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Structural influences on accentual lengthening in English

Alice E. Turk and Laurence White

Department of Linguistics, University of Edinburgh, Edinburgh EH8 9LL, U.K.

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Results of four experiments suggest modifications of Turk and Sawusch's 1997 hypothesis that accentual lengthening occurs throughout a within-word foot-sized domain, and is blocked by its boundaries. Instead, results suggest that (1) a relatively large amount of accentual lengthening occurs on the syllable (primarily its onset and nucleus) with which the pitch accent is associated, (2) there are relatively large rightward effects on syllables adjacent to the pitch accented syllable within a word, and (3) small leftward effects within a word for some speakers. These effects are attenuated, but not necessarily blocked, by the boundaries of a unit the size of an orthographic word, perhaps a prosodic word or clitic group. Both the left edge of a pitch accented syllable and the left and right edges of a word-sized unit thus appear to attenuate the spread of accentual lengthening, which can extend throughout all syllables in a trisyllabic word with primary stress on the initial syllable.

1. Introduction

There is a large amount of evidence that linguistic structure influences the phonetic shape of utterances (see Shattuck-Hufnagel & Turk 1996 for a review), and there is a well-developed theory of the type of constituent structure which accounts for the distribution of segmental phonological and intonational phenomena (Selkirk, 1978; Beckman & Pierrehumbert, 1986; Nespor & Vogel, 1986; Hayes, 1989, among others). This structure, called the Prosodic Hierarchy, consists of layered constituents with potentially largest constituents at the top (e.g., Utterance, Intonational Phrase), and the smallest constituents at the bottom (e.g., Mora, Syllable). Although the Prosodic Hierarchy was not developed to explicitly account for the location and distribution of durational adjustments, work on pause duration, final lengthening and initial strengthening/lengthening supports the view that some type of hierarchical structure also influences the domain and distribution of durational effects. In particular, greater magnitudes of pause duration, final lengthening and initial strengthening/lengthening have been found at the boundaries of relatively higher order constituents than that at the boundaries of lower-order constituents nested within them (Cooper & Paccia-Cooper, 1980; Gee & Grosjean, 1983; Wightman, Shattuck-Hufnagel, Ostendorf & Price, 1992; Fougeron & Keating, 1997).

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However, there are many remaining questions relating to the influence of linguistic structure on durational effects. First, little is known about the type of linguistic structure which influences non-boundary-related durational adjustments, such as prominence-related lengthening (e.g., the lengthening associated with phrasal stress) and polysyllabic shortening (the shortening mechanism proposed to account for the durational difference between "stick" in "sticky" and "stick" in "stickness"; Lehiste, 1972). It is clear that these durational adjustment mechanisms mostly occur within near-word-sized constituents (Huggins, 1975; Turk & Sawusch, 1997). However, the precise characterization of these constituents remains unclear, partly because there are quite a few new-word-sized constituent possibilities which are often isomorphic with lexical content words, namely the Syllable (many English content words are monosyllabic), the within-word foot (the within-word foot is delimited by lexical stresses, and many words contain only a single lexical stress), the Prosodic Word (the constituent which corresponds most closely to a content word) and Clitic Group (a constituent which consists of a content word and optionally adjacent function words),[1] not to mention morphosyntactic constituents, such as terminal elements of syntactic trees. For a fuller discussion of prosodic constituents, see Shattuck-Hufnagel & Turk (1996) and references therein. We would, therefore, like to know whether any of these proposed constituents or other types of constituent possibilities constrain non-boundary-related durational effects.

Another question which has not been adequately addressed in the literature is *how* linguistic structure constrains durational effects. The assumption in the prosodic phonology literature is that prosodic boundaries completely block and operation of phonological rules. We ask whether constituent boundaries, as indicated by specific points in the acoustic speech signal, *block* or merely *attenuate* durational adjustments.

The purpose of this paper is to address these questions with respect to accentual lengthening, specifically the lengthening associated with contrastive primary phrasal stress (contrastive nuclear accent) in English. Although an F0 excursion associated with a lexically stressed syllable is considered to be the primary cue to phrasal stress, duration is considered to be an important secondary cue. Studies of the durational effects of stress and perhaps accent (lexical stress and accent/phrasal stress are often confounded in the

[1]Within-word feet are bounded by lexically stressed syllables and may include adjacent lexically unstressed syllables. Languages differ as to whether within-word feet are bounded by lexical stresses on the left edge or in the right ridge edge (Halle & Vergnaud, 1987; Hayes, 1995); English is a language which is thought to have left-headed feet. For example, an English word like *Hallelujah* consists of two feet: ['halle]$_{\text{Foot}}$['lujah]$_{\text{Foot}}$; words like '*cat* and '*bacon* consist of single feet. Words like *ful'fil*, *re'pair*, *en'force*, etc., are thought to contain single feet with the initial unstressed syllables being regarded as unfooted and attaching at the Prosodic Word node:

$$[\text{en}[\text{force}]_{\text{Foot}}]_{\text{Pwd}}$$

The definition of Prosodic (or Phonological) Word varies somewhat between theorists (see discussion in Shattuck-Hufnagel & Turk, 1996). In Selkirk's (1980) theory, the lowest Prosodic Word element consists of a stem and tightly bound affixes (e.g., *-ity* and other affixes which affect stress placement on the stem). Loosely bound affixes which never affect stress placement (e.g., *-ing*, *-ness*, *-hood*) are attached to a higher Prosodic Word:

$$[[\text{happi}]_{\text{Pwd}}\text{ness}]_{\text{Pwd}}$$

Compound words (e.g., *baseball*) consist of two Prosodic words nested under a higher prosodic word: $[[\text{base}]_{\text{Pwd}}[\text{ball}]_{\text{Pwd}}]_{\text{Pwd}}$. In addition, Prosodic words can sometimes include adjacent object pronoun function words (Selkirk, 1996). Other theories (Nespor & Vogel, 1986; Hayes, 1989) do not allow more than a single level of Prosodic Word.

The Clitic Group does not figure in Selkirk's theory, but serves to group together content words and adjacent function words in Nespor & Vogel (1986) and Hayes (1989): e.g., English *gimme* and *gonna* are arguably clitic groups. In Selkirk's theory, the function of the Clitic Group is captured by the Prosodic Word and the Minor Phrase.

literature) have shown that initial consonants as well as vowels in English stressed syllables are lengthened relative to their counterparts in unstressed syllables (Klatt, 1974; Umeda, 1977; Ingrisano & Weismer, 1979; Stathopoulos & Weismer, 1983; Crystal & House, 1988). Turk & Sawusch (1997) showed that some lengthening can also occur on coda consonants in nuclear accented syllables. Furthermore, in English, Dutch and Swedish at least, accentual lengthening appears to extend beyond the syllable with which a nuclear pitch accent/primary phrasal stress is associated (Nooteboom, 1972; Eefting, 1991; Sluijter & van Heuven, 1995 for Dutch; Turk & Sawusch, 1995, 1997; Sluijter, 1995 for English, and Strangert & Heldner, 1998 for Swedish). Preliminary work for English (Turk & Sawusch, 1997) strongly supports the view that this lengthening is influenced by linguistic constituent structure. However, the restricted nature of the previous work did not allow for a complete characterization of the type of structure which influences it, i.e., whether the domain of accentual lengthening was a within-word foot, or another type of constituent (see Section 2), and raised some questions about whether accentual lengthening is always blocked by domain boundaries. The purpose of the present paper is therefore to extend the previous findings on this lengthening phenomenon in an attempt to come to a clearer characterization of how accentual lengthening works. It is hoped that this work will contribute to an understanding of both the type of constituents which influence accentual lengthening, and of how this influence is manifested e.g., through blocking or through constraining/attenuating the lengthening effects).

2. Background

The study by Turk & Sawusch (1997) of consonant durations in phonetically similar phrases such as *BEEF arm*/*BEE farm*/*beef ARM and bee FARM*, where test consonants are underlined and pitch accented syllables are indicated in capitals, showed that the extent of lengthening is influenced by boundary location. To be specific, a consonant preceding a pitch accent was longer only when it belonged to the same syllable, foot, or word as the pitch accent, as these units are coextensive in the test materials. That is, [f] in *bee FARM* is much longer than [f] in *BEE farm*, whereas [f] in *beef ARM* is shorter than [f] in *BEEF arm*. The length of the consonant could only be accounted for if its membership in an accented unit (syllable, foot, or word) was taken into account, and initial consonants showed a greater degree of lengthening than final consonants.

Moreover, Turk & Sawusch (1995, 1997) found that accentual lengthening extends to a syllable following the accented syllable when that syllable belongs to the same pitch accented word: the underlined unstressed syllable (e.g. [ən]) in phrases such as *BACon force* is consistently longer than a final unstressed syllable in phrases such as *bacon FORCE*, whereas there is no difference in the duration of, e.g. [ən] in *BAKE enforce vs. bake enFORCE*). These facts led Turk & Sawusch to conclude that the domain of accentual lengthening began at the onset of a pitch accented syllable and extended rightward to include a single unstressed syllable within the word. This finding is consistent with the view that the domain of accentual lengthening is the within-word foot (that is, a unit beginning with a lexically stressed syllable and including a following unstressed syllable within a word). However, as they point out, this finding is also consistent with the view that the domain of accentual lengthening is not the within-word foot, but a domain that begins with a pitch accented syllable and extends rightward until

a word boundary. Either way, the claim in this paper was that accentual lengthening is a domain span phenomenon which (1) begins abruptly at the onset of the pitch accented syllable (that is, the syllable with which the pitch accent is associated), and (2) is blocked by the right edge of its domain.

However, Sluijter (1995) provided some evidence which calls into question the view that accentual lengthening begins abruptly at the onset of a pitch accented syllable. She compared unstressed syllables in pitch accented words with the same syllables in unaccented words, e.g., *please say comPACT for me again vs. PLEASE say compact for me AGAIN* (initial test syllables, underlined) and *please say COMpact for me again vs. PLEASE say compact for me AGAIN* (final test syllables, underlined). Like Turk & Sawusch (1997), she found that most of the lengthening effects occurred on the pitch accented syllable (18.7% in weak–strong disyllables and 20.6% in strong–weak disyllables), and a syllable which follows it within a word (18% on the final syllable of strong–weak disyllables), but she also found that the initial syllable of pitch accented weak–strong disyllables were lengthened by 8% as compared to the initial syllable of unaccented weak–strong disyllables. This fact suggests that accentual lengthening may begin before the onset of the pitch accented syllable, contra claims in Turk & Sawusch (1995, 1997), if the initial unstressed syllables are compared to those in a completely unaccented baseline condition.

Unfortunately, Turk & Sawusch (1997) did not include a baseline condition. They compared target unstressed syllable durations in U # _ A *vs.* A # _ U and U _ # A *vs.* A _ # U environments, whereas Sluijter compared target syllable durations in U # _ A *vs.* U # _ U and A _ # U *vs.* U _ # U environments. Henceforth the symbols U and A refer to unaccented elements and to elements with which a nuclear pitch accent is associated, respectively; an underline indicates the target element, and the # symbol indicates a word boundary. Due to the different environments considered in each study, the results of the two studies are not necessarily contradictory. However, Sluijter's results suggest that the explanation Turk & Sawusch (1997) gave for the lack of lengthening on their initial syllables (that is, that lengthening began at the onset of the pitch accented syllable) may need modification. Equal syllable durations of initial unstressed syllables in the U # _ A and A # _ U environments could have been due to the balance of (1) a strong rightward adjacency effect in the A # _ U environment, attenuated by a word boundary, and (2) a weaker leftward effect within a word in the U # _ A environment. This hypothesis contrasts with the Turk & Sawusch's view that accentual lengthening is blocked by constituent boundaries.

In the present study, we present a series of experiments designed for several purposes:

(1) To determine the type(s) of constituents which influence accentual lengthening. In particular, the experiment was designed to test the hypothesis that the within-word foot serves as the domain of accentual lengthening.

