Chapter 4

Experiment 2: Domain-edge and domain-span processes

4.1 Introduction

Experiment 2 tests the existence of domain-edge and domain-span processes at two levels of linguistic structure, the word and the utterance; the locus of accentual lengthening and its interaction with domain-edge and domain-span processes are also examined. The results—described in detail in later sections of this chapter—show evidence for domain-edge processes, at both word level and utterance level: word-initial lengthening, utterance-initial shortening and utterance-final lengthening, effects which do not appear affected by the presence of pitch accent. The results do not support domain-span processes at either word level or utterance level. The previously-observed word-span effect (polysyllabic shortening) is shown to be a result of accentual lengthening: the locus of lengthening is the word, and the distribution of the effect varies between monosyllables, disyllables and trisyllables, such that there is less accentual lengthening of the primary stressed syllable when there are more additional syllables in the word. There is evidence for only one domain-span effect, at the word-rhyme level, and this may be interpretable as a word-final effect.

4.1.1 Background

Experiment 1, in Chapter 3, shows that stressed syllables have greater duration in monosyllabic words than in disyllabic words. This result is observed when the word is unaccented or accented, and whether the additional syllable in the disyllable is unstressed or secondary stressed. The shortening effect is much greater for stressed syllables which are word-initial in the disyllable than for those which are word-final: for example, /pe/ is 25 % shorter in *paper form* than in *pay perform*; /fɔɹm/ is 5% shorter in *pay perform* than in *paper form*[1].

The asymmetry in these observations suggests that they may arise from a small word-initial lengthening process and a large word-final lengthening process, but other explanations are possible: for example, polysyllabic shortening, a word-span compression process. As discussed in Chapter 2, domain-span processes are also linked with constituents other than the word: in particular, an utterance-span compression process has been proposed, such that words are longer in shorter sentences.

Several syntactic and prosodic constituents are identified with domain-edge processes: studies discussed in Chapter 2 link final lengthening with words, various syntactic and prosodic phrases, and utterances; others find initial lengthening in words and sometimes in higher-level phrases. Some studies suggest that domain-edge processes are associated with a number of levels of a prosodic constituent hierarchy, with greater lengthening at higher-level constituent boundaries, and there is also evidence for an utterance-initial *shortening* effect.

The durational effects of pitch accent, discussed in Chapters 2 and 3, are also examined in Experiment 2. The interactions of accent with edge and span processes are considered, to determine whether accent simply amplifies existing effects, or alters how they are manifest by, for example, changing the locus.

Research on domain-edge and domain-span processes at the word level and the utterance level and on the influence of pitch accent is reviewed[2] in Section 4.1.2, and experimental hypotheses are formulated. Questions of experimental design raised by studies which present evidence for a hierarchy of domain-edge processes are discussed in Section 4.1.3.

4.1.2 Experimental hypotheses

The experimental hypotheses to be tested in Experiment 2 are presented here, and the previous research which suggests each hypothesis is briefly reviewed. The hypotheses relate to the concept of the locus in general, and to:

- Word-edge and word-span processes.
- Utterance-span processes.
- Utterance-initial processes.
- Utterance-final processes.
- Accentual lengthening, and its interaction with edge and span processes.

[1]The transcriptions are for the experimental subjects, Scottish English speakers from Edinburgh.
[2]Previous research is discussed in detail in Chapters 2 and 3.

For each set of hypotheses, the findings of Experiment 2 are briefly noted at the end of the subsection (indicated thus $\Longrightarrow$); full details are given in the appropriate results section, as indicated.

The locus

Domain-edge locus hypothesis: each domain-edge process has a characteristic phonologically-defined locus.

- The alternative hypothesis is that lengthening is greatest at the boundary, and decreases gradually with distance from the edge, without being confined to particular phonological constituents.

As defined in Chapter 1, the locus is the stretch of speech which undergoes the durational effect associated with a domain: for example, the word is a domain of initial lengthening and the locus is the onset of the word-initial syllable. Studies of speech timing often look at the effect of some condition upon the duration of a particular preselected unit: for example, in Experiment 1 and elsewhere, the effect of word length on stressed syllable duration is reported. This approach could mask the fact that certain durational effects may be focused at specific loci: domain-final lengthening may be restricted to the final syllable rhyme (for example: Oller 1973; Campbell & Isard 1991; Wightman *et al.* 1992); domain-initial lengthening may be restricted to the initial syllable onset (for example: Oller 1973; Fougeron & Keating 1997). Lengthening may increase within the locus towards the domain boundary (for example: Cambier-Langeveld 2000) but this distribution may vary according to segmental identity (Oller 1973). To measure the duration of a syllable or a foot or a word ignores the possible differential distribution within this unit, with some constituents affected strongly and others not at all.

Domain-span locus hypothesis: a domain-span compression process shortens only the phonological head of the domain.

- This may be interpreted either as an all-or-nothing distinction, or as a gradient effect, with lesser compression seen outside the phonological head of the domain. The alternative hypothesis is that all parts of the domain are equally affected by domain-span shortening.

The position of the locus of a domain-edge process is, by definition, the domain boundary. For domain-span processes, two possibilities for the identity of the locus are suggested by previous studies. Firstly, studies such as Barnwell (1971) indicate that all the subconstituents of the domain may be affected: for example, all the syllables in the word are shortened as the length of the word increases; in this case, the domain and the locus are co-extensive. Secondly, studies such as Lehiste (1972) may be taken to imply that the domain head may be affected—for example, the primary stressed syllable in the word is shortened as the word increases in length—but the other syllables are unaffected; similarly, as found by Lehiste (1972) and Port (1981), the vowel nucleus within the stressed syllable may show a greater effect of word length than the onset or coda.

If the greatest effect of a domain-span process is found to occur on the domain head, this could either be because it is the locus of the process, or because the locus is co-extensive with the domain but the most prominent subconstituent of the domain is longer and more compressible. In the latter case, unstressed syllables, being shorter, may manifest smaller domain-span compression effects than a stressed syllable. Likewise, the syllable nucleus will often be the longest part of the stressed syllable, and even when it is no longer than the onset or coda, it may be more compressible than onset or coda consonants such as stops.

$\Longrightarrow$ The locus hypotheses pertain to all parts of Experiment 2. The domain-edge locus hypothesis is supported: in particular, word-initial lengthening (Section 4.6) and utterance-final lengthening (Section 4.5) are shown to be confined to phonologically-defined loci. The domain-span locus hypothesis is partially supported: the only domain-span effect indicated by Experiment 2—word-rhyme-span compression as described in Section 4.6—is localised within the stressed syllable on the nucleus; however, unstressed syllables within the word-rhyme also appear to be affected. The experimental outcomes relating to the locus hypotheses are discussed in detail in Section 4.10.

Word-edge and word-span processes

Word-span hypothesis: primary stressed syllable duration is inversely related to word length in syllables.

Word-rhyme-span hypothesis: primary stressed syllable duration is inversely related to word-rhyme length in syllables.

Word-initial hypothesis: the duration of the primary stressed syllable onset is greater word-initially than word-medially in utterance-medial words.

Word-final hypothesis: the duration of the primary stressed syllable rhyme is greater word-finally than word-medially in utterance-medial words.

The asymmetry in the word-level effect in Experiment 1 could be an experimental artefact: the word-final test syllables (underlined) are also phrase-final (for example: *SAY "knee capsize", don't SHOUT "knee capsize"*) and phrase-final lengthening may mask a symmetrical underlying word-span compression process: polysyllabic shortening as defined in Chapter 2. Turk & Shattuck-Hufnagel (2000) suggest this process accounts for their results, in conjunction with word-initial lengthening and what they call "syllable ratio equalisation"[3].

Alternatively, the asymmetry in Experiment 1 may be caused by a combination of polysyllabic shortening and another domain-span compression process, at the word-rhyme-level: as defined in Chapter 3, the word-rhyme begins with a primary stressed syllable and continues to a word boundary. The results of Lehiste (1972) and Port (1981) suggest a word-rhyme-span process, but the effect of adding syllables before the primary stress is not examined, and so comparison of word-rhyme-span and word-span hypotheses is not possible. Turk & Shattuck-Hufnagel (2000) consider the existence of "an asymmetric polysyllabic shortening effect", functionally equivalent to an additive combination of word-span and word-rhyme-span effects, but reject it for reasons outlined in Chapter 3. This combination of domain-span processes could account, however, for the observations of Lindblom (1968) for Swedish and Nooteboom (1972) for Dutch.

A combination of word-edge processes could also explain the results of Experiment 1: smaller word-initial lengthening and larger word-final lengthening. Oller (1973), Cooper (1991), Fougeron & Keating (1997) and Turk & Shattuck-Hufnagel (2000) all find evidence for word-initial lengthening; Beckman & Edwards (1990) present evidence which could indicate word-final lengthening, but Turk & Shattuck-Hufnagel (2000) do not find strong evidence for it.

Experiment 1 could also be interpreted as a combination of domain-edge and domain-span processes: in particular, word-initial lengthening and word-rhyme-span compression. The word-level experimental hypotheses presented above are thus expressed separately for each process. The hypotheses are formulated with reference to primary stressed syllable duration; the effect of word length on unstressed syllable duration is also examined.

Word-initial accent hypothesis: word-initial lengthening of stressed syllable onsets only occurs, or is significantly greater, in accented context.

