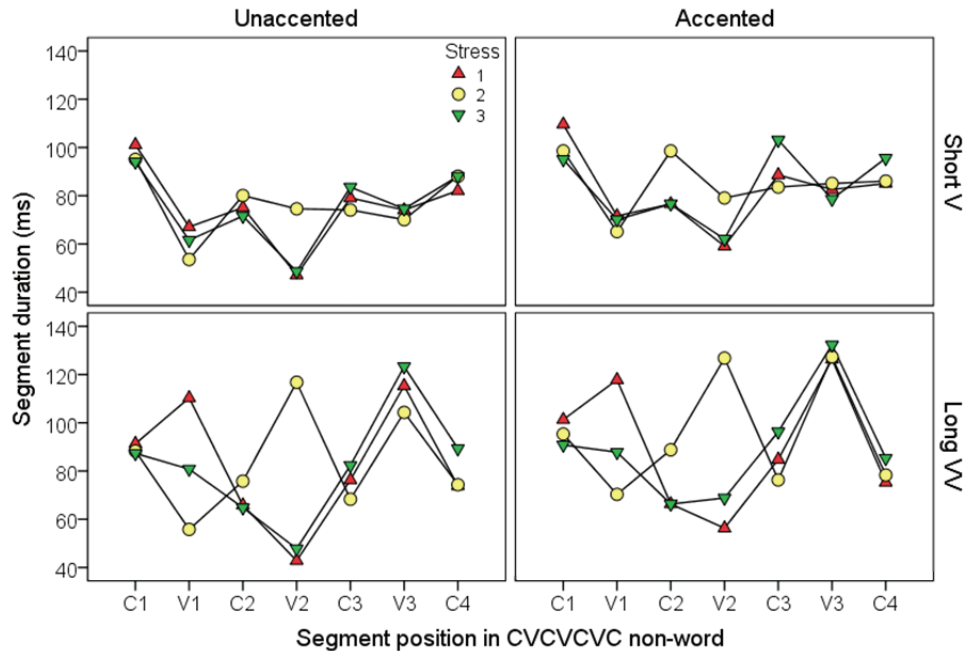


Figure 1. Duration (ms) of seven segments in the sequence /pVpVpVp/ as a function of stress position (initial, medial, final) in accented versus unaccented non-words with short (lax) and long (tense) vowels (data from Nootboom 1972, appendices 11-12).

The effects of stress on the temporal make-up of the non-words are very similar for accented and unaccented items – although durations are consistently longer overall under sentence stress. Hardly any effects of stress can be seen in the final syllable (which is something we will return to later). There are very large differences in the durations of V_1 and V_2 depending on the stress position. When the item is spoken with initial stress, V_1 is very long and V_2 short (ratio $V_1/V_2 > 1$). With medial stress, this pattern reverses completely, with a very short V_1 and a very long V_2 (ratio < 1), while items with final stress have intermediate vowel durations for V_1 and V_2 (ratio ≈ 1). The crucial observation, however, is that the effect of stress position on the durations of the consonant segments is relatively minor – though rather consistent: it is always the case that a C, whether onset or coda, is somewhat longer on average in the stressed version of the syllable than in the unstressed version (i.e. in a paradigmatic comparison).

An experiment on a smaller scale involving both non-words and real words in Dutch shows that the lengthening effect of stress is most clearly and consistently seen in the rhyme portions of the syllables (Sluijter and Van Heuven 1995). The effect of stress on onset consonants is less systematic or absent.

It would appear that onset C, vocalic nucleus and coda C contribute in different ways to the perceived overall duration of a syllable (monosyllabic CVC word). Goedemans and Van Heuven (1993, 1995) found that changing the duration on onset consonants was perceptually underestimated by Dutch listeners by a factor 4 (in an adjustment task), changes in the duration of the coda consonant were reproduced faithfully, whereas changes in the duration of the vocalic nucleus were perceptually overestimated by a factor 2. These findings seem to suggest that Dutch listeners are less sensitive (or practically insensitive) to the duration of onsets, which in turn might explain why the composition of the onset does not play a role in the definition of syllable weight, not only in Dutch but (almost) universally (Goedemans 1998, Goedemans and Van Heuven 1993, 1995; see Gordon 2005 for more discussion).