(2) To determine the way constituent structure affects accentual lengthening, that is, to determine whether particular constituents block the spread of accentual lengthening, or merely attenuate it.

(3) To determine if accentual lengthening is restricted to the pitch accented syllable and syllables immediately adjacent to it, or whether it can extend over a stretch of more than two syllables.

These experiments were designed to extend the findings of Turk & Sawusch (1997). The first experiment is a replication of Turk & Sawusch's first experiment, since, for

practical reasons, subjects in the present experiment were Edinburgh speakers of Scottish English. It tests the effect of contrastive pitch accents on consonants adjacent to the pitch accented vowel, both within the same word as the pitch accent and across words. The second experiment determines the role of constituent structure on accentual lengthening in two types of disyllabic words, disyllables made up of single feet (e.g., '*bacon*, *en*'*force*), as were used in the Turk & Sawusch experiment, and 2-foot disyllables (e.g., '*shakedown*, *down*'*stairs*) in three different accent conditions, including an unaccented baseline as used in Sluijter (1995). The purpose of the third experiment was to check whether predictions made on the basis of Experiment 2 could be confirmed for sequences of monosyllabic words, and the purpose of the fourth experiment was to test whether accentual lengthening would extend to all three syllables in a three-syllable word with primary stress on the first syllable (e.g., '*property*), as predicted by the view that accentual lengthening spans from a pitch accented syllable to the end of a word.

3. Experiment 1

3.1. *Introduction*

The purpose of this experiment was to check whether Scottish English speakers showed the same pattern of accentual lengthening as American English speakers with respect to consonants neighboring the accented vowel. We therefore measured the constriction durations of consonants (underlined) which were either word-final in the first word of a pair, or word-initial in the second word (e.g., *bee farm*/*beef arm*), and where a pitch accent occurs on either the first word (A_U environment, e.g., *BEE farm*/*BEEF arm*) or on the second word (U_A environment, e.g., *bee FARM*/*beef ARM*). If Scottish English speakers behave like American English speakers, their consonants would be expected to be longer when the unit they belong to is accented than when it is unaccented, and they would be expected to show more lengthening on initial consonants than final consonants.

3.2. *Methods*

3.2.1. *Subjects*

Talkers were four paid volunteers (three female, one male) who were native speakers of Scottish English from the Edinburgh area without any known hearing or speaking disorders.

3.2.2. *Test materials*

Eight pairs of phonetically similar phrases such as *bee farm*/*beef arm* were selected from the set used in Turk & Sawusch (1997). Four central consonants were chosen for having easily identifiable onset and offset characteristics in waveform and spectrogram analysis: /b/, /k/, /n/, and /f/. Two phonetically similar phrase pairs were thus constructed for each consonants:

/b/—"bay beagle" *vs.* "babe eagle"

/b/—"bar beating" *vs.* "barb eating"

/k/—"buy cakes" *vs.* "bike aches"

/k/—"may cough" *vs.* "make off"

/n/—"no notions" *vs.* "known oceans"

/n/—"be nice" *vs.* "bean ice"

/f/—"say fluster" *vs.* "safe lustre"

/f/—"bee farm" *vs.* "beef arm"

These phrases were presented to subjects in frame sentences designed to elicit a contrastive nuclear pitch accent on either the first or second word of the phrase, for example:

I said 'BEEF arm", not "REEF arm"[2] (test consonant is in the A_#U environment).
I said "beef ARM", not "beef AIM" (test consonant is in the U_#A environment).

This yielded a total of 32 test utterances: eight phrase pairs (e.g., *beef arm/bee farm*, etc.) × 2 consonant positions (initial *vs.* final) × 2 pitch accent conditions (U_A *vs.* A_U). A complete set of test materials is listed in Appendix A.

3.3.3. *Recording*

In the recording session, talkers initially read five practice sentences, which were randomly selected from the experimental sentences and other similar sentences.

The test sentences were presented in blocks of 64, composed of the 32 test sentences and 32 similar foil sentences in random order. The blocks were presented twice to each subject, in the first and fourth blocks of the whole recording session. (The other four blocks of 50 similarly structured sentences, each was used for a separate experiment.)

The sentences were presented to talkers in the center of a VT100 terminal screen. Each sentence was displayed for 5 s. Subjects were instructed to reach each sentence aloud when it appeared, and to make sure that they emphasized the words in capital letters. They were also encouraged not to pause between the words in inverted commas.

The subjects' productions were monitored and either they or the experimenter could pause the sentence presentation during a block in order for them to re-read incorrectly produced sentences. A small number of additional repeats were carried out at the end of the entire recording session. The experimenter asked subjects to repeat sentences that were incorrectly read either in terms of lexical content or in terms of prosodic realization. The latter judgment was made when the placement of emphasis in the sentence was not that indicated by the location of the block capitals, or when the experimenter perceived a pause between the words in inverted commas. Despite these repetitions, productions of a number of sentences were later found to be prosodically unacceptable, according to the criteria outlined in Section 3.3.5 below.

[2]We did not control the position or type of segments in the test word which were contrasted in the frame sentence. For examples, in *I said* "*BEEF arm*", *not* "*REEF arm*", the initial consonant in the accented word was contrasted, whereas in *I said* "*BABE eagle*, *not BATHE eagle*", the final consonant was contrasted. Although this could have potentially introduced an experimental artefact, there is no evidence in the literature that either English or Dutch speakers are able to selectively alter the durations of individual segments when these are explicitly contrasted in experimental situations (van Heuven, 1994; Ohala, 1995; Turk & Sawusch, 1995). The study by Turk and Sawusch (1995) was conducted to specifically address the possibility of this type of artefact in their experiments. Furthermore, the Turk and Sawusch experiment that Experiment 1 was designed to replicate used different contrasting words in several cases, e.g., "*bee FARM*", *not* "*bee CHARM*" (Turk & Sawusch, 1997) *vs.* "*bee FARM*, *not bee FORM*", (Experiment 1), with no apparent difference in results.

The speech was recorded on cassette tape, before being amplified, low-pass filtered at 7.8 kHz, sampled at 16 kHz, and transferred to disk.

3.3.4. *Measurements*

The closure duration of each consonant was determined by analysis of the waveform and spectrogram. The criteria used to determine the onset and offset of closure were similar to those described in Turk & Sawusch (1997).

3.3.5. *Missing data*

In all 256 test sentences were recorded for this experiment (2 repetitions × 4 subjects of 32 sentences). Of these, 235 were included in the analysis, and 21 were discarded: five because the emphasis was judged to be incorrectly realized; eight because of pauses inserted between the test words; four because of glottalization before the test consonant, and four because of an unreliable pronounciation. A judgment of incorrect emphasis was made either when the syllable in block capitals was not perceived as the most prominent within the phrase (each sentence comprising two comma-separated phrases, as shown in Section 3.2.2 above), or when another syllable within the phrase was perceived to be of approximately equal prominence. Thus, sentences were only acceptable in which the capitalized syllable carried the nuclear phrasal stress. A judgment of pausing was made if there was a silent gap in the waveform of more than 50 ms between the words in inverted commas, unless the gap could be associated with the constriction phase of an oral stop consonant. Cases of glottalization and allophonic variation caused sentences to be discarded where these prevented identical measurement criteria being applied to different examples of subjects' productions of each phrase type.

For the purposes of estimating mean durations in particular experimental contexts (for inclusion in the graphs), a balanced data set was created in which missing values were filled in with the alternate repetition for a given missing test item for each talker. In this experiment, there was one case where both repetitions of a particular test item were missing; the values for that item were estimated using a procedure based on the location of the talker's mean value for non-missing tokens in the overall distribution of values for all talkers' non-missing tokens.[3] Missing values were not replaced or estimated for the statistical analyses; a regression method was used for partitioning sums of squares. Analyses of variance were computed twice, once with Subjects as a random factor (by Subjects analysis), and once with Items as a random factor (by Items analysis). Treating Subjects and Items as random factors allowed the generality of the effects of the fixed

[3]The computation of the value of a missing token (where both repetitions of a particular phrase type in a given accent and position condition were missing) for a particular subject involved the following statistics:

(1) The mean and standard deviation for tokens in non-missing cells common to all subjects except for the tokens of the subject (henceforth Subject X) whose missing values were being estimated (Common Mean and Common S.D.).
(2) The mean of the subjects' values of the Phrase Type being estimated (Phrase Type mean).
(3) The difference in Common S.D. units between the Phrase Type Mean and the Common Mean (S.D. difference).
(4) The mean and S.D. for Subject X's Phrase Types common to all subjects (Subject X's Common Mean and Subject X's Common S.D.).

The estimated value was computed with the following formula:

Estimated Value = Subject X's Commmon Mean + (S.D. difference * Subject X's Common S.D.)

factors to be tested across the entire population of subjects and across the entire population of items, e.g., all of the phrases of a particular type within the English language. Treating them as fixed factors would only have yielded conclusions about the particular subjects and stimuli used in our experiments. See Loftus & Loftus (1982: 241–242) and Clark (1973) for discussions of these issues.

Our method for creating a balanced data set (i.e., estimating values for missing data points) for use in the graphs, and the analysis of variance technique were the same across all experiments reported in this paper.

3.4. *Results*

In order to determine whether Position in Syllable/Foot/Word and Accent Environment affected consonant constriction durations, analyses of variance were conducted with fixed factors of Accent Environment (U_A *vs.* A_U) and Position (initial *vs.* final) and random factors of Phrase Type (e.g., *bee farm/beef arm vs. bay beagle/babe eagle*, etc.) and Subject. These analyses showed main effects of: Accent [by Subjects: $F(1,3) = 62.51$; $p < 0.01$, by Phrase Type: $F(1,7) = 18.00$; $p < 0.01$], Position [by Subjects: $F(1,3) = 24.73$; $p < 0.05$, by Phrase Type: $F(1,7) = 26.66$; $p < 0.01$], and a significant interaction of Accent and Position [by Subjects: $F(1,3) = 166.85$; $p < 0.01$, by Phrase Type: $F(1,7) = 125.34$, $p < 0.01$]. The interaction between Accent and Position is illustrated in Fig. 1.

Initial consonants in the U # _A environment were 65% longer than initial consonants in the A # _U environment. Final consonants in the A_ # U environment were 13% longer than final consonants in the U_ # A environment. Planned comparisons (Fixed factor: Accent Environment, Random Factors: Subjects and Phrase Type) of the effects of Accent Environment on initial and final consonants, showed that the effect of Accent Environment on initial consonants were statistically significant [by Subjects: $F(1,3) = 141.55$, $p < 0.01$, by Phrase Type: $F(1,7) = 112.35$, $p < 0.01$], but the effect on final consonants was most significant by Phrase Type [by Subjects: $F(1,3) = 15.054$, $p < 0.05$, by Phrase Type: $F(1,7) = 2.29$, n.s.].