[3]It is argued in Chapter 3 that syllable ratio equalisation is superfluous to the interpretation of word-level results and thus no explicit hypothesis regarding it is formulated here. Where relevant, it is considered in relation to the results of Experiment 2.

Experiment 1 also suggests that word-initial lengthening is only significant in the presence of accent; similarly, Turk & Shattuck-Hufnagel (2000) find that word-initial lengthening is greatest and most statistically reliable when the syllable is accented.

Word-initial aspiration accent hypothesis: word-initial lengthening of aspiration in stressed-syllable-onset voiceless stops only occurs in unaccented syllables; in accented syllables, aspiration duration may be greater word-medially.

The duration of aspiration of syllable-onset voiceless stops may show a particular interaction between word position and lexical or phrasal stress. The results of Oller (1973) and Cooper (1991) suggest that in syllable-onset voiceless stops, closure duration is longer word-initially in all contexts, but aspiration duration is longer word-initially in unstressed syllables and word-medially in stressed syllables. If, as it appears, test words are accented in those studies, lexical stress and pitch accent are confounded. Turk & Shattuck-Hufnagel's (2000) results suggest that the presence of pitch accent may be the determining factor in this interaction: measuring the onsets of stressed syllables only, they find that aspiration duration of syllable-onset voiceless stops shows reliable word-initial lengthening only in unaccented context.

$\Longrightarrow$ The results for word-edge and word-span processes in Experiment 2 are described in Section 4.6. The word-span hypothesis is not supported, as an inverse relationship between primary stressed syllable duration and word length is only found for accented words. The word-rhyme-span hypothesis and the word-final hypothesis are both partially supported: there is an effect of word-rhyme length localised on the stressed syllable nucleus, which also affects unstressed syllables; this also could be interpreted as a word-final effect, as discussed in Section 4.6 and further in Chapter 5. The word-initial hypothesis is clearly supported, and the effect is comparable in accented and unaccented words, hence the word-initial accent hypothesis is not supported. The word-initial aspiration accent hypothesis is also not supported: for syllable-onset voiceless stops, closure and aspiration duration are similarly affected by word position, and there appears to be no interaction with accent.

Utterance-span processes

Utterance-span hypothesis: primary stressed syllable duration is inversely related to the number of syllables in an utterance.

Some studies claim that a domain-span process operates at the sentence/utterance level: Lehiste (1974), cited in Klatt (1976), finds that constituents of the sentence are shorter when the sentence is longer; a study by Rakerd *et al.* (1987) of monosyllabic content words supports this conclusion. In contrast, Gaitenby (1965) finds little effect of sentence length, beyond what could be explained as final lengthening. The syntactic sentence and the prosodic utterance are often co-extensive, particularly where, as in Experiment 2, single sentences are read in isolation.

$\Longrightarrow$ The utterance-span hypothesis is not supported in Experiment 2, as described in Section 4.5.

Utterance-initial processes

Utterance-initial hypothesis: word-initial stressed syllable onsets are shorter utterance-initially than utterance-medially.

Hierarchical lengthening studies indicate greater domain-edge lengthening at higher-level boundaries. Both Fourakis & Monahan (1988) and Fougeron & Keating (1997), however, find utterance-initial *shortening* of unstressed syllable onsets. Experiment 2 tests this effect in primary stressed syllables.

$\Longrightarrow$ The utterance-initial hypothesis is supported in Experiment 2 for certain stressed syllable onsets, as described in Section 4.5

Utterance-final processes

Utterance-final locus hypothesis: the locus of utterance-final lengthening is the word-rhyme.

Klatt (1976) and Cummins (1999) claim that utterance-final lengthening extends over several syllables, although Oller (1973) and Campbell & Isard (1991) indicate that the largest effect occurs on the utterance-final syllable rhyme. Cambier-Langeveld (2000) finds a similar locus for utterance-final lengthening to that suggested by Nakatani *et al.* (1981) and Turk (1999) for phrase-final lengthening: both the utterance-penultimate stressed syllable, if the final syllable is unstressed, and the absolute final syllable are lengthened. This result suggests that the locus could be the word-rhyme, possibly excluding the onset of the primary stressed syllable.

Utterance-final locus distribution hypothesis: the distribution of utterance-final lengthening is progressive within the locus.

Where both syllables in the word-rhyme show phrase-final or utterance-final lengthening, previous studies suggest that the effect appears to be progressive: that is, there is greater lengthening closer to the boundary. Cambier-Langeveld (2000) for Dutch and Berkovits (1993a, 1993b) for Hebrew suggest that lengthening is similarly progressive within the final syllable rhyme. Oller (1973) for English, however, indicates variations in the distribution of lengthening according to the segmental identity of subsyllabic constituents.

Utterance-final accent hypothesis: the magnitude of utterance-final lengthening is not affected by the presence of a pitch accent on the utterance-final word.

Some studies may confound final lengthening with the effects of pitch accent: Oller (1973), for example, measures utterance-final lengthening in words that appear likely to be accented. The locus and magnitude of final lengthening may be different when the utterance-final word is not accented. Price *et al.* (1991) suggest an interaction between accentual lengthening and phrase-final lengthening such that neither one is as great in the presence of the other as in its absence. Cambier-Langeveld (2000) finds, however, that the magnitude of lengthening on utterance-final syllables is very similar in accented and unaccented context: the proportion of final lengthening is greater in unaccented context, because the syllables are shorter, but the interaction is not significant. For Dutch, in contrast, she finds a large attenuation of final lengthening in accented context.

$\Longrightarrow$ As described in Section 4.8, the utterance-final locus hypothesis is supported, although lengthening does not occur on all parts of the word-rhyme: the stressed syllable coda is lengthened in utterance-antepenultimate position and utterance-penultimate position, as are the following unstressed syllables within the word; where the stressed syllable is in utterance-final position, the nucleus and coda are lengthened. The utterance-final locus distribution hypothesis and the utterance-final accent hypothesis are supported, although there is a non-significant trend towards attenuation of final lengthening in accented words.

Pitch accent

Word-rhyme accent hypothesis: the locus of accentual lengthening is the word-rhyme.

Bimodal accent hypothesis: the locus of accentual lengthening is the primary stressed syllable and the word-final syllable.

Sluijter (1995), Turk & Sawusch (1997) and Turk & White (1999) find that pitch accent causes lengthening of all parts of the accented syllable and also affects other syllables in the same word. In disyllables, a syllable following the accented syllable (for example: /kæp/ in *kneecap*) is lengthened more than a syllable preceding an accented syllable (for example: /kæp/ in *capsize*). In left-headed trisyllables such as *property*, both unstressed syllables show some lengthening. Two interpretations of the locus of accentual lengthening are suggested, as presented above. In one case, the bimodal hypothesis, the locus is suggested to comprise two discrete subconstituents. In either case, it appears that syllables adjacent to the locus within the word also manifest small lengthening effects.

Word-span accent hypothesis: the magnitude of accentual lengthening on the primary stressed syllable is inversely related to word length.

In Experiment 1, accentual lengthening of the primary stressed syllable is greater, in absolute and proportional terms, in monosyllables than in disyllables. Experiment 2 examines this apparent interaction between pitch accent and word length.

$\Longrightarrow$ As described in Section 4.9, the word-rhyme accent hypothesis and the bimodal accent hypothesis are not supported in Experiment 2: although there is accentual lengthening within the word rhyme, there is also lengthening in the unstressed syllable preceding the word-rhyme, suggesting that the locus of accentual lengthening is the word; furthermore, lengthening appears greatest at word edges. The word-span accent hypothesis is supported: accentual lengthening on the stressed syllable is greatest in monosyllables and progressively less in disyllables and trisyllables.

4.1.3 Experimental design considerations

The design of Experiment 2, which tests the hypotheses outlined above, is described in Section 4.2. Some of the issues which inform the design and interpretation of the experiment are discussed now, with particular reference to two previous studies of domain-edge processes in hierarchical constituents.

When measuring the magnitude of a domain-edge durational effect in a particular constituent, it is necessary to reliably identify the constituent itself. Syntactic constituents have well-established discovery procedures, but as illustrated in Chapter 2, it seems clear that syntactic constituents do not consistently comprise the domains of durational processes. In many cases, there is a process of re-analysis of syntactic constituents into the prosodic constituents which appear to be the domains of durational processes. Important aspects of this mapping remain uncertain, however:

- The number of prosodic constituents required to account for the segmental and suprasegmental processes of connected speech.
- Whether prosodic hierarchies comprise a single structure or partially-independent structures, such as prominence and constituent hierarchies.
- The balance between syntax and other factors such as speech rate, constituent length and pragmatic interpretation in the construction of prosodic constituents.

At the highest and lowest levels of structure, prosodic constituents are quite well motivated. Each lexical word appears to comprise a prosodic word, although, as discussed in Chapter 2, the prosodic status of grammatical words and the existence of nested prosodic words remain matters of debate. Intonational phrases are readily identifiable in speech through characteristic events—one or more pitch accents, declination of fundamental frequency, and a boundary tone—although the mapping of intonational phrases onto syntax is variable, with a number of possibilities available for most sentences. Utterances are fairly well-defined in most contexts, generally identifiable with a single sentence, encompassing one or more intonational phrases, and very likely to be pause-delimited.