Given the above findings, then, one would like to know to what extent consonant and vowel segment durations are different cues in the perception of stress. On the one hand, one may expect regularities in speech production to be mirrored in speech perception. In that case, the contribution of consonant duration should be smaller than that of varying vowel duration. On the other hand, perception of stress may well be indifferent to the specific segment whose duration is varied, as long as the change contributes to the overall duration of the syllable. The perception experiment I will now present examines the differential contribution of onset, nucleus and coda segment duration to the perception of stress.⁴

3. Experiment

3.1. Stimuli

The stimulus material was comprised of ten Dutch (quasi) reiterant non-words, as schematised in table 1. Here only the items with a medial C.C sequence are true repetitions of the same syllable; the segment structures of the two syllables that make up the non-word are phonologically identical. This is not the case when the non-word contains a single C. It is generally held that the medial C is the onset of the second syllable if it follows a long (or better: tense) vowel – both in Dutch and in English. However, when the medial C follows a short (or better: lax) vowel, it is often stated that the intervocalic C is shared by both syllables, that is, it is the coda of the first syllable and at the same time the onset of the second syllable. This geminate or ambisyllabic status of the medial C is motivated by the constraint that a syllabic rhyme in Dutch must contain at least two segments (for a summary of positions see Booij 1995: 31-35).

⁴ Section 3 is a reanalysis of the data presented in an (unpublished) MA thesis written under my supervision (Van Biezen 1988, appendices C-D).

Table 1. Construction of stimulus non-words.

	Single medial C			Medial C.C	
	[p]	[f]	[m]	[f.p]	[s.t]
Short vowel [α]	papap	fαfαf	mamam	pafpaf	tastast
Long vowel [a]	papap	fafaf	mamam	pafpaf	tastast

The ten non-words were embedded medially in a fixed carrier sentence *Wil je ... eens zeggen* [vɪljə... əsɛɣə] ‘would you say ...’, preceded and followed by a neutral vowel schwa. These utterances were then synthesized from diphones, using the Elsendoorn and ‘t Hart (1982) diphone set. The synthesis building blocks in this set were excepted from syllables originally spoken in non-words with sentence stress (i.e. with a rise-fall prominence-lending pitch movement) on the target syllable. As a result the syllables in the synthesis were equally suggestive of stress (with the exception of syllables containing schwa). After concatenation of the required diphones, the utterances were synthesized with 10 LPC coefficients (0 to 5 kHz bandwidth) on a monotone (flat pitch with a 100-Hz frequency), with the best possible quality afforded by the system, i.e. without parameter quantisation. Discontinuities across diphone boundaries were avoided by applying parameter smoothing over a 30-ms window.

In the synthesis the duration of each of the phones making up the target word was varied in five steps (50, 75, 100, 125, 150 %), while the remaining phones kept their original duration (= 100 %). In the case of plosives, only the duration of the silent interval was changed; burst durations were kept at 100%. This yielded 21 temporally different versions for CVCVC items, and 25 for the CVCCVC types. The total number of stimuli amounted to 226.

3.2. Listeners

The stimuli were presented to 54 native Dutch listeners (16 female) with ages varying between 19 and 47 years. They were either students or instructors at the Haagse Hogeschool (Hogere Informatica Opleiding, HIO, i.e. Advanced Computer Science Department). All listeners declared to have normal hearing and participated voluntarily and without payment.

3.2. Procedure

The stimuli were presented to the listeners in two quasi-random orders, A and B, such that no target word and no temporal structure occurred more than three times in immediate succession. Order B was the reverse of order A. Subjects listened to the stimuli in groups of maximally six persons over individual headphones in a quiet language laboratory. One half of the listeners responded to stimulus order A, the other half listened to the stimuli in the reversed order B. After practice, stimulus sentences

were played with 2 seconds in between (offset-to-onset), with a short beep after every tenth stimulus (both preceded and followed by a 2-s pause).

Listeners received standardized written instructions and a response sheet with the 226 stimulus items printed in normal Dutch orthography in either order A or B – depending on the particular listener group. Subjects were instructed to decide for each stimulus they heard whether the first or the second syllable in the target item was stressed, by encircling either the number ‘1’ or ‘2’ that was printed after each stimulus on the answer sheet, with forced choice; they were to gamble if they could not hear a difference in stress between the first or second syllable.

3.4. Results

The part of the data that speaks most directly to the research question I formulated is in the CVC.CVC subset, i.e. the items with repetitions of phonologically identical segment sequences. In these items either the onset C, the V or the coda C was varied in duration in the initial or final syllable. Figure 2 plots the percentage of perceived initial stresses as a function of the duration manipulation (shortening or lengthening by 0, 25 or 50% of the original segment duration) of the onset, nucleus or coda segment in first or second syllable with tense (long) versus lax (short) vowels. When duration changes are implemented on the target-initial syllable we expect increased durations (125, 150%) to yield larger percentages of stress perceived on the first syllable (and shortened segments, 75, 50%, to yield less stress on the first syllable). When the same changes are implemented on the second syllable, the effect on perceived initial stress should be reversed, i.e. longer segments in the final syllable should yield a decrease in perceived initial stress. This overall tendency is, in fact, seen in the figure.