3.5. *Discussion*

This pattern of results is similar to that found in Turk & Sawusch (1997), that is, the effect of Accent environment on consonant constriction duration depends on the consonant's position in the syllable/foot/word: consonants are longer when the unit they belong to is accented. Furthermore, as Turk & Sawusch (1997) report, initial consonants were affected to a much larger degree than final consonants. However, although lengthening due to membership of an accented unit was statistically significant for final consonants in the Turk & Sawusch experiment, in this experiment, lengthening on final consonants seemed to depend on Phrase Type. We have no good explanation for this difference in findings between the two experiments. It could have been due to the additional test consonants used in the Turk & Sawusch experiment (they tested /p, b, k, m, n, s, f/), or even to a subtle dialectal difference between Scottish and American English speakers with respect to accentual lengthening. However, due to the limited number of subjects in the present experiment, we hesitate to make such a claim. Results of this experiment nevertheless confirm that in Scottish English, as in American English, accentual lengthening can extend both leftward and rightward from the pitch accented syllable, but

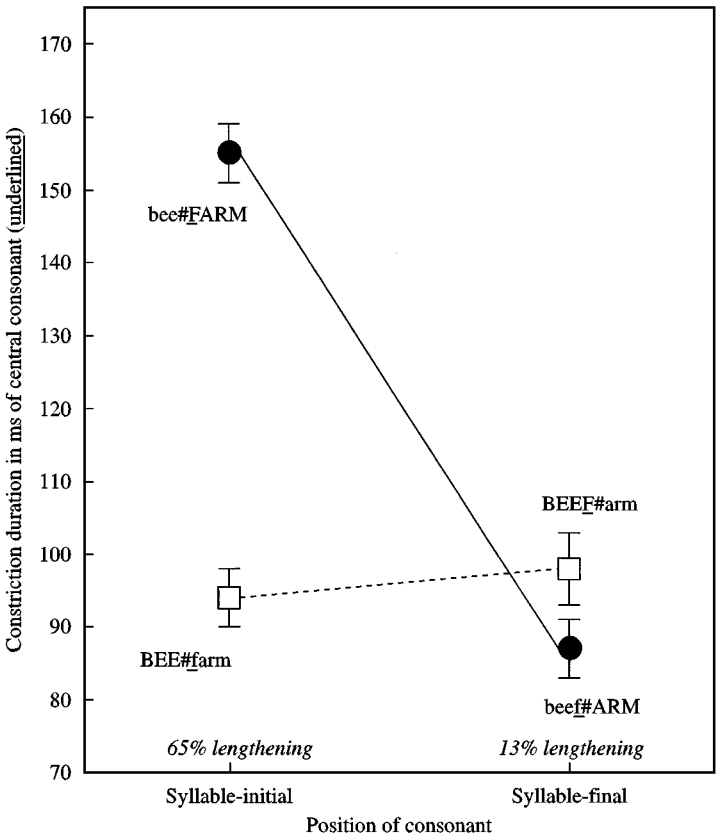

Figure 1. Mean durations (and standard errors) of underlined test consonant constrictions in two accent environments: A_U and U_A (Experiment 2). The "bee farm/beef arm" text exemplifies the type of word sequence occurring in each environment. - - -□- - -, initial accent (A_U); —●—, final accent (U_A).

whether a consonant will be affected depends crucially on its membership of a linguistic unit which is at least the size of a syllable. Because the words in this experiment were monosyllabic, it is impossible to tell whether the effects on these consonants are due to the fact that they belong to an accented syllable, or to the fact that they belong to an accented foot or word.

4. Experiment 2

4.1. *Introduction*

The purpose of the second experiment was two-fold: firstly, to determine whether the strongest effects of accentual lengthening occur within a within-word foot, as suggested by Turk & Sawusch (1997) (see footnote 1 for a definition of a within-word foot), and secondly, to determine how accentual lengthening is affected by constituent structure—that is, to see if it is *blocked* by boundaries of its domain, of if it is better described as being *attenuated* by the boundaries of particular types of prosodic units. The design of

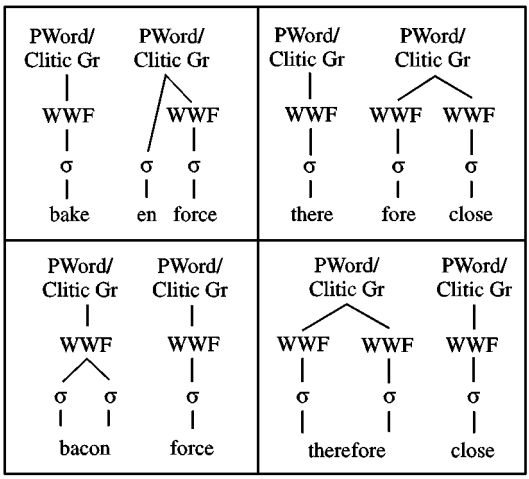

Figure 2. Prosodic structures for the types of test phrases used in Experiment 2. PWord/Clitic Gr = Prosodic Word/Clitic Group, WWF = Within-Word Foot, σ = Syllable.

the experimental materials was analogous to that of the second Turk & Sawusch experiment. That is, test materials consisted of phonetically similar trisyllabic word pairs with primary lexical stresses on the first and third syllables, that differed in word boundary location (e.g., *bake enforce*/*bacon force*, *shakedown stairs*/*shake downstairs*). The test materials were designed to elicit nuclear pitch accents (phrasal stress) on the primary lexically stressed syllables of either the first or second word (e.g., on *bake* in *bake* and *bacon*, on *force* in *force* and *enforce*, on *shake* in *shake* and *shakedown*, and on *stairs* in *stairs* and *downstairs*). Henceforth, we will refer to the syllable-sized unit with which the pitch accent is associated as the *accented syllable*. Phrases such as *shakedown stairs*/*shake downstairs* were included in the test materials so that accentual lengthening in 2-foot words could be compared with accentual lengthening in 1-foot words, such as *bacon* and *enforce* (c.f. Fig. 2).

Assuming that accentual lengthening is blocked by constituent boundaries, if the within-word foot is the domain of accentual lengthening, we would expect (1) no lengthening on initial syllables in words such as *enforce* or *downstairs*, in which the first syllable does not form part of the same foot as the accented second syllable, (2) lengthening on both first and second syllables in words like *bacon*, since the second syllable forms part of the same foot as the accented initial syllable, and (3) no lengthening on the second syllable in words like *shakedown*, since the second syllable occurs in a different foot from the accented syllable. Crucially, then, final syllables in words containing 2 feet should behave differently from final syllables in words containing single feet.

In addition to the two A_U and U_A Accent Environments used in the Turk & Sawusch (1997) experiment, a baseline U_U condition was included to determine if constituent boundaries block or constrain the spread of accentual lengthening. If constituent structure blocks lengthening completely, syllables outside the accented constituent should have comparable durations, whether adjacent to an accented constituent or not. The baseline condition provides the latter, non-adjacent condition.

As a check to see if the different accentual lengthening behavior of word-initial *vs.* word-final unstressed syllables observed in the Turk & Sawusch experiment could have been due to subjects trying to contrast initial *vs.* final syllables within a phonetically similar pair of test phrases (that is, in order to contrast, e.g., *bacon force* stimuli with *bake enforce* stimuli, they may have chosen to put a different accentual lengthening pattern on initial *vs.* final unstressed syllables), the stimulus set included phrases containing initial test syllables which were not paired with corresponding phrases containing final test syllables (e.g., *joke enforce*). Also, the unpaired stimulus set consisted of an equal number of meaningful and nonsense stimuli. These were included to see if accentual lengthening results observed on nonsense phrases follows the pattern of accentual lengthening for meaningful phrases.

4.2. *Methods*

4.2.1. *Subjects*

Talkers were six paid female native speakers of Scottish English from the Edinburgh area without any known speaking or hearing disorders.

4.2.2. *Materials*

There were 48 different two-word, three-syllable phrases prepared for this experiment. These included 16 pairs of phonetically similar two-word phrases, in which the central syllable may belong to either the first or the second word (termed "paired-test phrases"). Half of these phrases were the same or similar to the materials used in Turk & Sawusch (1997), with a central syllable which contains a reduced vowel (henceforth a 'reduced syllable"). These phrases are shown in cells A and B of Table I. The other homophonic phrase pairs have a central syllable containing a full vowel (a "full syllable"). These phrases are shown in cells C and D of the table. There were therefore a total of 32 paired phrases.

The remaining 16 phrases were unpaired, with the central syllable of the three always belonging to the second word of the phrase. There were eight unpaired phrases with a reduced central syllable (cells E and G of Table I), and eight with a full central syllable (cells F and H of the table). In addition, half of the phrases were judged to be nonsensical (cells E and F), and half were judged to be meaningful (cells G and H).

These phrases were presented to subjects in frame sentences designed to elicit a contrastive nuclear pitch accent either on the first word of the phrase, the second word of the phrase, or on a word outside the phrase, for example:

Say "BACON force", don't say 'REGAL force"

Say "bacon FORCE", don't say "bacon HOARD"

SAY "bacon force", don't SHOUT "bacon force"

There were therefore three accent environments for the middle unaccented syllable (underlined): A_U (e.g., *BAC<u>on</u> force*/*BAKE <u>en</u>force*), U_A (e.g., *bac<u>on</u> TENT*/*bake <u>en</u>FORCE*), and U_U (e.g., *bac<u>on</u> force*/*bake <u>en</u>force*). A complete list of test sentences is given in Appendix B.

TABLE I. Test stimuli for Experiment 2

	Reduced central syllable		Full central syllable	
Homophonic word pairs (mainly nonsense)	bake enforce can inspire thank fulfil cube explain toe content pay perform Dan surprise day today *A*	bacon force cannon spire thankful Phil cubics plane token tent paper form dancer prize data day *B*	knee capsize near bisect there foreclose skim Peking shake downstairs there foursquare crow barbette hard whereby *C*	kneecap size nearby sect therefore close skimpy king shakedown stairs therefore square crowbar bet hardware buy *D*
Unpaired words: nonsense	joke enforce plane inspire plank fulfil tube explain *E*		tree capsize pier bisect hair foreclose swim Peking *F*	
Unpaired words: meaningful	play today big surprise please perform stay content *G*		stay downstairs new Peking don't capsize stand foursquare *H*	

4.2.3. *Recording*

In the recording session, subjects initially read 16 practice sentences, which were randomly selected from all of the experimental sentences. They then read six blocks of 48 test sentences each. These blocks were constructed so as to keep the phonetically similar pairs apart, in order to deflect attention away from the ambiguity in the phrases. Thus, block 1 comprised the phrases from cells A, F and H; block 2 the phrases from cells B and D; and block 3 the phrases from cells C, E and G. Within the blocks, each phrase was presented in all three of the frame sentence types, corresponding to the three pitch accent conditions. The order of sentences within the blocks was random, and subjects read through each block twice (in different random orders) before moving on to a new block. The order of block presentation was counterbalanced across subjects.

For this experiment, each sentence was printed in the centre of a $6'' \times 4''$ record card. These cards were given to the subject a block at a time, as outlined above, and subjects read through the sentences at their own space. They were instructed at the start of the experiment to read each sentence aloud, speaking naturally and emphasizing the words in capital letters, as though, for example, they were correcting someone. Sentences were re-read before the subject moved on to the next card, if the subject or the experimenter judged that a sentence had not been read satisfactorily, according to criteria similar to those outlined in Section 3.3.3.

The speech was recorded directly to disk, after being amplified, low-pass filtered at 7.8 kHz and sampled at 16 kHz.

4.2.4. *Measurements*

Syllable durations were measured with reference to waveforms and spectrograms, using criteria similar to those described in Turk & Sawusch (1997). Measurements for

the middle syllable in the three-syllable test sequences were taken in all experimental conditions (e.g., in both initial and final position, in three accent environments). Measurements for the first syllable in the sequence, e.g., [bek] in *bacon force/bake enforce*, [ʃek] in *shake downstairs/shakedown stairs*, were taken in two accent environments, when a pitch accent occurred on the first syllable (e.g., *BACon force/BAKE enforce*) and in the baseline unaccented condition (e.g., *bacon force/bake enforce*).

4.2.5. *Missing data*

There were 1728 sentences recorded for this experiment (2 repetitions × 6 subjects × 48 test sentences × 3 accent environments). Of these, 117 (6.8%) were discarded before analysis, 102 because of incorrect emphasis, three because of pauses inserted within the target phrases, four because of pronunciations which prevented reliable segmentation, and eight because of recording errors. Thus, 1611 sentences were available for analysis. In 15 cases, both repetitions of a test item for a particular speaker were missing, that is, for 1.7% of the data. The criteria used to discard sentences were the same as those applied in Experiment 1. Procedures for creating a balanced data set for calculating descriptive statistics were the same as in Experiment 1.

4.3. *Results*

In this section, we present results for the primary lexical stressed syllable in the first word (e.g., [bek] in *bacon force/bake enforce*, [θɛɹ] in *therefore close/there foreclose*), followed by results for syllables without primary lexical stress, e.g., [ən] in *bac<u>on</u> force/bake <u>en</u>force* or [fɔɹ] in there<u>fore</u> stairs.