Between the levels of the word and the intonational phrase, however, the number of prosodic constituents and their segmental and suprasegmental consequences are less clear. The evidence for certain constituents, such as the clitic group and various types of phonological phrase, is discussed in Chapter 2. In the current context, the important questions are:

- How are the boundaries of these putative constituents identified?
- What are the durational processes associated with these boundaries?

Experiments on hierarchical lengthening processes generally adopt one of two approaches to identifying prosodic boundaries. In corpus-based studies, such as Ladd & Campbell (1991) and Wightman *et al.* (1992), a set of recorded sentences is examined by a phonetician, who locates boundaries of different types according to acoustic criteria. In experimental studies, such as Ferreira (1991) and Fougeron & Keating (1997), sentences are designed to elicit specific prosodic boundaries at particular points in the recorded utterance. One study of each type is examined here, to illustrate the difficulties inherent in such experiments, and thereby inform the design and interpretation of Experiment 2.

Wightman, Shattuck-Hufnagel, Ostendorf and Price (1992)

Four professional radio announcers read 35 pairs of phonetically-similar but syntactically-ambiguous sentences, which are designed to be fully voiced. Speech segment labels are aligned automatically and the resulting segment durations are normalised for phoneme identity and speech rate.

Three researchers assess boundary strength between each pair of words, using a system of seven "break indices", the precursor to that described in Silverman *et al.* (1992) as part of the ToBI ("Tone and Break Indices") system for the transcription of prosody. The number of indices reflects the maximum number of prosodic constituents at and above the word level proposed in the literature, except for proposals such as Ladd (1986) allowing recursion of constituents[4]. An index of 0 indicates no perceived prosodic break and corresponds to a clitic group boundary; an index of 4 corresponds to an intonational phrase boundary, the lowest level with a boundary tone; an index of 6, marking the end of a sentence, effectively equates to an utterance boundary.

Wightman *et al.* test the hypothesis that boundaries induce lengthening in the stress-delimited foot that contains them (see for example: Lehiste 1977). They measure the duration of four stretches of speech before each boundary: the final stressed syllable vowel and the segments between the final stressed vowel and the final vowel (where the preboundary syllable is not stressed), the final syllable vowel and the final syllable coda. They also measure the duration from the boundary to the start of the next stressed vowel. They find lengthening correlated with break index is confined to the vowel and coda of the preboundary syllable. As the preboundary vowel shows the highest correlation, they compare vowel duration, normalised for phoneme identity and speech rate, at boundaries marked with different break indices and find significant differences between vowels preceding boundaries marked with break indices 1, 2, 3 and 4. The durational differences between indices 0 and 1, and between indices 4, 5 and 6 are not significant, the latter meaning that utterance-final lengthening is no greater than intonational-phrase-final lengthening, at least on the final vowel. They conclude that preboundary lengthening can distinguish four levels of prosodic constituents: prosodic word; "a grouping of words within a larger unit", possibly the accentual phrase (Beckman & Pierrehumbert 1986); intermediate intonational phrase; intonational phrase.

[4]The seven break indices used by Wightman *et al.* (1992) do not correspond exactly to the seven levels, discussed in Chapter 2, described by Nespor & Vogel (1986): two of Nespor & Vogel's constituents—the syllable and the within-word foot—are below the word level, whereas the break indices used by Wightman *et al.* refer to perceived degrees of juncture *between* (but not within) orthographic words. Clearly, the seven break indices thus imply more prosodic constituents above the word level than the proposal of Nespor and Vogel, although it may be noted that the number of break indices is reduced to five in the subsequent development of the ToBI system.

There are several reasons to doubt the ubiquitous occurrence in normal speech of all these constituents and their distinctive degrees of preboundary lengthening. The first is the method of allocating break indices to boundaries: labels are assigned by ear, with no visual display, and another paper on the same corpus states that: "care was taken in the discussion [of discrepancies between labellers] to point out possible biases from syntax in order to avoid such influences insofar as possible" (Price *et al.* 1991:2963). This implies that the assignment of labels for constituent boundaries below the level of the intonational phrase—for which independent cues to juncture are available—is based largely on perceptions of degrees of lengthening, as segmental effects will only be manifest sporadically.

It seems unlikely that all biases from syntax could be eliminated: for example, would an intermediate intonational phrase boundary be placed within a prepositional phrase, contravening the theoretical accounts of its construction, if the degree of acoustic juncture demanded it? Moreover, it seems that some account *should* be taken of syntax if the experiment is not merely to demonstrate labellers' skill in perceiving degrees of durational variation. The later development of the ToBI system reflects this: as Wightman (2002) observes that: "the subjective opinion of the labeller was de-emphasised in favour of the identification of a specified set of prosodic phrasal constituents." In the prototype system exploited by Wightman *et al.* (1992), however, the determining characteristic of break indices below the intonational phrase appears to be perceived final lengthening.

Another problem is that the durational effects observed are not necessarily associated with boundaries, given the absence of control for the effects of pitch accent. Some of the boundaries associated with break indices will be preceded by pitch-accented words, which will be lengthened as a result of accent. Indeed, such lengthening could induce in the listener the perception of a lower-level boundary: a boundary thus identified would show relative lengthening, but it would be wrong to identify this as final lengthening. Accentual lengthening and final lengthening might be distinguished by their locus: final lengthening mainly affects the final syllable rhyme; accentual lengthening also affects the syllable onset, and preceding syllables within the word. Wightman *et al.* do find lengthening correlated with break index only on the final vowel and coda, but the manner of their segmental groupings may mask lengthening elsewhere. For instance, stressed and unstressed preboundary syllables are grouped together, and the onset duration of preboundary stressed syllables is not reported. Where this syllable is accented, it should show lengthening on the onset as well[5]. In addition, final

[5]Wightman *et al.*, furthermore, find no hierarchical lengthening effect in the post-boundary stretch, contradicting Fougeron & Keating (1997), discussed below, who find hierarchical syllable-onset lengthening. This discrepancy may arise because Wightman *et al.* do not report onset duration separately, but group it with all the post-boundary material up to the first stressed vowel. Similar masking of a localised

lengthening appears to be progressive, but here the greatest effect is evident on the final syllable nucleus; inspection of the confidence intervals for the normalised means suggests that differences in coda duration between different break indices are not significant. This pattern of durational variation may mean that final lengthening and accentual lengthening are somewhat confounded in the experimental materials.

Apart from the problem of interpretation of Wightman *et al.*'s study, there is also the question of its applicability to normal speech. Firstly, significant differences in preboundary lengthening are only obtained with data that is twice manipulated to reduce variance, using normalisation procedures for phoneme identity and speech rate; in a related study using the same data-set, Price *et al.* (1991) report mean durations normalised only for phone identity, and find the only significant difference in preboundary lengthening is between break index 4 (the intonational phrase) and the lower level indices. Secondly, as Price *et al.* (1991) indicate, the corpus is produced by professional announcers using their "standard radio style of speaking". They acknowledge that the manner of speech is not what would be observed in spontaneous conversation: "we found the FM radio style to have more clearly and consistently marked prosodic cues than a nonprofessional speaking style (Price *et al.* 1988), while sounding acceptably natural. Our hope was that this style would be easier to label prosodically, and therefore the contributions of specific phonological cues would be easier to identify [...] However, care must be taken in generalising our results to spontaneous speech, where prosodic cues may be less clearly marked" (Price *et al.* 1991:2959). One may go further, and suggest that this style of speech is qualitatively distinct from normal speech, and even from the reading of printed text in a laboratory by untrained speakers. Even if it is safe to conclude that trained speakers can make a certain number of durational distinctions that become significant in rate-normalised data, it does not follow that these distinctions, and the constituents that they imply, are customarily used by normal speakers or perceivable by normal listeners.

Fougeron and Keating (1997)

Three phoneticians, including the second author, read reiterant versions of algebraic expressions, for example:

- $89 + 89 + 89 + 89 = $ a lot
- $(89 + 89) \times (89 + 89) = $ a lot
- $89 \times (89 + 89 + 89) = $ a lot

are all spoken as the sequence:

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effect may occur in the preboundary vowel-to-vowel stretch.

- nonono no nonono no nonono no nonono = a lot

with brackets indicating the intended phrasing.

Five levels of prosodic constituency are identified: utterance; intonational phrase, generally ending at the close of a bracketed expression; phonological phrase, generally encompassing a "plus" or "times" and a subsequent numeral (a phonological phrase boundary is identified acoustically as an "intermediate break"); word, each numeral, such as "89", being regarded as a single word; syllable.

Durational measurements are reported for the recordings based on the "89" paradigm, with word-final lexical stress; other numerals are used to vary the position of lexical stress for a larger articulatory study. Mean durations of syllable onset /n/ are reported according to the highest constituent boundary they follow. Two of the three speakers distinguish four constituents according to onset duration: greatest intonational-phrase-initially: less phonological-phrase-initially; less again word-initially; shortest word-medially. One speaker shows a marked utterance-initial shortening effect, with duration comparable to word-medial position; the other has utterance-initial /n/ comparable to IP-initial /n/. The third speaker also shows a large utterance-initial shortening effect; intonational phrases and phonological phrases are not distinguished, but show initial lengthening relative to word-initial position, which shows lengthening relative to word-medial position.