More specifically, Figure 2 shows that, overall, effects of changing the duration of the vocalic nucleus are large but changes in consonant durations, whether in the onset or in the coda, have little or no effect on stress perception. A complete cross-over from stress perceived on the first syllable to stress perceived on the second syllable is found for vowel duration change, but not when the vowel is phonologically short (lax) and in the final syllable of the target non-word (top-right panel). Moreover, the effect of changing the (vowel) duration is weaker overall when the changes are implemented in the second (final) syllable than in the initial syllable. It is probably the case that varying the relative duration of a long vowel (such as /a/) is more noticeable, and influences stress perception more strongly, than applying the same relative duration changes to a short (lax) vowel. Also, if the changes are applied to the final syllable, the duration effects of stress are in competition with the effect of word-final lengthening, which may detract from the efficacy of duration as a stress cue in word-final syllables. The latter effect has been found on several other occasions in Dutch (e.g. Nooteboom 1972, Cambier-Langeveld, Nespor and Van Heuven 1997, see also Figure 1).

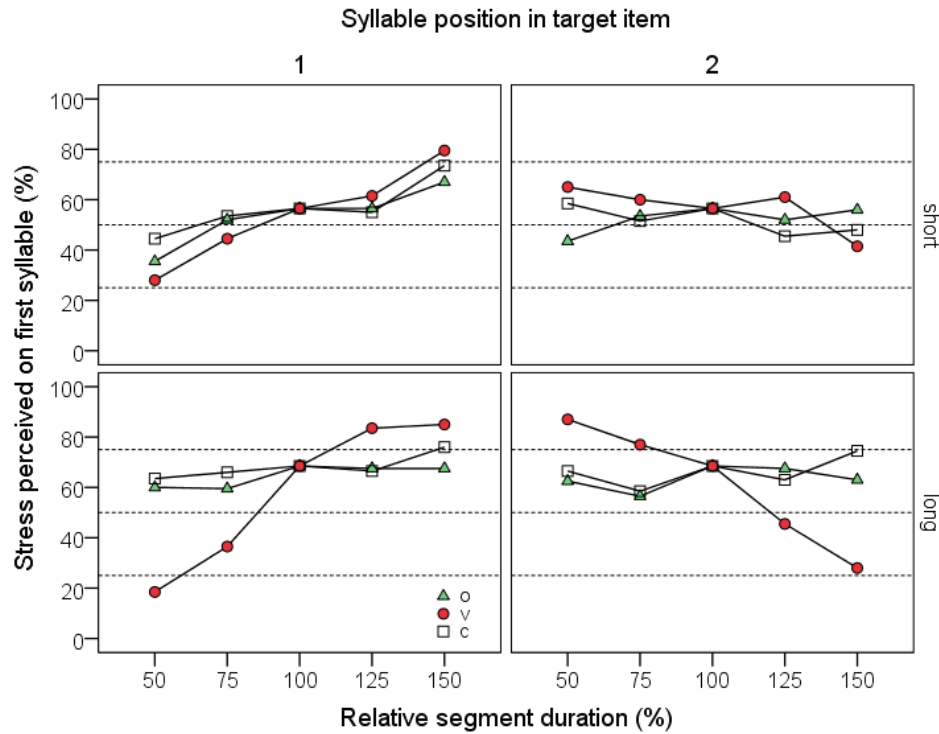


Figure 2. Percent stress perceived on first syllable as a function of relative duration of manipulated segment (onset, vocalic nucleus, coda) in either first (left panels) or second (right panels) syllables with short/lax (upper panels) or long/tense (lower panels) vowel. Target segments are embedded in reiterant CVC.CVC non-words.

Changing the duration of a consonant only affects stress perception if the change takes place in a word-initial syllable with a short (lax) vowel (top-left panel) but even then the effect is still somewhat smaller for consonants than for the vowel. In this condition, it does not matter whether the consonant is in the onset or in the coda. Next, we will examine the results for that part of the data with the non-words of the CV.CVC type. These stimuli have different syllable types in initial and final position in the target items. Nevertheless, the first syllable allows a comparison of the effect of the onset C with that of the nucleus V. The same comparison can be made in the final syllable, which additionally affords a comparison of onset and coda C. It should be borne in mind, though, that effects in the final syllable will be weak (or absent) since word-final syllables are lengthened on account of their pre-boundary position; no lengthening of a

stressed (final) syllable is seen in Dutch if the syllable is already affected by pre-boundary lengthening.⁵ The results are presented in figure 3, which is organized the same way as figure 2.