4.3.1. *Primary stressed syllables*

Fig. 3 shows the mean durations of primary stressed syllables in the first word of the test stimuli, e.g., [θɛɹ] in *therefore close/there foreclose*, when the word was unaccented (in the SAY_environment, e.g., SAY "there foreclose", . . . *vs.* when it was accented, e.g., say "THERE foreclose" . . . . On average, accented syllables in monosyllabic words were 23.4% longer than the same syllables when unaccented (as "[θɛɹ] in there foreclose", and accented syllables in disyllabic words such as THEREfore were on average 15.9% longer than the same syllables when unaccented (as "[θɛɹ] in therefore close) (cf. Fig. 3).

An ANOVA with fixed factors of Accent (Accented *vs.* Unaccented), Number of Syllables in the Word (1 *vs.* 2), and random factors of Phrase Type (e.g., *bacon force/bake enforce*, *therefore close/there foreclose*) and Subjects showed main effects of Accent [by Subjects: $F(1,5) = 119.73$; $p < 0.01$, by Phrase Type: $F(1,15) = 90.75$; $p < 0.01$], Number of Syllables in the Word [by Subjects: $F(1,5) = 37.37$; $p < 0.01$, by Phrase Type: $F(1,15) = 73.49$; $p < 0.01$], and an interaction between Accent and Number of Syllables in the Word which tended towards significance in the by-Subjects analysis, and reached significance in the by-Phrase Type analysis [by Subjects: $F(1,5) = 4.43$; $p < 0.01$, by Phrase Type: $F(1,15) = 34.84$; $p < 0.01$]. This interaction suggests that the magnitude of the effect of accent depends on the number of syllables in the word (a bigger effect for monosyllables). Planned comparisons of the effect of Accent on primary stressed syllables in (1) monosyllabic words (e.g., [θɛɹ] in *there foreclose* vs. *THERE foreclose*) and in (2) disyllabic words (e.g., [θɛɹ] in *therefore close* vs. *THEREfore close*) showed that the effect of Accent was significant in both cases [for monosyllabic words, by Subjects

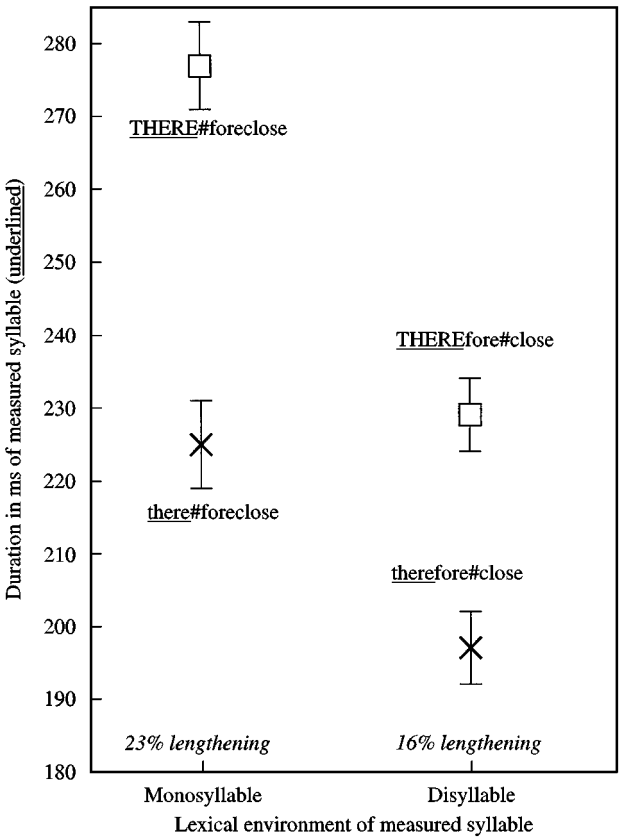

Figure 3. Mean durations (and standard errors) of (1) monosyllables and of (2) both syllables in trochaic words in the A_U and U_U accent environments (Experiment 2). The "there foreclose/therefore close" text exemplifies the type of word sequence occurring in each environment. □, initial accent; ×, no accent in phrase.

$F(1,5) = 64.41$; $p < 0.01$, by Phrase Type: $F(1,15) = 95.104$; $p < 0.01$; for disyllabic words, by Subjects: $F(1,5) = 50.49$; $p < 0.01$, by Phrase Type: $F(1,15) = 57.81$; $p < 0.01$].

4.3.2. *Within-word foot hypothesis*

In this section, we present results for the second syllable in the trisyllabic test sequence, e.g., [ən] in *bacon force/bake enforce*, and [fɔɹ] in *therefore close|/there foreclose*, to see if accentual lengthening is blocked by the presence of a within-word foot boundary.

The results of measurements of reduced and full vowel test syllables show that the second syllable/foot in words containing 2 feet (e.g. [fɔɹ] in *therefore*) is affected by accentual lengthening to the same degree as an unstressed syllable in a word containing a single foot (e.g., [ən] in *bacon*) cf. Fig. 4): 12.5% lengthening was found on reduced syllables in the A_#U environment as compared to the U_#U environment, and a comparable 12.65% lengthening was found on full syllables in the same environments. An analysis of variance with fixed factors of Accent Environment (A_U, U_A and

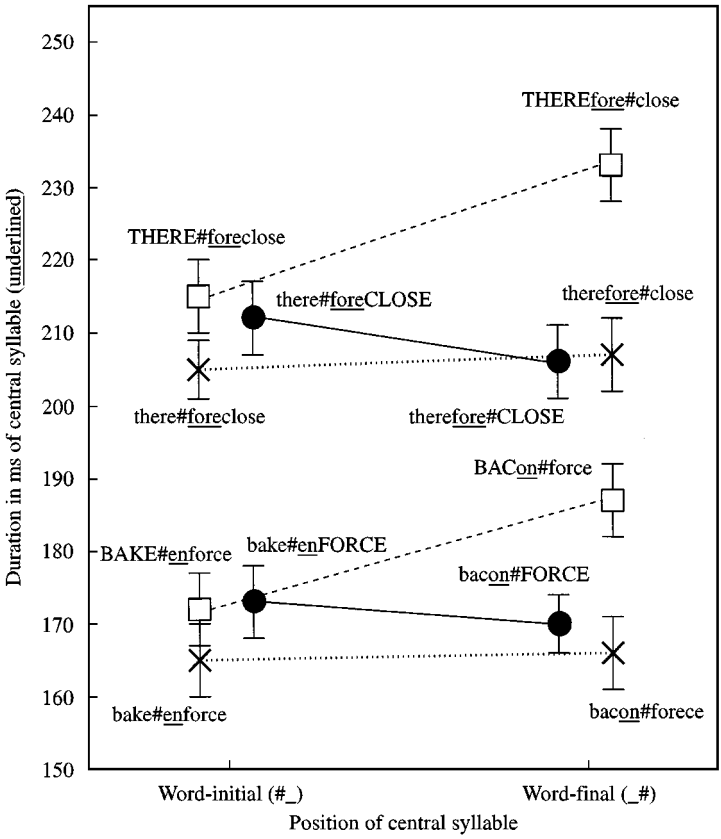

Figure 4. Mean durations (and standard errors) of full and reduced unaccented test syllables (underlined) in three accent environments: A_U, U_A and U_U (Experiment 2). The "there foreclose/therefore close/bake enforce/bacon force" text exemplifies the type of word sequence occurring in each environment. - - -□- - -, initial accent (A_U); —●—, final accent (U_A); ·····×····· , no accent (U_U).

U_U), Position (initial *vs.* final), and Syllable Type (reduced *vs.* full) and random factors of Phrase Type-Within-Syllable Type and Subjects is consistent with this view. There was a significant effect of Accent [by Subjects: $F(2,10) = 13.26$, $p < 0.01$, by Phrase Type-Within-Syllable Type: $F(2,28) = 37.10$, $p < 0.01$]. The effect of Position was not significant in either type of analysis [by Subjects: $F(1,5) = 1.338$, n.s., by Phrase Type-Within-Syllable Type: $F(1,14) = 0.857$, n.s.]. The main effect of Syllable Type was significant in the by-Subjects analysis, but only tended towards significance in the by-Phrase Type-Within-Syllable-Type analysis, [by Subjects: $F(1,5) = 190.84$, $p < 0.01$, by Phrase Type-Within-Syllable Type: $F(1,14) = 4.29$; $p < 0.1$]. The interaction between Accent and Position was significant [by Subjects: $F(2,10) = 6.98$, $p < 0.05$, by Phrase Type-Within-Syllable Type: $F(2,28) = 18.821$; $p < 0.01$]. The two-way interaction of Syllable-Type with Position, was not significant by Subjects) [($F(1,5) = 0.374$; n.s.)] and by Phrase Type-Within-Syllable Type [$F(1,14) = 0.003$; n.s.]. The fact that the three-way interaction of Syllable Type, Accent Environment and Position was insignificant by Subjects [$F(2,10) = 0.509$, n.s.] and by Phrase Type-Within-Syllable Type

[$F(2, 28) = 0.239$, n.s.] suggests that Accent and Position affected reduced and full syllables similarly, and thus provides no support for the view that the domain of accentual lengthening is the within-word foot. Words composed of 2 feet appear to have the same accentual lengthening behavior as words composed of 1 foot.

The significant interaction between Accent Environment and Position confirms what is visible on the graph (Fig. 4): more accentual lengthening occurs on word-final syllables than on word-initial syllables within an accented word. These results are consistent with data in Turk & Sawusch (1995, 1997), where accentual lengthening (in A_U *vs.* U_A environments) was observed on word-final unstressed syllables, but not on word-initial syllables. Taken together with results for initial consonants (e.g., [f] in *bee FARM vs. BEE farm*) and the primary stressed syllable (e.g., [bek] in *BACON force vs. bacon force*), these result support the view that *most*, but not all, of the lengthening associated with nuclear pitch accents occurs within a domain beginning with the onset of the pitch accented syllable and extending rightward to the end of a word: 15.9% on accented syllables, and 12.6% on a following unaccented syllable within a word as compared to a baseline, but 4.1% on initial unstressed syllables in a pitch accented word as compared with a baseline (see Fig. 4 and Table II). Planned comparisons were conducted to see if the within-word effects of accent were significant for both initial and final syllables. Initial syllables in the U#_A environment were compared with initial syllables in the U#_U environment (e.g., [ən] in *bake enFORCE vs.* [ən] in *bake enforce*/[θɛɹ] in *there foreCLOSE* vs. [θɛɹ] in *there foreclose*), and final syllables in the A_#U environment were compared with final syllables in the U_#U environment (e.g., [ən] in *BACon force vs.* [ən] in *bacon force*/[fɔɹ] in *THEREfore close vs.* [fɔɹ] in *therefore close*). ANOVA's were conducted with fixed factors of Accent Environment [either (1) U#_A *vs.* U#_U for initial syllables, or (2) A_#U *vs.* U_#U for final syllables], Syllable Type (full *vs.* reduced), and random factors of Phrase Type-within-Syllable-Type and Subjects. Not surprisingly, these showed an effect of Syllable Type dependent to some degree on Phrase Type for both types of comparisons [for initial syllables, by Subjects: $F(1, 5) = 87.399$, $p < 0.01$, by Phrase Type-within-Syllable-Type, $F(1, 14) = 4.062$, $p < 0.1$; for final syllables, by Subjects: $F(1, 5) = 307.116$, $p < 0.1$, by Phrase Type-within-Syllable-Type, $F(1, 14) = 4.180$, $p < 0.1$], probably a reflection of relative intrinsic segment duration differences in the different types of phrases we used.