Results for vowel duration preceding constituent boundaries are less clear-cut: "final vowels are generally poor indices of the hierarchical level of prosodic domains both in their spatial (linguopalatal) and temporal characteristics, though all three speakers have longer vowels [intonational and phonological] phrase-finally than [word-] finally" (Fougeron & Keating 1997:3736). The use of reiterant open syllables may contribute to this, because syllable codas may show greater final lengthening than nuclei. The relative lack of differentiation of boundary strength by preboundary vowels contrasts with Wightman *et al.*, where vowels actually show stronger hierarchical effects than coda consonants: the failure to replicate this result supports the view that Wightman *et al.*'s observations might in part be due to the presence of accent rather than phrase boundaries.

Another comparison demonstrates the limited applicability of these results: Wightman *et al.* look for seven levels of phrasing and find final lengthening evidence for most, including two levels between word and intonational phrase. Fougeron & Keating use materials designed to induce three levels of phrasing above the word-level, and find evidence for these levels from onset consonant durations. They do not, however, find reliable evidence for a single level of hierarchical final lengthening between the word and the intonational phrase, whereas Wightman *et al.* find two such levels. Furthermore, Wightman *et al.* do not find evidence for the hierarchical lengthening of syllable onsets observed by Fougeron & Keating. Clearly, these results are incompatible.

One reason for this difference may be the rather specialised nature of the experimental tasks. Wightman *et al.* use professional radio announcers and admit that their phrasing of the experimental materials may be rather different from that of ordinary speakers in everyday context. Fougeron & Keating use trained phoneticians, including one of the authors and two others who are "naive about the present study". Firstly, if it relevant to mention ignorance of the purpose of the recordings, it may be asked why one of the authors is nevertheless used as a subject: Vogel (1992), amongst others, have questioned the validity of data produced by experimenters themselves in phonological studies. Secondly, the tasks of disambiguating contrived bracketed expressions, like the reading of texts by professional radio announcers, clearly requires a special type of linguistic performance. Apparently, the strategy adopted in the disambiguation task involves lengthening of syllable onsets at phrase boundaries focused at phrase onsets; however, finding that trained subjects are capable of performing a particular task does not demonstrate that normal speakers habitually exhibit such behaviour.

Factors in the design of Experiment 2

This above discussion illustrates difficulties inherent in experimental examinations of durational variation in speech, where not all potential influences can be reliably controlled, and some factors, such as the number of levels of prosodic constituents, are neither theoretically agreed nor empirically established. A possible criticism of Experiment 1 is that, in restricting potential durational influences, the experimental materials are too tightly constrained. For example, the linguistic status of the test materials (underlined) is uncertain in phrases such as:

- SAY " <u>thank fulfil</u>", don't SHOUT "thank fulfil".

This could be interpreted as the phrasal equivalent of citation form; certainly, the prosodic phrasing is not subject to the degree of variation found in normal speech.

The sentences in Experiment 2 are designed to allow subjects a more normal range of prosodic choices, whilst at the same controlling the environment of the measured segments in certain important ways. Firstly, as in Experiment 1, the intended placement of pitch accent is specified in the sentence by writing words to be emphasised in block capitals. As there are a range of possible locations for accents within utterances, this should not require subjects to deviate further from a normal speaking style than is inherent in a sentence-reading task.

The question of constituent boundary location is more problematic. Two domain-edge conditions are examined: word-edge and utterance-edge. As the utterance is the highest constituent, certainly within single, short sentences, controlling the placement of utterance boundaries is straightforward. At the word-level, however, the task is more complicated given the number of putative higher-level constituents whose boundaries could coincide with the boundaries of experimentally-significant words. Furthermore, because the relationship between syntax and prosody is not deterministic, sentences cannot be written which elicit a particular phrasing consistently.

The approach taken in Experiment 2 is to eliminate the well-established durational effects of intonational phrase boundaries, whilst allowing variation in the placement of boundaries of such lower-level constituents as may exist, and which may have durational consequences. As the comparison of Wightman *et al.* (1992) and Fougeron & Keating (1997) shows, the durational consequences of constituents between word-level and intonational-phrase-level are far from clearly established. As discussed in Chapter 2, at least one constituent, the phonological phrase, may be required to account for segmental and suprasegmental effects in connected speech: whether it manifests distinctive domain-initial and/or domain-final lengthening remains uncertain[6].

Intonational phrase boundaries are controlled in Experiment 2 in a number of ways. Firstly, the experimental sentences are relatively short, and free of any syntactic structures associated with obligatory intonational phrase construction. Secondly, as utterance-internal pauses are most strongly associated with intonational phrase boundaries, subjects are instructed to read each experimental sentence without pausing. Thirdly, each recorded utterance is listened to, and those with perceptible intonational phrase boundaries adjacent to the experimentally-significant words are excluded from analysis.

The lack of specific measures to control the placement of phrase boundaries below the level of the intonational phrase has consequences for the interpretation of the experimental findings with regard to word-edge effects. The edges of some experimentally-significant words may coincide with boundaries of, for example, phonological phrases; therefore, if word-initial or word-final lengthening effects are found, these may be attributed, at least in part, to phrasal boundaries rather than word boundaries. This proviso is considered further in the discussion of the experimental results. The possible occurrence of phonological phrase boundaries is less relevant to hypotheses about word-span, utterance-edge and utterance-span effects, and about pitch accent and its interactions.

[6]A study by Cambier-Langeveld (2000) of Dutch, discussed in Chapter 2, found no difference in speech segment duration word-finally and phonological-phrase-finally.

4.2 Experimental design

Experiment 2 is designed to examine the experimental hypotheses outlined in Section 4.1.2. The durations of the onset, nucleus and coda of a primary stressed syllable are measured when spoken in words and utterances of varying lengths, where the syllable's position with respect to word and utterance boundaries is varied, and where the syllable is accented and unaccented. The durations of unstressed syllables in polysyllabic words are also measured.

4.2.1 Experimental materials

Stressed syllable durations in Experiment 1 are measured in monosyllabic words and in left-headed and right-headed disyllabic words. Word-level contexts are extended in Experiment 2 to include left-headed and right-headed trisyllabic words, because the word-edge, word-span and word-rhyme-span hypotheses make different predictions about stressed syllable duration in these trisyllables compared with disyllables.

For both left-headed pairs like *captain* and *captaincy* and right-headed pairs like *commend* and *recommend*, the word-span hypothesis predicts shorter primary stressed syllable duration in trisyllables than disyllables. The word-rhyme-span hypothesis predicts such shortening in left-headed pairs, but not in right-headed pairs.

The word-edge hypotheses predict no difference in either left-headed or right-headed pairs, because the alignment of the stressed syllable with the word boundary is unchanged: in both *captain* and *captaincy*, the measured syllable /kæp/ is word-initial and not word-final; in both *commend* and *recommend*, the measured syllable /mɛnd/ is word-final and not word-initial.

When the primary stress is word-medial in the trisyllable, comparisons with either left-headed or right-headed disyllables do not allow distinction of the word-edge and word-span hypotheses: both the word-initial and word-span hypotheses predict shortening of /sɛns/ in *consensus* compared with *census*; likewise, the word-final, word-span and word-rhyme-span hypotheses all predict shortening of /tɛnt/ in *contentment* compared with *content*. Such trisyllables do not usefully distinguish the hypotheses and so are not used here.

It is possible that edge and span processes may both operate. For example, a large amount of shortening of /mɛnd/ between *mend* and *commend* and a smaller shortening effect between *commend* and *recommend* could indicate a word-span effect together with a word-initial effect. In order to test this, it is necessary to examine subsyllabic durations: the locus of word-initial lengthening, which affects only the *mend* vs *commend* comparison, is likely to be the syllable onset, whereas the word-span shortening effect is likely to affect all parts of the syllable and possibly the nucleus more than the onset and coda.

Keywords

The dependent variables in this experiment are the durations of the onset, nucleus and coda of syllables carrying primary lexical stress, referred to as "test syllables". The word containing the test syllable is referred to as the "keyword".

The experiment uses sixteen different test syllables, each spoken in three different lexical contexts: monosyllable, disyllable and trisyllable. The three keywords for each test syllable are referred to as "keyword triads". There are eight keyword triads in which the test syllable is always word-initial, the left-headed keywords, and eight in which the test syllable is always word-final, the right-headed keywords. The full set of keywords[7] is given in Table 4.1.

Left-headed triads				**Right-headed triads**			
Test syllable	$\boldsymbol{\sigma}$	$\boldsymbol{\sigma}\sigma$	$\boldsymbol{\sigma}\sigma\sigma$	Test syllable	$\boldsymbol{\sigma}$	$\sigma\boldsymbol{\sigma}$	$\sigma\sigma\boldsymbol{\sigma}$
/kæp/	**cap**	captain	captaincy	/mɛnd/	**mend**	commend	recommend
/sɛns/	**sense**	censor	censorship	/pəʊz/	pose	**dispose**	indispose
/dɒg/	**dog**	dogma	dogmatist	/pɔt/	**port**	report	misreport
/fɪʃ/	**fish**	fissure	fisherman	/dʒus/	**juice**	produce	reproduce
/meɪs/	**mace**	mason	masonry	/pəʊz/	pose	**suppose**	presuppose
/pɑt/	**part**	partner	partnership	/pəʊz/	pose	**compose**	decompose
/spɛk/	**speck**	spectre	spectacle	/sɛnd/	**send**	descend	condescend
/tɛn/	**ten**	tendon	tendency	/meɪn/	**main**	humane	inhumane

Table 4.1: Keywords used in Experiment 2. Test syllables are shown schematically as $\boldsymbol{\sigma}$, other syllables as σ. The keywords used to refer to each triad are shown in bold.