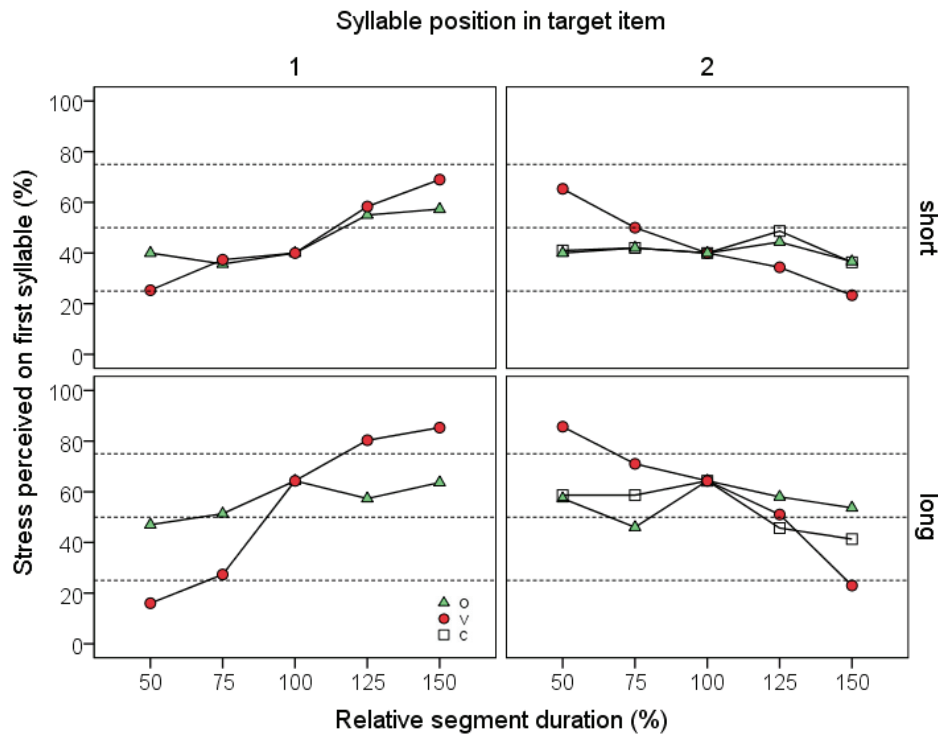


Figure 3. Percent stress perceived on the first syllable in quasi-reiterant CV.CVC target items (further see figure 2).

This figure repeats the findings of figure 2. Generally, changing vowel durations influences stress perception more than changing the duration of a consonant. A proportional change in the duration of a long vowel has a larger effect on stress perception than of a short vowel, whether the change is applied to the initial or to the final syllable. Changing the duration of a consonant does not affect stress perception if the change takes place in the final syllable (nor does the position of the C within the syllable matter). However, when duration changes are made in the initial syllable – which is not

⁵ In this respect Dutch and English are different. Effects of stress and pre-boundary lengthening were found to be additive in English but not in Dutch (Cambier-Langeveld & Turk 1999).

subject to pre-boundary lengthening – the effects on stress perception are more pronounced: both changes in the duration of the vocalic nucleus and in the onset consonant affect stress, although the vowel effect is stronger than the consonant effect.

4. Conclusion and discussion

The general conclusion to be drawn from the results presented above is that vowel duration determines stress perception in Dutch (and presumably in many other languages) to a considerably greater extent than consonant duration does. This perceptual state of affairs mimics what is seen in speech production: here, the vowel in a stressed syllable is lengthened much more than the consonant(s).

An important consideration in the set-up of the perception experiment is that segment durations were changed by proportional increments/decrements relative to the ‘normal’ duration of the target segment. The results showed that changing the relative duration of a short/lax vowel makes a smaller contribution to stress perception on the syllable that contains the target segment, than changing a long/tense vowel by the same percentage. At first sight this seems plausible enough, since adding 50% to a long vowel /a/ increases the duration of the syllable a lot more than adding 50% of the duration to a short vowel /α/. Yet, this reasoning is flawed. In principle, changing the duration of a vowel sound from 100 to 150 ms should be as noticeable as is lengthening a 200-ms vowel to 300 ms (e.g. Nootboom 1972: 18 and references given there). The just noticeable difference for vowel duration is on the order of 10 per cent for the entire range of vowel durations found in natural speech. So, as matters stand, I have no ready explanation for the weaker duration effects of manipulating the duration of short vowels. Interestingly, however, the effect of changing the duration of the consonants (whether onset or coda) in initial syllables with short vowels are stronger than in syllables with long vowels (*ceteris paribus*), and are almost as strong as those of the short vowel itself. The upshot of the above findings is that the contribution of segment duration to stress perception is not the same as that to duration perception of individual segments or of the syllable. This state of affairs is reminiscent of what has been reported on the effects the changing the size of pitch differences to the perception of sentence stress as opposed to the perception of the pitch difference *per se*. When the percept tested is prominence, the size of the pitch movement is best expressed in terms of Equivalent Rectangular Bandwidth units (ERB scale, see Hermes and Van Gestel 1991; Nootboom 1997) but when the percept is the pitch interval itself, then the psychophysically most appropriate scaling is terms of musical intervals (e.g. semitones, see Nolan 2003).

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