TABLE II. Proportional lengthening of the test syllables in accented conditions as compared to the unaccented (U_U) baseline

Accent environment	Position of central syllable	
	Word-initial (#_)	Word-final (_#)
1. *Reduced central syllables*		
A_U	4%	13%
U_A	5%	2%
2. *Full central syllables*		
A_U	5%	13%
U_A	3%	0%
3. *All central syllables* (*full and reduced pooled*)		
A_U	5%	13%
U_A	4%	1%

As expected, final syllables showed a significant effect of being in an accented word [A_#U *vs.* U_#U, by Subjects $F(1,5) = 13.218$, $p < 0.01$; by Phrase Type-within-Syllable-Type $F(1,14) = 28.291$, $p < 0.01$]. Initial syllables showed a significant effect of being in an accented word in the by-Phrase Type-within-Syllable Type analysis, but not in the by-Subjects analysis [U#_A *vs.* U#_U, by Subjects: $F(1,5) = 3.514$, n.s., by Phrase Type-within-Syllable-Type: $F(1,14) = 9.748$, $p < 0.05$]. The interaction between Accent Environment and Syllable Type was neither significant for initial syllables [by Subjects: $F(1,5) = 0.181$, n.s.; by Phrase Type-within-Syllable Type: $F(1,14) = 0.027$, n.s.], nor for final syllables [by Subjects: $F(1,5) = 0.501$, n.s., by Phrase Type-within-Syllable-Type: $F(1,14) = 0.808$, n.s.]. The significant effect of Accent in the by-Phrase Type-within-Syllable Type analysis suggests that accentual lengthening *can* occur before the onset of the pitch accented syllable within a word, contra claims in Turk & Sawusch (1997), and consistent with the results of Sluijter (1995).

As this results suggests that there was some inter-subject variability, at least for initial syllables, we show plots of individual subjects' results in Fig. 5.

This figure shows that some of the subjects, Speakers 3–6, show some degree of lengthening on initial syllables as compared to the unaccented baseline condition. Interestingly, in spite of the fact that the accentual lengthening effect on final syllables was reliable by both subjects and items, the plots show that there was some inter-subject variability here as well, most notably, Speaker 4 shows no evidence of accentual lengthening on final syllables, and Speaker 1 has little evidence of an asymmetry in accentual lengthening on initial *vs.* final syllables.

4.3.3. *The role of constituent boundaries in constraining accentual lengthening effects*

Results reported in Section 4.3.2 suggest that accentual lengthening within a word is asymmetric; lengthening on a syllable following a pitch accented syllable is of greater magnitude and is more reliable than lengthening on a syllable preceding a pitch accented syllable. Together with the results of Experiment 1, these results implicate the left edge of a pitch accented syllable and the right edge of a word in the accentual lengthening process. As compared to a baseline unaccented condition, a small amount of lengthening can be found to the left of the onset of the pitch accented syllable within a word, and a large amount can be found between this boundary and the right edge of a word. In this section, we ask whether the left edge of a word has any role in the accentual lengthening process, and also whether right-hand boundaries completely block, or just attenuate the accentual lengthening effects.

To determine the role of the left-hand word boundaries, we compared the effect of accent on initial syllables in the U#_A *vs.* U#_U environments, 4.1% lengthening, significant in a by-Phrase Type-within-Syllable Type analysis, reported above, with the effect of accent on final syllables in the same accentual environment (U_#A *vs.* U_#U). If a left-hand word boundary attenuates the effect, we expect to see less effect of Accent in the U_#A *vs.* U_#U comparison. An analysis of variance (ANOVA) was conducted with fixed factors of Accent environment (U_#A *vs.* U_#U), Syllable Type (Full *vs.* Reduced), and random factors of Subjects and Phrase Type-within-Syllable Type. There was a significant effect of Syllable Type in the by-Subjects analysis [$F(1,5) = 91.653$, $p < 0.01$], but only a tendency towards significance in the by-Phrase Type-within-Syllable Type analysis [$F(1,14) = 3.519$, $p < 0.1$]. The effect of interest for our

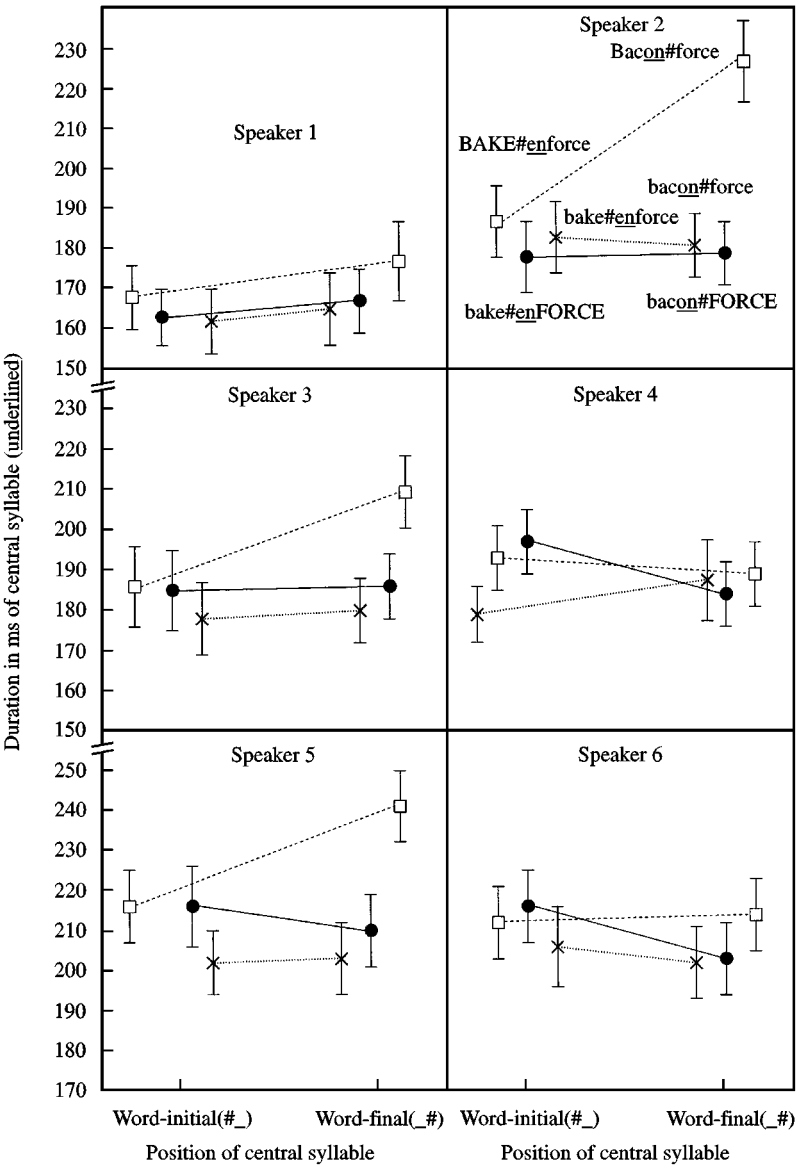

Figure 5. Mean durations (and standard errors) of unaccented test syllables in three accent environments: A_U, U_A and U_U, plotted for each subject individually, The 'bake enforce/bacon force" text exemplifies the type of word sequence occurring in each environment. - - -□- - -, initial accent (A_U); —●—, final accent (U_A); ·····×·····, no accent (U_U).

hypothesis, the effect of Accent Environment, did not reach significance [by Subjects: $F(1,5) = 0.123$, n.s.], by Phrase Type-within-Syllable Type: $F(1,14) = 2.292$, n.s.], perhaps not surprisingly, given that the difference in percent between U_#A and U_#U tokens was only 1%. The interaction between Accent Environment and Syllable Type was not significant [by Subjects: $F(1,5) = 2.815$, n.s., by Phrase Type-within-Syllable

Type: $F(1,14) = 1.054$, n.s.]. The fact that the effect of Accent in the U_A *vs.* U_U environment was significant in the by-Phrase Type-within-Syllable Type analysis for initial syllables, but was not for final syllables, suggests that left-hand word boundaries may play an additional attenuating role, in addition to the robust attenuating role of the left-hand boundary of the pitch accented syllable. It may be difficult to find conclusive evidence that left-hand word boundaries attenuate, but do not block accentual effects, since leftward effects will always be attenuated to a large degree by the presence of the left edge of a pitch accented syllable. When the left-hand word boundary further attenuates this small leftward effect, there may be nothing left to "spill over" onto the preceding syllable.

We investigated whether the role of a right-hand word boundary was a blocking *vs.* attenuating one by determining whether residual lengthening to the right of a word boundary in the A#_U environment as compared to the U#_U environment was statistically significant. ANOVAs with fixed factors of Accent Environment (A#_U *vs.* U#_U) and Syllable Type (Full *vs.* Reduced), and random factors of Phrase Type-within-Syllable Type and Subjects, showed a significant effect of Accent Environment [by Subjects: $F(1,5) = 24.576$, $p < 0.01$; by Phrase Type-within-Syllable Type: $F(1,14) = 28.291$, $p < 0.01$]. The effect of Syllable Type was again significant by Subjects and tended towards significance by Phrase Type-within-Syllable Type [by Subjects: $F(1,5) = 88.872$, $p < 0.01$; by Phrase Type-within-Syllable Type: $F(1,14) = 4.180$, $p < 0.1$]. The interaction between Accent Environment and Syllable Type was not significant [by Subjects: $F(1,5) = 0.394$, n.s.; by Phrase Type-within-Syllable Type: $F(1,14) = 0.546$, n.s.]. The 4.7% residual lengthening observed in the A#_U *vs.* U#_U comparison thus appears to be reliable, suggesting that the role of the right-hand boundary is to attenuate, but not to block, the lengthening effects of accent.

4.3.4. *Paired vs. unpaired stimuli*

There was no evidence that subjects used different strategies for paired *vs.* unpaired stimuli: ANOVAs were conducted with fixed factors of Accent Environment, Pair Type (Paired *vs.* Unpaired), and random factors of Phrase Type-within-Pair Type and Subjects. The interaction between Accent Environment and Pair Type was not significant for both reduced and full syllables [Reduced syllables, by Subjects: $F(2,10) = 0.086$, n.s.; by Phrase Type-Within-Pair Type: $F(2,28) = 0.031$, n.s.; Full syllables, by Subjects: $F(2,10) = 0.075$, n.s., by Phrase Type-Within-Pair Type: $F(2.28) = 0.008$, n.s.]. Even when a potentially more powerful analysis was conducted with full and reduced syllables pooled, a significant interaction of Accent Environment and Pair Type did not emerge [by Subjects: $F(2,10) = 0.292$, n.s., by Phrase Type-Within-Pair Type: $F(2,60) = 0.031$, n.s.]. There is thus no evidence that the ambiguous nature of the paired stimuli affects subjects' production of the phrases, at least with regard to durational effects.

4.3.5. *Meaningful vs. nonsense stimuli*

Likewise, there was little positive evidence that the meaningful *vs.* nonsense nature of the test stimuli influenced the durations of accented *vs.* unaccented tokens. ANOVA's with fixed factors of Accent Environment and Meaning (Meaningful *vs.* Nonsense and random factors of Phrase Type-Within-Meaning and Subjects) showed insignificant interactions between Meaning and Accent Environment for both reduced and full

syllables for all tests except for the by-Subjects analysis for the reduced syllables; which tended towards significance [for Reduced syllables, by Subjects: $F(2, 10) = 3.432$, $p < 0.1$, by Phrase Type-Within-Meaning: $F(2, 12) = 1.479$, n.s.; for Full syllables, by Subjects: $F(2, 10) = 0.283$, n.s., by Phrase Type-Within-Meaning: $F(2, 12) = 0.586$, n.s.]. There may be a slight difference in the effect of accent in meaningful *vs.* nonsense phrases, but this difference is likely to depend on the type of utterance being considered.

4.4. *Discussion*

Experiment 2 showed clearly that the within-word foot is not the domain of accentual lengthening. Instead, two types of boundaries appear to influence accentual lengthening: the left edge of a syllable, and the left and right edges of words. To be specific, most of the effects of accentual lengthening appear to extend from the beginning of a pitch accented syllable to the end of a word, regardless of whether the word consists of a single foot, or two monosyllabic feet. However, when test syllables in pitch accented words were compared with an unaccented baseline condition, residual lengthening effects emerged on the syllable to the left of the pitch accented syllable within a word, at least for some subjects, and on the syllable to the right of a pitch accent across a word boundary. These residual effects (lengthening of 3–5% as compared to an unaccented baseline) supported the view that the role of constituent boundaries (as defined by specific points in the acoustic signal) was to attenuate accentual lengthening, but not to block it.