The syllables immediately adjacent to the test syllable are unstressed, to control stress-adjacent lengthening, and are identical in the disyllables and trisyllables in each keyword triads, to minimise any effect of local phonetic variation on test syllable duration. Stress and phonetic environment are also controlled in the carrier sentence.

Carrier sentences

In Experiment 1, experimental phrases are placed in what could be described as a metalinguistic context within the complete sentence, for example:

- Say "BAKE enforce", don't say "TANK enforce".

[7] Transcriptions are given for Standard Southern British English. Unlike American English, *juice* and the final syllable of *produce* and *reproduce* are homophonous, being pronounced /dʒus/.

In Experiment 2, keywords are placed in sentences designed to be read as meaningful utterances, with a full normal prosodic realisation. At the same time, the length of the utterances and the immediate environment of the test syllables is controlled[8].

The full design of the experimental materials is shown schematically in Table 4.2 for right-headed keywords. The design of the materials for left-headed keywords is the mirror-image of the syllable configurations shown.

	Number of added syllables: … **in utterance**	… **in word** 0	1	2
Utterance-medial	0	$\Vert\ldots\sigma\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\Vert$	$\Vert\ldots\sigma\sharp\sigma\boldsymbol{\sigma}\sharp\ldots\Vert$	$\Vert\ldots\sharp\sigma\sigma\boldsymbol{\sigma}\sharp\ldots\Vert$
	1	$\Vert\ldots\sigma\sigma\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\Vert$	$\Vert\ldots\sigma\sigma\sharp\sigma\boldsymbol{\sigma}\sharp\ldots\Vert$	
	2	$\Vert\ldots\sigma\sigma\sigma\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\Vert$		$\Vert\ldots\sigma\sigma\sharp\sigma\sigma\boldsymbol{\sigma}\sharp\ldots\Vert$
Utterance-edge	0	$\Vert\boldsymbol{\sigma}\sharp\ldots\Vert$		
	1	$\Vert\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\Vert$	$\Vert\sigma\boldsymbol{\sigma}\sharp\ldots\Vert$	
	2	$\Vert\sigma\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\Vert$		$\Vert\sigma\sigma\boldsymbol{\sigma}\sharp\ldots\Vert$

Table 4.2: Schematic representation of the experimental keywords and carrier sentences. The design shown is for right-headed words; the design for left-headed words is the mirror image of this representation. KEY: $\boldsymbol{\sigma}$- target syllable; σ- other syllable; $\Vert$ - utterance boundary; $\sharp$ - word boundary; … symbolises the initial and final parts of the utterance, of fixed length within each triad, and at least two syllables long.

The design shown in Table 4.2 systematically varies word length and utterance length. Where the test syllable is utterance-medial, these factors are varied both independently and concurrently. Where the test syllable is close to the utterance edge, utterance length covaries with word length and varies whilst word length is fixed. The resultant five series of test syllable environments are outlined in turn now.

Keyword Series A: utterance-medial; fixed utterance-length; variable word-length

Keyword Series A primarily tests the word-edge, word-span and word-rhyme-span hypotheses, and is illustrated schematically for right-headed keywords in the top line of the utterance-medial section of Table 4.2. Utterance-level factors are kept constant, so that word-level effects of length and position can be examined. To eliminate utterance-length effects, the number of syllables within the keyword is counterbalanced in the rest of the sentence, maintaining a constant number of syllables in the

[8]The requirement for phonetic balance in the environment of the test syllable, together with sentence length constraints, mean that some of the sentences are semantically rather strange. Subjects appeared, however, to have no difficulty in reading these sentences with the same fluency as with the others.

complete sentence for each keyword of a triad. To minimise utterance-edge effects, the distance of test syllables from utterance edges is kept constant within each keyword triad and keywords are separated from the ends of the carrier sentence by at least two syllables.

In left-headed triads the monosyllabic keyword has one more syllable to its right than the disyllabic keyword and two more than the trisyllabic keyword. For the right-headed triads, the counterbalancing syllables are to the left of the keyword. Examples of counterbalanced sentences are shown in Table 4.3: in that table and subsequently, keywords are in bold, and words emphasised in the unaccented condition—as outlined below—are in capitals. The complete set of sentences is shown in Table C.1 in Appendix C.

Right-headed keywords	
$\|\ldots\sigma\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\|$	JOHN saw Jessica **mend** it AGAIN.
$\|\ldots\sigma\sharp\sigma\boldsymbol{\sigma}\sharp\ldots\|$	JOHN saw Jessie **commend** it AGAIN.
$\|\ldots\sharp\sigma\sigma\boldsymbol{\sigma}\sharp\ldots\|$	JOHN saw Jess **recommend** it AGAIN.
Left-headed keywords	
$\|\ldots\sharp\boldsymbol{\sigma}\sharp\sigma\sigma\ldots\|$	I SAW the **mace** unreclaimed AGAIN.
$\|\ldots\sharp\boldsymbol{\sigma}\sigma\sharp\sigma\ldots\|$	I SAW the **mason** reclaimed it ALL.
$\|\ldots\sharp\boldsymbol{\sigma}\sigma\sigma\sharp\ldots\|$	I SAW the **masonry** cleaned AGAIN.

Table 4.3: Experimental sentences for Keyword Series A.

The syllable immediately following the test syllable in the left-headed triads and immediately preceding the test syllable in the right-headed triads is unstressed, whether it is within the same word or within an adjacent content word, as in Table C.1, or comprises an adjacent function word, for example:

Series A.1 Kate GAVE the **sense** <u>of</u> the SCRIPT away. (cf. Kate GAVE the **cens<u>or</u>** the SCRIPT again.)

Series A.1 John THREW the **cap** <u>to</u> the BED again. (cf. John THREW the **cap<u>tain</u>** the BADGE again.)

This is to control the effect of stress adjacency on the test syllable.

The left-headed keywords *dog* and *part* are followed in Series A monosyllables by closed-class words containing syllables (underlined) that are reducible but could be realised with full vowels:

Series A.1 Tim KNEW the **dog** <u>may</u> decline AGAIN. (cf. Tim KNEW the **dogma** declined AGAIN.)

Series A.1 Jim LIKES his **part** <u>no</u> more than MOST. (cf. Jim LIKES his **partner** more than MOST.)

As described in Chapter 2, a stressed syllable may be lengthened when followed immediately by another stressed syllable, relative to when followed by an unstressed syllable. It is considered unlikely that merely full-vowel unstressed syllables will cause this effect, but because of this possibility, the keywords *dog* and *part* are excluded from those analyses which make a comparison which could be biased by stress-adjacent lengthening if it did occur: for example, shortening of the test syllable between *dog may* and *dogma* could be regarded either as a word-level effect or a consequence of adjacent full vowel syllables in the former but not the latter.

The immediate phonetic environment of the test syllable is kept constant, as far as possible. As shown in Table 4.3, /mɛnd/ is always preceded by /kə/ and followed by /ɪt, and /meɪs/ is always preceded by /ðə/ and followed by /ən/. In the examples above for keywords *sense* and *cap*, the reduction of function words in connected speech means that the test-word-adjacent syllables are similar to the within-word equivalents: thus, *sense of* vs *censor*; *cap to* vs *captain*. In these sentences, in contrast with those shown in Table 4.3, the requirement to maintain a consistent phonetic environment and the lack of segmentally-appropriate counterbalancing words means that the syntactic structure of the sentences differs within the keyword triads. All of the left-headed triads except *mace* show some variation in syntactic structure in Series A. For the right-headed triads, three keywords—*port*, *juice* and *pose*—have structural variation between the three sentences; for the latter two, this variation is minimal.

There are two pitch accent conditions: in the accented condition, subjects emphasise the keyword (shown, in the examples given here, in bold); in the unaccented condition, they emphasise two other words in the sentence (shown, in the examples given here, in block capitals), one before and one after the test syllable. Words to be emphasised in the unaccented condition never immediately precede the test syllable, as the word following an accented word may be lengthened somewhat. The required placement of emphasis is indicated to subjects in all cases by the use of block capitals.

The two accent conditions apply in all keyword series, likewise the consistent environment of the test syllable in terms of lexical stress and segmental identity, except where otherwise stated.

Keyword Series B: utterance-medial; variable utterance-length; fixed word-length

Keyword Series B primarily tests the utterance-span hypothesis, and is illustrated schematically for right-headed keywords in the left-hand column of the utterance-medial section of Table 4.2. The length of the keyword is fixed whilst the length of the whole utterance varies. Example sentences are shown in Table 4.4 and the full set of sentences in Series B is shown in Table C.2 in Appendix C.

Right-headed keywords	
$\|\ldots\sigma\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\|$	JOHN saw Jessica **mend** it AGAIN.
$\|\ldots\sigma\sigma\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\|$	JOHNNY saw Jessica **mend** it AGAIN.
$\|\ldots\sigma\sigma\sigma\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\|$	JONATHAN saw Jessica **mend** it AGAIN.
Left-headed keywords	
$\|\ldots\sharp\boldsymbol{\sigma}\sharp\sigma\sigma\ldots\|$	I SAW the **mace** unreclaimed AGAIN.
$\|\ldots\sharp\boldsymbol{\sigma}\sharp\sigma\sigma\sigma\ldots\|$	I SAW the **mace** unreclaimed once AGAIN.
$\|\ldots\sharp\boldsymbol{\sigma}\sharp\sigma\sigma\sigma\sigma\ldots\|$	I SAW the **mace** unreclaimed by them AGAIN.

Table 4.4: Example experimental sentences for Keyword Series B.

As indicated in Table 4.2, the shortest sentence in Series B is also the monosyllabic keyword sentence in Series A. In order to keep the phonetic environment of the test syllable constant, additional syllables in the other two sentences are not placed immediately adjacent to the keyword, but elsewhere in the utterance. Due to an oversight in the preparation of the materials for the keyword *part*, the additional syllables are adjacent to the keyword; because of the resulting unbalanced phonetic environment, *part* is not analysed with the other keywords in Series B.

Keyword Series C: utterance-medial; variable utterance-length; variable word-length

Keyword Series C primarily tests the utterance-edge hypotheses by comparison with Series E, as outlined below; it also tests the word-edge, word-span and word-rhyme-span hypotheses examined in Series A. Series C is illustrated schematically for right-headed keywords in the diagonal line of the utterance-medial section of Table 4.2. As in Series A, the number of syllables in the keyword is varied; in contrast with Series A, the length of the carrier sentence is not counterbalanced with the length of the keyword. As the length of the keyword increases from monosyllable to disyllable to trisyllable, the length of the utterance also increases. Example sentences are shown in Table 4.5 and the full set of sentences is shown in Table C.3 in Appendix C.

As indicated in Table 4.2, the sentence containing the monosyllabic keyword is common also to Series A and Series B[9]. In Series A the requirement to counterbalance word length and sentence length whilst maintaining the phonetic environment of the test syllable often means that the syntactic structure of the sentences varies within

[9] As for Series A, the left-headed keywords *dog* and *part* are excluded from analyses where the potential stress-adjacent lengthening in the monosyllables could confound examination of the experimental hypotheses.

Right-headed keywords	
$\|\ldots\sigma\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\|$	JOHN saw Jessica **mend** it AGAIN.
$\|\ldots\sigma\sigma\sharp\sigma\boldsymbol{\sigma}\sharp\ldots\|$	JOHN saw Alison **commend** it AGAIN.
$\|\ldots\sigma\sigma\sharp\sigma\sigma\boldsymbol{\sigma}\sharp\ldots\|$	JOHN saw Alison **recommend** it AGAIN.
Left-headed keywords	
$\|\ldots\sharp\boldsymbol{\sigma}\sharp\sigma\sigma\ldots\|$	I SAW the **mace** unreclaimed AGAIN.
$\|\ldots\sharp\boldsymbol{\sigma}\sigma\sharp\sigma\sigma\ldots\|$	I SAW the **mason** disinclined it ALL.
$\|\ldots\sharp\boldsymbol{\sigma}\sigma\sigma\sharp\sigma\sigma\ldots\|$	I SAW the **masonry** disinterred AGAIN.

Table 4.5: Example experimental sentences for Keyword Series C.

the keyword triad. In Series C, however, this variability is eliminated. The carrier sentences for the monosyllabic, disyllabic and trisyllabic keywords are structurally equivalent except for very minor differences for the keywords *mace* and *port*.

The carrier sentences are often identical within a keyword triad; elsewhere, small non-structural changes occur where a repeated sequence of syllables is potentially awkward to pronounce. For example, for the keyword *mend*, the repeated /kəkə/ sequence in *Jessica commend* was avoided by substituting *Alison* for *Jessica*.

Keyword Series D: utterance-edge; variable utterance-length; fixed word-length

Keyword Series D tests the utterance-edge and utterance-span hypotheses, and is illustrated schematically for right-headed keywords in the left-hand column of the utterance-edge section of Table 4.2. This is the utterance-edge equivalent of Series B, both having fixed word-length and variable utterance-length. The keyword is a monosyllable in all three sentences and adjacent to the sentence edge in the shortest. As the number of syllables in the sentence increases, the distance between the test syllable and the utterance edge also increases. Example sentences are shown in Table 4.6 and the full set of sentences is shown in Table C.4 in Appendix C. There is only one emphasis in the carrier sentence in the unaccented condition; this is similarly true for Series E, the other utterance-edge series.

In contrast with the other keyword series, it is not possible in Series D always to keep the immediate stress and phonetic environment of the test syllable constant. In particular, syntactic restrictions on the occurrence of function words and phonological restrictions on their realisation—phrase-final function words are generally pronounced in their strong form—mean that sentences cannot be constructed in which the keyword is separated from the boundary by a single unstressed syllable. Thus *mend* is preceded by the adverb *now* in this condition and *mace* is followed by the preposition

Right-headed keywords	
$\Vert\boldsymbol{\sigma}\sharp\ldots\Vert$	**Mend** it AGAIN for me please.
$\Vert\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\Vert$	Now **mend** it AGAIN for me please.
$\Vert\sigma\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\Vert$	Will you **mend** it AGAIN for me please.
Left-headed keywords	
$\Vert\ldots\sharp\boldsymbol{\sigma}\Vert$	Albert THREW the **mace**.
$\Vert\ldots\sharp\boldsymbol{\sigma}\sharp\sigma\Vert$	Albert THREW the **mace** up.
$\Vert\ldots\sharp\boldsymbol{\sigma}\sharp\sigma\sigma\Vert$	Albert THREW the **mace** again.

Table 4.6: Example sentences for Keyword Series D.

up, a function word which receives stress by virtue of its phrase-final position. These restrictions on sentence construction place limitations on the interpretation of results in this part of the keyword series; but when the keyword is separated from the boundary by two syllables there is scope for placing it adjacent to an unstressed syllable. All the left-headed keywords in this condition are either followed by *again* or by *today*, which have initial unstressed syllables. The right-headed keywords are all preceded by either *Will you*, *Can you* or *All the*.

Given the restrictions on the lexical items available in sentence-initial and sentence-final position, it is furthermore very difficult to keep the phonetic environment of the test syllable the same within the series, and also by comparison with the disyllables and trisyllables in other keyword series. It is possible in some cases: *speck* is followed by /tə/ in both *spectacle* and in *speck today*; in some other left-headed triads the test syllable is followed by /ə/ both in the polysyllabic words and in the Series D condition. In general, however, the variations in the phonetic environment of the test syllable provide further reason for caution, although any durational differences due to phonetic environment are unlikely to be systematic with respect to the experimental hypotheses.

Keyword Series E: utterance-edge; variable utterance-length; variable word-length

Keyword Series E primarily tests the utterance-edge hypotheses, by comparison with the utterance-medial Series C: in both series, word-length and utterance-length covary and so differences in durational patterns between the series reflect the presence of the utterance boundary in Series E, where the distance between the test syllable and the utterance-edge increases as the length of the keyword increases from monosyllable to disyllable to trisyllable. The series is illustrated schematically for right-headed keywords in the diagonal line of the utterance-edge section of Table 4.2. Example sentences are shown in Table 4.7 and the full set of sentences is shown in Table C.5 in Appendix C.

Right-headed keywords	
$\|\mathit{\sigma}\sharp\ldots\|$	**Mend** it AGAIN for me please.
$\|\sigma\mathit{\sigma}\sharp\ldots\|$	**Commend** it AGAIN for me please.
$\|\sigma\sigma\mathit{\sigma}\sharp\ldots\|$	**Recommend** it AGAIN for me please.
Left-headed keywords	
$\|\ldots\sharp\mathit{\sigma}\|$	Albert THREW the **mace**.
$\|\ldots\sharp\mathit{\sigma}\sigma\|$	Albert THREW the **mason**.
$\|\ldots\sharp\mathit{\sigma}\sigma\sigma\|$	Albert THREW the **masonry**.

Table 4.7: Example materials for Keyword Series E.

The sentence containing the monosyllabic keyword is also the shortest sentence in Series D; additional sentences are constructed by replacing the monosyllabic keyword with the disyllabic or trisyllabic versions. Direct comparisons may be made with Series A and C as the stress and phonetic environment of the test syllable is constant between these series[10].

4.3 Experimental procedure

There are five keyword series for each test syllable, each containing three sentences. As shown in Table 4.2, the three utterance-medial series have one sentence in common, as do the two utterance-edge series, making a total of twelve sentences for each keyword, each to be read in two accent conditions. There are eight right-headed keywords and eight left-headed keywords, making 384 experimental sentences in total, listed according to keyword series in Tables C.1 to C.5 in Appendix C.

4.3.1 Recording

The experimental sentences were divided into three blocks for the purposes of the recording: Block A contains 112 sentences; Blocks B and C contain 136 sentences each. The composition of each block is shown in Table C.6 in Appendix C.

For each of the six subjects, two full sets of sentences from each block were prepared in separate random orders. For Block A, each randomised set was split into two

[10]For the left-headed keywords, the preceding phonetic environment is the same in Series A, C and E except for the keyword *speck*; for the right-headed keywords, it is the same except for *port*, *send* and *main*. The durational effect of these differences is, however, likely to be small and non-systematic with respect to the experimental hypotheses.

groups of 56 sentences each; for Blocks B and C, each set was split into three groups, two of 45 sentences and one of 46 sentences.

Each group of sentences was converted into a Postscript file, with one sentence in the centre of each page. These files were displayed on a Sun workstation monitor. Each subject took part in three recording sessions, reading through all of the six or eight groups of sentences for one block in each session. The order of presentation of the blocks was counterbalanced between subjects.