This experiment also showed that the relative magnitude of lengthening on the pitch accented syllable (16% as compared to an unaccented baseline) was comparable to that on the syllable following it within a word (13%), although it should be noted that the phonetic composition of the two syllables was not the same, and therefore their relative magnitudes are not strictly comparable. Nevertheless, this finding is consistent with the view that accentual lengthening extends relatively uniformly from a pitch accented syllable to the end of a word. However, another view consistent with these findings is that accent-related lengthening comes from two sources: (1) from lengthening on the pitch accented syllable itself (with more lengthening on the first part of the syllable, than on the latter part, see results of Experiment 1), and (2) from word-final lengthening primarily on the last syllable of a pitch accented word. This latter view presupposes that word-final lengthening shows up more reliably and to a much greater degree on pitch accented words than on unaccented words, which is perhaps difficult to explain.

In summary, the findings of the current experiment are consistent with the results of both Turk & Sawusch (1997) and Sluijter (1995), even though different conclusions were reached by each author. By viewing accentual lengthening as a process which is modulated by particular types of boundaries, but not necessarily as something contained within a particular domain, the results of all three studies can be unified.

5. Experiment 3

5.1. *Introduction*

Results of Experiment 2 showed evidence of residual lengthening to the right of a pitch accented syllable across a word boundary, but no evidence of residual lengthening to the

left of a pitch accented syllable across a word boundary. This asymmetry can be accounted for if leftward spreading is attenuated by two boundaries, namely the left edge of a pitch accented syllable and the left edge of a word, whereas rightward spreading is attenuated by a single boundary, namely the right edge of a word.

Results of Experiment 2 therefore make the prediction that the same type of asymmetry in residual effects across word boundaries should be found in sequences of three monosyllables, e.g., *BLESS Mark now vs. bless Mark NOW*. If the leftward spread of lengthening is weaker due to the combined attenuating effects of two coinciding boundaries, then the central test word in *BLESS Mark now* should be longer than the test word in *bless Mark NOW*.

5.2. *Methods*

5.2.1. *Subjects*

Six talkers (all female) served as paid volunteers. One of these subjects had also been a subject in Experiment 1. All were speakers of Scottish English from the Edinburgh area without any known hearing or speaking difficulties.

5.2.2. *Materials*

Twelve three-word phrases were constructed, in which the first two words were monosyllabic. In the first six phrases, the middle word of the phrase was an adjective and thus more closely attached syntactically to the right; in the final six phrases the middle word was a noun which serves as the direct object of the initial verb:

"dream sad scenes"
"drag white socks"
"miss nine steps"
"send six more"
"hold new scores"
"sing four songs"
"calm Sam soon"
"bless Mark now"
"chase Nick never"
"hide Sue faster"
"keep Sam smarter"
"drop Stan slowly"

As in the previous experiments, frame sentences were used in order to elicit contrastive nuclear pitch accent on either the initial or the final word in the phrase:

I said "BLESS Mark now", not "MISS Mark now"
I said "bless Mark NOW", not "bless Mark THEN"

Test syllables were the middle words of the three word sequence, e.g., *Mark* in *BLESS Mark now*, which thus occurs in two Accent environments: A # _ # U (e.g., *BLESS Mark now*) and U # _ # A (e.g., *bless Mark NOW*). Due to time limitations, a baseline

U#_#U condition was not included. A complete list of test sentences is found in Appendix C.

5.2.3. *Recording*

In the recording session, subjects initially read 10 practice sentences, which were randomly selected from the experimental sentences and other similar sentences. The 24 test sentences were presented in random order along with 122 similar sentences, the whole group being split into two blocks. Another two blocks were prepared for a second reading of the sentences. The whole recording also included another practice session and two blocks of 48 sentences. These related to a separate experiment.

The presentation of the sentences to the subjects was carried out as described in Experiment 1. The recording and processing procedure was as in Experiment 2.

5.2.4. *Measurements*

The duration of the second word in the target phrase was determined by analysis of the waveform and spectrogram, using standard segmentation criteria.

5.2.5. *Missing data*

There were 288 test sentences recorded for this experiment (2 repetitions × 6 subjects of 24 sentences). Of these, 38 sentences were discarded before measuring: 34 because the emphasis was judged to be incorrect; two because of pauses inserted within the phrase: and two because of pronunciation variants which prevented consistent segmentation. This left 250 test sentences for analysis. There were four cases in which both repetitions of a subject's test tokens were missing, so that 2.8% of the data was estimated for use in the graph. The criteria used to discard sentences were the same as those applied in Experiment 1. Procedures for creating a balanced data set for calculating descriptive statistics were the same as in Experiment 1.

5.3. *Results*

Fig. 6 shows that the middle monosyllable in the A_U environment was 5% longer than the middle monosyllable in the U_A environment, e.g., test words such as "*Mark*" were longer in e.g. *BLESS Mark now* than in *bless Mark NOW*. An ANOVA with fixed factors of Accent Environment (A_U *vs.* U_A), Syntactic Category (Noun *vs.* Modifier) and random factors of Phrase Type-within-Syntactic Category and Subjects showed that this difference was not significant in the by-Subjects analysis, but tended towards significance in the by-Phrase Type-within-Syntactic Category analysis [by Subjects: $F(1,5) = 0.232$, n.s.; by Phrase Type-within-Syntactic Category: $F(1,10) = 3.927$, $p < 0.1$]. There was no effect of Syntactic Category [by Subjects: $F(1,5) = 0.316$, n.s., by Phrase Type-within-Syntactic Category: $F(1,10) = 0.003$, n.s.], and the interaction between Syntactic Category and Accent Environment was not significant [by Subjects: $F(1,5) = 2.976$, n.s., by Phrase Type-within-Syntactic Category: $F(1,10) = 0.114$, n.s.].

5.4. *Discussion*

Although the effect of Accent only tended towards significance in the by-Phrase Type-within-Syntactic Category analysis, and did not reach significance in the by-Subjects

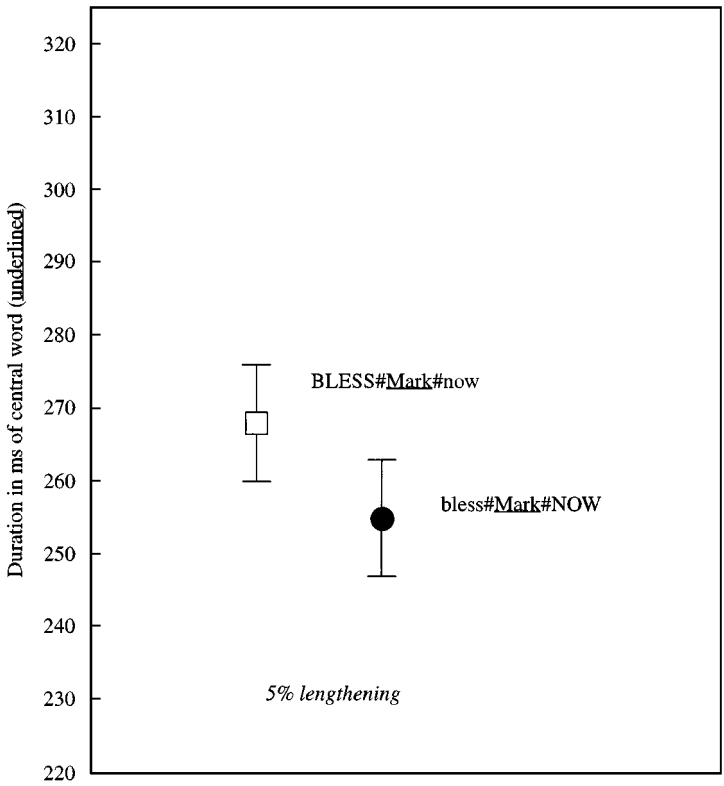

Figure 6. Mean durations (and standard errors) of test words in two accent environments: A_U and U_A (Experiment 3). The "bless Mark now" text exemplifies the type of word sequence occurring in each environment. - - -□- - -, initial accent; —●—, final accent.

analysis, the size and direction of the effect is consistent with the findings of Experiment 2. Residual accentual lengthening effects across word boundaries thus appear to be slightly asymmetric, with more residual lengthening across a right-hand word boundary than across a left-hand word boundary. This asymmetry could be accounted for by a slightly stronger attenuating effect of a left-hand word boundary which coincides with the left edge of a pitch accented syllable.

There was no evidence that the syntactic structure of the test phrases had any influence on accentual lengthening patterns. The present results are thus consistent with the view that word boundaries strongly attenuate accentual lengthening effects.

6. Experiment 4

6.1. *Introduction*

Experiments 1–3 investigated the role of accentual lengthening in monosyllabic and disyllabic words; the purpose of Experiment 4 was to begin to explore the effects of accentual lengthening in words with three syllables. To this end, we present

accentual lengthening results for three-syllable words with primary stress on the first syllable, e.g., *property*, in phrases such as *PROperty sale vs. property SALE*. We ask whether accentual lengthening can extend throughout all syllables in this type of word.

One of the possibilities raised by the results of Experiment 2 is that the apparent rightward spread of lengthening until a word boundary in words like *bacon* is not due to the spread of accentual lengthening *per se*, but due to a combination of accentual lengthening and extra final lengthening on pitch accented words. The present experiment was also designed as a preliminary test of this hypothesis. If it turns out that accentual lengthening extends only through the first two syllables, then the final lengthening account must be ruled out. On the other hand, the composite view of accentual lengthening and final lengthening becomes more plausible if the middle syllable, which is neither the pitch accented syllable nor word-final, does not show any lengthening in an accented word.

6.2. *Methods*

6.2.1. *Subjects*

Six talkers (five female, one male) served as paid volunteers. All were speakers of Scottish English from the Edinburgh area. None reported any speaking or hearing difficulties.

6.2.2. *Materials*

Eight different two-word phrases were selected, in which the first word had primary lexical stress on the antepenultimate syllable. Seven of the test words consisted of three-syllable words with primary lexical stress on the first syllable; and one test word, "alternative", consisted of four syllables and had primary lexical stress on the second syllable. The test phrases were:

"catapult over"
"cavity drill"
"fantasy tale"
"functional dress"
"monitor clock"
"obstacle down"
"property sale"
"alternative name"

As in Experiment 1, these phrases were presented to subjects in frame sentences designed to elicit a contrastive nuclear pitch accent on either the first or the second word of the phrase, for example:

I said "PROPERTY over", not 'GENERATE over" (Accented test word)
I said "property OVER", not "property AFTER" (Unaccented test word)

Since Experiment 2 showed no evidence of residual leftward accentual lengthening across a word boundary, we did not include a baseline unaccented condition in this experiment. A complete list of test sentences is listed in Appendix D.

6.2.3. *Recording*

In the recording session, subjects initially read 5 or 10 practice sentences, which were randomly selected from the experimental sentences and other similarly constructed sentences. They then read the 16 test sentences (8 phrases $\times$ 2 pitch accent conditions), which were presented in random order with 96 similar sentences (or 120 similar sentences for one subject), and split into two blocks. The sentences were similarly randomized and blocked for a second reading of the sentences. The whole recording also included another practice session and two blocks of 48 sentences. These related to a separate experiment.

The presentation of the sentences to the subjects was carried out as described in Experiment 1. Once again subjects were encouraged to emphasize the words in capital letters. The recording and subsequent processing was as in Experiment 2.

6.2.4. *Measurements*

The durations of the antepenultimate, penultimate, and final syllables in the first word of the target phrases were measured by reference to the waveform and spectrogram, using standard segmentation criteria. Syllabification was determined by the maximal onset principle (Kahn, 1976; Clements & Keyser, 1983).

6.2.5. *Missing data*

Of the 192 test sentences (2 repetitions $\times$ 6 subjects of 16 sentences), 34 were discarded before measuring: 13 because of incorrect emphasis; three because of inserted pauses; 17 because of production variations that prevented consistent segmentation, such as elision and glottalization; and one sentence missing due to a recording error.