Before the first recording, subjects were given an instruction sheet telling them to read aloud the sentences as they appeared on the screen, and to emphasise the words in capital letters, speaking naturally and without pausing mid-sentence. Subjects were told to re-read a sentence if they made a mistake or did not place the emphasis in the correct place. They were told they could control the rate of presentation of the sentences, pressing the space bar on the computer keyboard to bring up the next. Before each session they were given a short practice, using a random sample of ten sentences from the block of sentences to be read.

During a recording session, subjects read the two or three groups of sentences from the first randomised set of sentences from a block, followed by the two or three groups from the second randomised set, pausing if they wished between groups of sentences. Subjects were not made aware of any systematic grouping or repetition of sentences. Each recording session lasted around half an hour and subjects attended three sessions, thereby reading all of the experimental sentences twice.

Subjects were asked to repeat sentences during the recording if:

- the lexical content of the sentence was misread.
- the words in capitals were not emphasised.
- words not in capitals were emphasised.
- a pause was perceived within the utterance.

Recordings were made direct to disk in ESPS format at a sample rate of 16 kHz.

4.3.2 Experimental subjects

Three females and three males took part in the recordings, all undergraduate or postgraduate students of Edinburgh University. Four of the subjects were speakers of Standard Southern British English; two were speakers of Northern English dialects. Subjects received five pounds after each recording session and an additional five pounds for completing all three sessions. Subjects were not given any specific information about the purpose of the recordings until after they had completed them.

4.3.3 Measurement of syllable duration

Each subject recorded 768 experimental sentences, excluding corrections—that is, two repetitions of each sentence—making a total of 4608 recorded sentences. UNIX shell scripts were used on a SparcStation for file processing; the recordings were analysed using XWaves.

Utterances were extracted from the original recordings and merged into sound files with other sentences for the same speaker and keyword, to facilitate the application of consistent measurement criteria for each test syllable. There were four sound files for each keyword for each subject:

- 2 repetitions $\times$ 7 sentences, utterance-medial, unaccented.
- 2 repetitions $\times$ 7 sentences, utterance-medial, accented.
- 2 repetitions $\times$ 5 sentences, utterance-edge, accented.
- 2 repetitions $\times$ 5 sentences, utterance-edge, accented.

Identifying labels were aligned with each utterance and a three-stage labelling procedure took place. Firstly, utterance production labels—for example, identifying incorrect placement of emphasis—were applied as appropriate. Secondly, the start and end points of the onset, nucleus and coda of each test syllable were identified by inspection of waveforms and spectrograms. Finally, the start and end points of the additional syllables within polysyllabic keywords were identified for a large subset of the utterances. Each of these stages is now described in detail.

Utterance production labelling

Each utterance was listened to in order to determine whether it had been produced correctly. This judgement involved the application of a number of criteria regarding pronunciation, placement of emphasis and the presence of audible boundaries within the utterance.

An utterance was labelled as excluded due to pronunciation if the speaker misread the words in the sentence, or pronounced the keyword differently from their other productions of the same keyword. In some cases, this label was applied during test syllable labelling, when it was determined that some acoustic feature of the keyword meant that segmentation criteria could not be reliably applied.

An utterance was labelled as excluded due to accent placement if the keyword was perceived as unaccented in the accented condition or accented in the unaccented condition. Often this judgement was straightforward; where it was more difficult, the decision was based on the relative prominence of the keyword and other words in the utterance. On a few occasions, reference was made to the fundamental frequency contour of the utterance, but this often proved inconclusive. If the keyword correctly carried or did not carry an accent, other misplacement of accent did not exclude the utterance from analysis: in the unaccented condition, where an accent was not placed on a word emphasised with block capitals but elsewhere in the utterance; in the accented condition, where there was an additional accent in the utterance to that on the keyword.

Another source of accent misplacement was the shifting of primary stress in polysyllables. For example, the right-headed word *reproduce* should in this experiment have the primary stress on the final syllable, but subjects occasionally placed the primary stress—thus also the accent if present—on the initial syllable of the word. Utterances in which this occurred were excluded.

Utterance production labels were also applied regarding the occurrence of boundaries within the utterance. The judgement of the presence of a boundary was perceptual, and was made where a juncture was perceived corresponding to an intonational phrase boundary: the primary criterion was the presence of an audible boundary tone, such as a steep fall or a fall-rise; additional criteria were the presence of an audible pause or perceptible pre-boundary lengthening, or the existence of two complete intonational phrases within the utterance. Visual inspection of fundamental frequency contours, which were often discontinuous, was seldom used. Utterances were excluded if an intonational phrase boundary was perceived adjacent to the keyword, but were not excluded if the boundary was elsewhere in the utterance.

The number of utterances excluded from analysis according to each criterion was:

- Utterance misread: 35 (0.8%)
- Keyword accented in the unaccented condition: 60 (1.3%)
- Keyword unaccented in the accented condition: 43 (0.9%).
- Primary lexical stress misplaced within the keyword: 29 (0.6%).
- Intonational phrase boundary adjacent to the keyword: 187 (4.1%)

Utterances for which both repetitions are excluded represent missing data points. There are 72 such utterances—3.1% of the total—listed in Tables D.1–D.3 in Appendix D. The number of missing data points is given in the results for each analysis; in most cases, less than 5% of the total data points are missing.

Test syllable labelling

The start and end points of subsyllabic constituents of each test syllable were labelled by visual inspection of the waveform and spectrogram. For consistency, labelling was performed keyword-by-keyword. To eliminate bias due to the order of labelling, each speaker's four files for each keyword were labelled in random order. The order of speakers for each keyword was also random.

Labels are placed for all keywords at the start point of each of subsyllabic constituent: onset, nucleus, and coda. The start of the nucleus marks the end of the onset and the start of the coda marks the end of the nucleus; the end of the coda is also labelled. It should be noted that singleton test syllable coda consonants could also be regarded as ambisyllabic or as unstressed syllable onsets in left-headed disyllables and trisyllables: for example *mason* and *masonry*. For consistency, such consonants are always labelled as codas in Experiment 2, a decision which appears to be supported by evidence from final lengthening reported in Section 4.8.

The right-headed *port*, *compose*, *dispose* and *suppose*, and the left-headed *ten*, *cap* and *part* all have voiceless stops as their syllable onset. In this experiment, the onset measurement includes both the duration of stop closure and the duration of aspiration following the release of the stop. There are arguments for treating aspiration as part of the nucleus, because the vocalic gesture begin in the oral cavity at the stop release; however, the laryngeal vocalic gesture begins with the onset of voicing, and this is taken as the start of the nucleus in Experiment 2. There are hypotheses which predict distinct effects in closure and aspiration duration, as discussed in Section 4.1.2, and so these are measured separately within the overall onset measurement. The decision to include aspiration as part of the onset appears to be justified by the results reported in Section 4.6 regarding the effect of word position on onset duration: the pattern of variation is very similar for stop closure duration and aspiration duration.

The words containing voiceless stops as their syllable onset thus all have an additional label placed at the point of stop release, corresponding to the start of aspiration[11]. Similarly, the test syllable onset of the keyword *juice* has a label at the position of plosive release in the affricate onset /dʒ/, corresponding to the start of frication: the duration of frication is wholly contained within the onset measure, but the extra label provide a partial-onset measure utterance-initially, where stop closure duration cannot be determined acoustically. The aspiration of voiceless stops similarly provides a partial-onset measure in utterance-initial position.

The placement of the labels for each keyword is illustrated in Tables E.1 and E.2 in Appendix E. The criteria used for segmentation are described in Appendix A. Labels were placed by reference to a speech waveform and a colour wideband spectrogram. For consistent application of visual criteria, judgements were made using a window size of not less than 400ms. As spectrogram colour indicates intensity, the appearance of a particular colour at a particular frequency was sometimes used to aid segmenta-

[11]Being preceded by an /s/, the /p in *speck* is unaspirated, and thus did not receive this additional label.

tion, for example, for the start of certain fricative consonants.

Not all constituents of all test syllables are reliably measurable in all contexts. As mentioned above, the period of stop closure in the syllable onsets for the right-headed keywords *compose*, *dispose*, *port*, *suppose* and *juice* does not have an acoustic correlate in utterance-initial position, and aspiration or frication duration is used where necessary as a partial-onset measure; full syllable duration is therefore available in utterance-edge conditions only for *main*, *mend* and *send*.

Coda stop consonants are sometimes difficult to measure reliably: the codas of the right-headed *port* and the left-headed *cap*, *dog*, *part* and *speck* are all occasionally elided or glottalised. For the right-headed keywords, *port* is excluded from measurements relating to coda duration, including whole syllable duration. For the left-headed keywords, measurements relating to coda duration, including whole syllable duration, are consistently available only for the keywords *fish*, *mace*, *sense* and *ten*. Where measurements are reliably available for all keywords, such as syllable onsets of left-headed keywords, or syllable nuclei of all keywords, then data are combined across the full set.

Additional syllable labelling

The additional syllables in disyllabic and trisyllabic keywords were measured for Keyword Series C and Keyword Series E (Series B and D feature only monosyllabic keywords). Because the primary comparison required for these syllables is between accented and unaccented keywords of the same length and in the same utterance position, it was not necessary to include Keyword Series A: that is, the fact that Series A has fixed utterance length is not relevant for the analysis of the effects of accent on additional syllable duration. Series C was used rather than Series A because the sentences in Series C have consistent structure within each keyword triad.