Thus, 158 sentences were available for analysis. In three cases, the duration of the antepenultimate syllable could not be measured because of difficulties in accurate segmentation; so there were 155 antepenultimate syllables measured (37 discarded). In the same three cases, plus 2 others, the penultimate syllable could not be measured due to segmentation difficulties; so 153 penultimate syllables were measured (39 discarded). The final syllable was measured for all 158 available sentences (34 discarded, as outlined above). Cases where both repetitions of a test item were missing were eight for antepenultimate syllables (8.3%), nine for penultimates (9.3%), and nine for final syllables (9.3%). The criteria used to discard sentences were the same as those applied in Experiment 1. Procedures for creating a balanced data set for calculating descriptive statistics were the same as in Experiment 1.

6.3. *Results*

6.3.1. *Antepenultimate syllable*

The antepenultimate syllable was on average 23.3% longer when accented than when unaccented. This effect was significant from an analysis of variance with Accent as a fixed factor (Accented *vs.* Unaccented), and Phrase Type and Subjects as random factors (by Subjects: $F(1, 5) = 22.923$, $p < 0.01$, by Phrase Type $F(1, 7) = 26.691$, $p < 0.01$).

6.3.2. *Penultimate syllable*

A 12% lengthening was observed on the penultimate syllable when in a pitch accented word (cf. Fig. 5). As for the antepenultimate syllable, this effect was significant from an analysis of variance with Accent as a fixed factor (Accented *vs.* Unaccented), and Phrase Type and Subjects as random factors [by Subjects: $F(1,5) = 16.016$, $p < 0.05$, by Phrase Type: $F(1,7) = 8.314$, $p < 0.05$]. This result suggests that accentual lengthening does extend to the second syllable in trisyllabic words.

6.3.3. *Final syllable*

The final syllable in accented trisyllabic words was on average 13.7% longer than the final syllable in unaccented trisyllabic words. Again, this effect was significant from an analysis of variance with Accent as a fixed factor (Accented *vs.* Unaccented), and Phrase Type and Subjects as random factors [by Subjects: $F(1,5) = 16.016$, $p < 0.05$; by Phrase Type: $F(1,7) = 8.314$, $p < 0.05$]. Mean durations for the antepenultimate, penultimate, and final syllables are plotted in Fig. 7.

6.4. *Discussion*

This experiment showed that lengthening related to accent extends throughout a trisyllabic word. These results eliminate the possibility that lengthening related to accent only extends one syllable away from the pitch accented syllable. However, we unfortunately have no positive evidence to support either the view that accentual lengthening extends to the right of a pitch accent until the end of the word, or, that accentual lengthening spills over to a following syllable and is combined with final lengthening which is more or less localized on a final syllable of a word. It is possible that these two mechanisms can be distinguished in terms of the distribution of lengthening within the segments of the final syllable (cf. Turk and Shattuck-Hufnagel submitted, for a discussion of the durational pattern expected for word-final lengthening). Another finding which warrants further investigation is the fact that the syllable with which the pitch accent is associated was found to lengthen the most, while penultimate and final syllables had approximately the same magnitude of lengthening. However, we hesitate to make much of this finding given the fact that the segmental composition of the three syllables in our words was not comparable. Further work is needed to determine if this type of asymmetry is real.

7. General Summary and Discussion

Experiment 1 showed that accentual lengthening extends beyond the vowel with which a pitch accent is associated, but that consonants were lengthened if they belonged to a pitch accented syllable/foot/word. The experiment showed an interesting asymmetry: initial consonants were lengthened more and more reliably than final consonants. Experiment 2 showed that accentual lengthening extends beyond a syllable with which the pitch accent is associated, and provided more information about the type of structure which influences its extent. Experiment 2 showed that most of the effects of accent occurred on the pitch accented syllable and on a syllable to its right within a word, regardless of whether the word contained a single foot, or two monosyllabic feet. A small amount of lengthening was found on an initial syllable in a pitch accented word for some

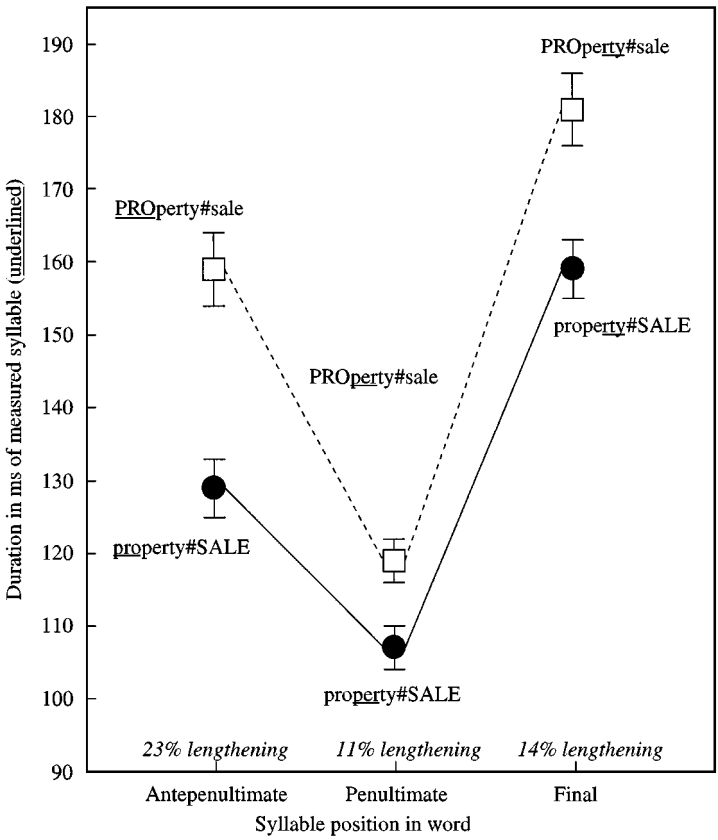

Figure 7. Mean durations (and standard errors) of antepenultimate, penultimate, and final syllables in accented *vs.* unaccented words with primary stress on the antepenultimate syllable (Experiment 4). The "property sale" text exemplifies the type of word sequence used in the experiment. □, initial accent (A_U); ●, final accent (U_A).

subjects, and a small amount of lengthening was also found on a syllable adjacent to a pitch accented syllable across a right-hand word boundary. No lengthening effects were observed on a syllable to the left of a pitch accented syllable across a word boundary. Taken together with the results of Experiment 1, these results suggest that both the left edge of a pitch accented syllable and the left and right edges of a word attenuate the spread of accentual lengthening. Experiment 3 corroborated the findings of Experiment 2 in clearly showing the influence of a word-sized unit, and in the fact that rightward residual effects across a word boundary were marginally stronger than leftward effects across the combination of the left edge of a pitch accented syllable and the left edge of a word. Experiment 4 showed that accentual lengthening could extend throughout all syllables in a three-syllable word with primary stress on the first syllable.

These experiments have contributed to a better characterization of the structures which influence accentual lengthening, and they have shown clearly that the role of constituent boundaries as we have defined them is to attenuate, but not necessarily to block the effects. This finding is perhaps not surprising, given the fact that durational adjustments are not likely to happen instantaneously, and it may indicate that the

structural influence of boundaries on durational effects is qualitatively different from their apparent all or none influence on segmental phonological phenomena (Selkirk, 1978; Nespor & Vogel, 1986; Hayes, 1989). On the other hand, it may be that the acoustic landmarks used as correlates of constituent boundaries are not an accurate reflection of their true location, if indeed such locations can be identified with specific points in the speech stream. In this study, word and syllable boundaries were said to occur at the onset or offset of the acoustic reflexes of consonantal constrictions. As we know from studies of coarticulation, the articulatory trajectories towards these constrictions can begin well before a maximum constriction is achieved, and often end several tens of milliseconds after the constriction has been released. A better characterization of the locations of constituent boundaries may make accentual lengthening look as though it is better contained within particular domains. Studies of the articulatory characteristics of accentual lengthening may eventually resolve this issue.

Another issue which remains unresolved is whether the fact that most accentual lengthening effects appear to extend from the left edge of a pitch accented syllable to the right edge of a word is due to accentual lengthening *per se* or rather to a combination of accentual lengthening and word-final lengthening on a pitch accented word. While the composite view is attractive, since it would mean that each of the effects could be more or less localized, it nevertheless raises a problem, since only pitch accented words seem to exhibit large amounts of word-final lengthening.

The view that accentual lengthening is an effect which spans uniformly over several syllables and segments is also problematic given some of the asymmetries that were observed in these experiments. In Experiment 1, pitch accented syllable onsets were lengthened more than comparable codas. In Experiment 2, lengthening on both syllables in words like *bacon* appears to be fairly uniform, although this uniformity may be illusory given the possibility that onset segments in pitch accented syllables may have been lengthened more than the coda segments. In Experiment 4, the primary stressed syllable of three-syllable words like *property* showed more accentual lengthening than the second and third syllables. Granted, the comparisons of magnitudes of effects in different syllables in Experiments 2 and 4 may not be valid, since the syllables which made up the test words were composed of different phonetic segments, and it is unclear whether all phonetic segments show similar accentual lengthening patterns. More information is therefore needed about relative magnitudes of lengthening in the syllables and segments of polysyllabic words.

Yet another question that deserves further attention is how to best characterize the word-sized unit which clearly constrains this lengthening phenomenon. Results of Experiment 2 suggest that it is probably not the size of a stem—many of the stimuli in Experiment 2 were 2-foot compound words, and accentual lengthening worked the same way in compound words as it did in non-compound words. The fact that this unit is not likely to be stem-sized precludes the possibility that it is a minimal prosodic word, as described in Selkirk (1980) or McCarthy (1993). Assuming that prosodic words can be nested under higher prosodic words, as in $[[[\text{sing}]\text{ing}]_{\text{Pwd}}]_{\text{Pwd}}$ or $[[\text{shake}]_{\text{Pwd}}$ $[\text{down}]_{\text{Pwd}}]_{\text{Pwd}}$, it is possible that it corresponds to a higher prosodic word, or perhaps Clitic Group in the sense of Hayes (1989) and Nespor & Vogel (1986). However, Clitic Groups in both Hayes' and Nespor and Vogel's theories can include certain types of adjacent function words, and we are only beginning to understand the behavior of function words with respect to accentual lengthening (cf. Cambier-Langeveld & Turk, submitted and Turk and Shattuck-Hufnagel, submitted). Alternatively, it could turn out

that this unit corresponds better to a terminal element of a syntactic tree, that is, to something that corresponds more closely to something of the size of an orthographic word.

We also call attention to the fact that the type of accentual lengthening discussed in this paper was lengthening related to contrastive nuclear accent in sentences spoken at a normal rate. It is still unclear whether these lengthening patterns also apply to non-nuclear prominences, or to accentual lengthening at faster or slower rates of speech.

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Appendix A: Test sentences for Experiment 1

/b/ I said "BAY beagle", not "RAY beagle"
I said "bay BEAGLE", not "bay BAGEL"
I said "BABE eagle", not "BATHE eagle"
I said 'babe EAGLE", not "babe EAGER"

I said "BAR beating", not "MAR beating"
I said "bar BEATING", not "bar BOATING"
I said "BARB eating", not "BARD eating"
I said 'barb EATING", not "barb EARRING"

/k/ I said "BUY cakes", not "MY cakes"
I said "buy CAKES", not "buy COKES"
I said "BIKE aches", not "MIKE aches"
I said "bike ACHES", not "bike APES"

I said "MAY cough", not "BAY cough"
I said "may COUGH", not "may CAUGHT"
I said "MAKE off", not "BAKE off"
I said "make OFF", not "make OUGHT"

/n/ I said "NO notions", not "LOW notions"
I said "no NOTIONS", not "no NATIONS"
I said "KNOWN oceans", not "MOAN oceans"
I said "known OCEANS", not "known OPENS"

I said "BEAN ice", not "MEAN ice"
I said "bean ICE", not "bean IKE"

I said "BE nice", not "ME nice"
I said "be NICE", not "be NOOSE"

/f/ I said "SAY fluster", not "FAY fluster"
I said "say FLUSTER", not "say FLOATER"
I said "SAFE lustre", not "SAKE lustre"
I said "safe LUSTRE", not "safe BUSTER"

I said "BEE farm", not "KNEE farm"
I said "bee FARM", not "bee FORM"
I said "BEEF arm", not "REEF arm"
I said "beef ARM", not "beef AIM"

Appendix B: Test sentences for Experiment 2

Homophonic word pairs with reduced central syllables (*underlined*):

Say "BAKE enforce", don't say "TANK enforce"
Say "bake ENFORCE", don't say "bake REMOVE"
SAY "bake enforce", don't SHOUT "bake enforce"
Say "BACON force", don't say "REGAL force"
Say "bacon FORCE", don't say "bacon HOARD"
SAY "bacon force", don't SHOUT "bacon force"

Say "CAN inspire", don't say "TAKE inspire"
Say "can INSPIRE", don't say "can REQUITE"
SAY "can inspire", don't SHOUT "can inspire"
Say "CANNON spire", don't say "BANKER spire"
Say "cannon SPIRE", don't say "cannon TIRED"
SAY "cannon spire", don't SHOUT "cannon spire"

Say "THANK fulfil", don't say "BOAT fulfil"
Say "thank FULFIL", don't say "thank SURREAL"
SAY "thank fufil", don't SHOUT "thank fulfill"
Say "THANKFUL Phil", don't say "SHAMELESS Phil"
Say "thankful PHIL", don't say "thankful BOB"
SAY " thankful Phil", don't say SHOUT "thankful Phil"

Say "CUBE explain", don't say "TIME explain"
Say "cube EXPLAIN", don't say "cube IMPRESS"
SAY "cube explain", don't SHOUT "cube explain"
Say "CUBICS plane", don't say "QUADRAL plane"
Say "cubics PLANE", don't say "cubics BRAKE"
SAY "cubics plane", don't SHOUT "cubics plane"

Say "TOE content", don't say "SEE content"
Say "toe CONTENT", don't say "toe REPINE"

SAY "toe content", don't SHOUT "toe content"
Say "TOKEN tent", don't say "BUNKER tent"
Say "token TENT", don't say "token RHYME"
SAY "token tent", don't SHOUT "token tent"

Say "PAY perform", don't say "DRY perform"
Say "pay PERFORM", don't say "pay DECIDE"
SAY "pay perform", don't SHOUT "pay perform"
Say "PAPER form", don't say "SPECIAL form"
Say "paper FORM", don't say "paper CHART"
SAY "paper form", don't SHOUT "paper form"

Say "DAN surprise", don't say "PARK surprise"
Say "Dan SURPRISE", don't say "Dan PRETEND"
SAY "Dan surprise', don't SHOUT "Dan surprise"
Say "DANCER prize", don't say "TOKEN prize"
Say "dancer PRIZE", don't say "dancer CHANT"
SAY "dancer prize", don't SHOUT "dancer prize"

Say "DAY today", don't say "WELL today"
Say "day TODAY", don't say "day DEPART"
SAY "day today", don't SHOUT "day today"
Say "DATA day", don't say "LONGER day"
Say "data DAY", don't say "data FORM"
SAY "data day", don't SHOUT "data day"

Homophonic word pairs with full central syllables (*underlined*):

Say "KNEE capsize", don't say "DOWN capsize"
Say "knee CAPSIZE", don't say "knee PREVENT"
SAY "knee capsize", don't SHOUT "knee capsize"
Say "KNEECAP size", don't say "AWESOME size"
Say "kneecap SIZE", don't say "kneecap JERK"
SAY "kneecap size", don't SHOUT "kneecap size"

Say "NEAR bisect", don't say "HOLD bisect"
Say "near BISECT", don't say "near DELETE"
SAY "near bisect", don't SHOUT "near bisect"
Say "NEARBY sect", don't say "GRUESOME sect"
Say "nearby SECT", don't say "nearby PARK"
SAY "nearby sect", don't SHOUT "nearby sect"

Say "THERE foreclose", don't say "BANK foreclose"
Say "there FORECLOSE", don't say "there INTRUDE"
SAY "there foreclose", don't SHOUT "there foreclose"
Say "THEREFORE close", don't say "DOORWAY close"
Say "therefore CLOSE", don't say "therefore MOVE"
SAY "therefore close", don't SHOUT "therefore close"

Say "SKIM Peking", don't say "DRAIN Peking"
Say "skim PEKING" don't say "skim DELUDE"
SAY "skim Peking", don't SHOUT "skim Peking"
Say "SKIMPY king" don't say "AWFUL king"
Say "skimpy KING", don't say "skimpy SHIRT"
SAY "skimpy king", don't SHOUT "skimpy king"

Say "SHAKE downstairs", don't say "JUMP downstairs"
Say "shake DOWNSTAIRS", don't say "shake RELEASE"
SAY "shake downstairs", don't SHOUT "shake downstairs"
Say "SHAKEDOWN stairs", don't say "RECENT stairs"
Say "shakedown STAIRS", don't say "shakedown PARTS"
SAY "shakedown stairs", don't SHOUT "shakedown stairs"

Say "THERE foursquare", don't say "WAIT foursquare"
Say "there FOURSQUARE", don't say "there DECIDE"
SAY "there foursquare", don't SHOUT "there foursquare"
Say "THEREFORE square", don't say "RANDOM square"
Say "therefore SQUARE", don't say "therefore PROVE"
SAY "therefore square", don't SHOUT "therefore square"

Say "CROW barbette", don't say "HIGH barbette"
Say "crow BARBETTE", don't say "crow ENTHUSE"
SAY "crow barbette", don't SHOUT "crow barbette"
Say "CROWBAR bet", don't say "EVIL bet"
Say "crowbar BET", don't say "crowbar FORCE"
SAY "crowbar bet", don't SHOUT "crowbar bet"

Say "HARD whereby", don't say "STAND whereby"
Say "hard WHEREBY", don't say "hard MALIGN"
SAY "hard whereby", don't SHOUT "hard whereby"
Say "HARDWARE buy", don't say "USEFUL buy"
Say "hardware BUY", don't say "hardware STORE"
SAY "hardware buy", don't SHOUT "hardware buy"

Nonsense unpaired words with reduced central syllables (*underlined*):

Say "JOKE enforce", don't say "BRAND enforce"
Say "joke ENFORCE", don't say "joke DEPEND"
SAY "joke enforce", don't SHOUT "joke enforce"

Say "PLANE inspire", don't say "BOAT inspire"
Say "plane INSPIRE", don't say "plane REDUCE"
SAY "plane inspire", don't SHOUT "plane inspire"

Say "PLANK fulfil", don't say "SPEED enforce"
Say "plank FULFIL", don't say "plank EXPOSE"
SAY "plank fulfil", don't say SHOUT "plank fulfil"

Say “TUBE explain”, don’t say “PAST explain”
Say “tube EXPLAIN”, don’t say “tube LAMENT”
SAY “tube explain”, don’t SHOUT “tube explain”

Nonsense unpaired words with full central syllables (*underlined*):

Say “TREE capsize”, don’t say “WHEN capsize”
Say “tree CAPSIZE”, don’t say “tree FORFEND”
SAY “tree capsize”, don’t SHOUT “tree capsize”

Say “PIER bisect”, don’t say “SAND bisect”
Say “pier BISECT”, don’t say “pier RECOIL”
SAY “pier bisect”, don’t SHOUT “pier bisect”

Say “HAIR foreclose”, don’t say “ROOT foreclose”
Say “hair FORECLOSE”, don’t say “hair RELEASE”
SAY “hair foreclose”, don’t SHOUT “hair foreclose”

Say “SWIM Peking”, don’t say “PRAY Peking”
Say “swim PEKING”, don’t say “swim PRETEND”
SAY “swim Peking”, don’t SHOUT “swim Peking”

Meaningful unpaired words with reduced central syllables (*underlined*):

Say “PLAY today”, don’t say “WATCH today”
Say “play TODAY”, don’t say “play AGAIN”
SAY “play today”, don’t SHOUT “play today”

Say “BIG surprise”, don’t say “NICE surprise”
Say “big SURPRISE”, don’t say “big DEBATE”
SAY “big surprise”, don’t SHOUT “big surprise”

Say “PLEASE perform”, don’t say “DON’T perform”
Say “please PERFORM”, don’t say “please ATTEND”
SAY “please perform”, don’t SHOUT “please perform”

Say “STAY content”, don’t say “BE content”
Say “stay CONTENT”, don’t say “stay BELOW”
SAY “stay content”, don’t SHOUT “stay content”

Meaningful unpaired words with full central syllables (*underlined*):

Say “STAY downstairs”, don’t say “EAT downstairs”
Say “stay DOWNSTAIRS”, don’t say “stay COMPLETE”
SAY “stay downstairs”, don’t SHOUT “stay downstairs”

Say “NEW Peking”, don’t say “OLD Peking”
Say “new PEKING”, don’t say “new BANGKOK”
SAY “new Peking”, don’t SHOUT “new Peking”

Say "DON'T capsize", don't say "PLEASE capsize"
Say "don't CAPSIZE", not "don't ESCAPE"
SAY "don't capsize", don't SHOUT "don't capsize"

Say "STAND foursquare", don't say "MARCH foursquare"
Say "stand FOURSQUARE", don't say "stand ALERT"
SAY "stand foursquare", don't SHOUT "stand foursquare"

Appendix C: Test sentences for Experiment 3

(Test words are underlined)
I said "DREAM sad scenes", not "PLAY sad scenes"
I said "dream sad SCENES", not "dream sad SONGS"
I said "DRAG white socks", not "MEND white socks"
I said "drag white SOCKS", not "drag white SHIRTS"
I said 'MISS nine steps", not "TAKE nine steps"
I said "miss nine STEPS", not "miss nine STOCKS"
I said "SEND six more", not "SIGN six more"
I said "send six MORE", not "send six THERE"
I said "HOLD new scores", not "TOLD new scores"
I said "hold new SCORES", not "hold new GOALS"
I said "SING four songs", not "PLAY four songs"
I said "sing four SONGS", not "sing four HYMNS"
I said "CALM Sam soon", not "WARN Sam soon"
I said "calm Sam SOON", not "calm Sam DOWN"
I said "BLESS Mark now", not "MISS Mark now"
I said "bless Mark NOW", not "bless Mark THEN"
I said "CHASE Nick never", not "RACE Nick never"
I said "chase Nick NEVER", not "chase Nick AFTER"
I said "HIDE Sue faster", not "SCARE Sue faster"
I said "hide Sue FASTER", not "hide Sue LATER"
I said "KEEP Sam smarter", not "MAKE Sam smarter"
I said "keep Sam SMARTER", not "keep Sam FITTER"
I said "DROP Stan slowly", not "MEET Stan slowly"
I said "drop Stan SLOWLY", not "drop Stan QUICKLY"

Appendix D: Test sentences for Experiment 4

I said "ALTERNATIVE name", not "PATERNITY name"
I said "alternative NAME", not "alternative LOOK"
I said "PROPERTY over", not "GENERATE over"
I said "property OVER", not "property AFTER"
I said "CAVITY drill", not "QUALITY drill"
I said "cavity DRILL", not "cavity DRAIN"
I said "FANTASY tale", not TERRIBLE tale"
I said "fantasy TALE", not fantasy PLAY"

I said “FUNCTIONAL dress”, not “SUITABLE dress”
I said “functional DRESS”, not “functional DRAIN”
I said “MONITOR clock”, not “CALIBRATE clock”
I said “monitor CLOCK”, not “monitor WATCH”
I said “OBSTACLE down”, not “CONSTABLE down”
I said “obstacle DOWN”, not “obstacle GONE”
I said “PROPERTY sale”, not “LEGACY sale”
I said “property SALE”, not “property THEFT”