The additional syllables are labelled syllable-2 and syllable-3. For the left-headed keywords, syllable-2 immediately follows the primary stressed syllable in the disyllable and trisyllable, and syllable-3 follows syllable-2 in the trisyllable: for example, in *cap(tain)(cy)*, /tən/ is syllable-2 and /sɪ/ is syllable-3. For the right-headed keywords, syllable-2 immediately precedes the primary stressed syllable in the disyllable and trisyllable, and syllable-3 precedes syllable-2 in the trisyllable: for example, in *(mis)(re)port*, /ɹə/ is syllable-2 and /mɪs/ is syllable-3.

The labelling procedure was the same as for the test syllable, with labelling done keyword-by-keyword, and the order of speech files and speakers randomised. For the unstressed syllables, however, only full syllable durations were measured, for two main reasons. Firstly, due to the constraints on the experimental materials described in Section 4.2.1, the unstressed syllables have variable composition; thus, onset, nucleus and coda measures are not available for all syllables. Secondly, unstressed syllables are likely to manifest reduction and elision of segments; the variability in these processes place severe restrictions on the application of consistent segmentation criteria.

The placement of labels for unstressed syllables is illustrated in Tables E.3 and E.4 in Appendix E. The criteria used for segmentation are described in Appendix A.

For the right-headed keywords, syllable-initial stop closure durations could not be measured utterance-initially. Thus, for the disyllables *commend*, *dispose*, *produce*, *compose* and *descend*, syllable-2 duration is taken from the onset stop release. Similarly, for the trisyllables *presuppose*, *decompose* and *condescend*, syllable-3 duration is taken from the onset stop release. In addition, syllable-2 of the keyword *humane* is excluded from comparisons between disyllabic and trisyllabic contexts: the syllable-initial /h/ is realised quite differently in the two contexts (*develop humane* vs *inhumane*), and thus its durations are not considered comparable. It is included in other comparisons, such as those regarding the durational effects of accent, examined separately in disyllables and trisyllables.

Data processing

Test syllable constituent durations and additional syllable durations were derived from XWaves label files using UNIX shell scripts and extracted together with utterance production labels. Checks were carried out on this data. Firstly, missing or duplicated tokens were accounted for, and relabelled where necessary. Secondly, the range of values was inspected for each subsyllabic unit in each type of target syllable and outlying values were identified. The speech files corresponding to these tokens were inspected again: in some cases, misplaced labels were realigned; in other cases, unusually large or small subsyllabic durations were seen to have been correctly measured. The full set of durations was then recalculated prior to statistical analysis.

4.3.4 Statistical analysis

In the analyses reported in this chapter, items (that is, the test syllables being measured) are matched between experimental conditions. Therefore, as discussed in Chapter 3, the By-Subjects (F_1) analysis of variance is considered the appropriate statistical test. Following widespread practice, By-Items (F_2) analyses are also reported, but only By-Subjects statistics are taken as the benchmark of significance. Analysis of variance are performed using SPSS statistical software.

There are 72 missing data points, where utterances have both tokens excluded from analysis. Where less than about 5% of data are missing in a particular analysis, no action is taken; where a greater proportion are missing, the keyword with the most missing data points is excluded from the analysis—indicated in the text as "missing data"—this procedure being repeated until the proportion of missing data points is less than 5%. This step was only necessary in a few of the reported analyses. The total number of data points is reported below each table reporting mean duration in the following results sections; also noted is the proportion of the total data points that are missing.

Values of F, degrees of freedom[12] and significance levels are reported for the main analyses relating to each experimental hypothesis, and for subsidiary analyses where new results are obtained. Where subsidiary analyses simply corroborate established results, the results of ANOVAs are reported as "not significant", "approaching significance", "significant" ($p < .05$) or "highly significant" ($p < .01$). Except where otherwise stated, such reporting implies that By-Subjects and By-Items analyses have the same outcome.

4.4 Results overview

The 4608 recorded sentences represent a large data-set addressing the hypotheses outlined in Section 4.1.2 regarding domain-edge and domain-span processes and the durational effects of pitch accent. These hypotheses are tested by statistical analysis of durational variation in test syllable onset, nucleus and coda, and in the unstressed syllables in polysyllables. The analyses utilise different subsets of the full data-set to address different hypotheses, and are presented in later sections of this chapter, after an overview of the main results.

The most important findings in Experiment 2 are:

- There are no domain-span processes at word level (polysyllabic shortening) or utterance level, although there is evidence for a sub-word level process, word-rhyme-span compression.

- The word is the locus of accentual lengthening and the variation in distribution of accentual lengthening between monosyllables, disyllables and trisyllables accounts for previously-observed polysyllabic shortening: there is less lengthening of the stressed syllables in a disyllable than in a monosyllable, and less still in a trisyllable.

- Word-initial lengthening has a syllable onset locus; there may be additional lengthening of the onset phrase-initially.

- There is inverse relationship—word-rhyme-span compression—between stressed

[12]Where data are missing in a particular By-Subjects or By-Items analysis, the degrees of freedom reported may be non-integral.

syllable nucleus duration and word-rhyme length; the duration of unstressed syllables shows a similar inverse relationship with word-rhyme length[13].

- Word-initial stressed syllable onsets are, in some cases, shorter utterance-initially than utterance-medially.

- Utterance-final lengthening affects stressed syllable codas in penultimate and antepenultimate position, plus the following unstressed syllable(s); in absolute-final position, the stressed syllable nucleus and coda are lengthened. For all constituents, the lengthening effect is greater closer to the boundary.

- There is some evidence of compensatory shortening[14] in segments near to the loci of domain-edge lengthening processes.

These results are now described according to the experimental hypotheses formulated in Section 4.1.2.

Word-edge and word-span hypotheses

Word-edge and word-span results are described in detail in Section 4.6, where Figure 4.4 shows the effect of word length on onset, nucleus and coda duration. The results are outlined here according to the experimental hypotheses.

Word-span hypothesis: primary stressed syllable duration is inversely related to word length.

This hypothesis is not supported, as there is an inverse relationship between primary stressed syllable duration and word length only in accented words. For example, in the accented condition: /mɛnd/ is shorter in *commend* than in *mend*, and shorter still in *recommend*; likewise, /meɪs/ is shorter in *mason* than in *mace* and shorter still in *masonry*. These effects arise from variations in accentual lengthening, as described below.

Word-rhyme-span hypothesis: primary stressed syllable duration is inversely related to word-rhyme length.

Word-final hypothesis: the duration of the primary stressed syllable rhyme is greater word-finally than word-medially in utterance-medial words.

[13] Subsyllabic durations are not measured for unstressed syllables, as noted in Section 4.3.3.

[14] As described in Section 4.5.2, the term "compensatory" is used here to characterise durational effects in which some constituent shortens or lengthens apparently as a result of an opposite durational variation elsewhere, whatever the underlying interpretation of the effect.

These hypotheses are both supported, although the locus of the effect is not the whole syllable or the syllable rhyme: in accented and unaccented words, there is an inverse relationship between word-rhyme length and stressed syllable nucleus duration; this could be interpreted as a word-final effect, although the coda is not affected. Thus, /eɪ/ is shorter in *mason* than in *mace* and shorter still in *masonry*, even when unaccented. Unstressed syllables also show an effect of word-rhyme length in accented and unaccented left-headed keywords: for example, /ən/ is shorter in *masonry* than in *mason*.

Word-initial hypothesis: the duration of the primary stressed syllable onset is greater word-initially than word-medially in utterance-medial words.

Word-initial accent hypothesis: word-initial lengthening of stressed syllable onsets only occurs, or is significantly greater, in accented context.

The word-initial hypothesis is clearly supported, and the effect is comparable in accented and unaccented words, hence the word-initial accent hypothesis is not supported. Thus, /m/ is much longer in *mend* than in *commend* both when accented and when unaccented; there is, however, no difference in the duration of /m/ between *commend* and *recommend* when unaccented.

Word-initial aspiration accent hypothesis: word-initial lengthening of aspiration in stressed-syllable-onset voiceless stops only occurs in unaccented syllables; in accented syllables, aspiration duration may be greater word-medially.

This hypothesis is not supported: the effects of word position are similar for closure and aspiration duration of syllable-onset voiceless stops, and there appears to be no interaction with accent. Thus, the closure and aspiration of /p/ are longer in *pose* than in *suppose* or *presuppose*, both when accented and when unaccented.

Utterance-initial hypothesis

Utterance-initial results are described in detail in Section 4.7; Figure 4.5 shows the effect of utterance position on test syllable onsets in right-headed keywords, where these are fully-measurable utterance-initially.

Utterance-initial hypothesis: word-initial syllable onsets are shorter utterance-initially than utterance-medially.

This hypothesis is supported for certain stressed syllable onsets. The right-headed keywords *main*, *mend* and *send* have show utterance-initial shortening of stressed syllable onset duration: thus, /m is shorter in ‖*mend…* than in ‖*…mend ….* The right-headed keywords *port*, *compose*, *dispose*, *suppose* and *juice* show no effect of utterance position on aspiration/frication duration when accented and a slight lengthening of aspiration/frication duration utterance-initially when unaccented.

Utterance-final hypotheses

Utterance-final results are described in detail in Section 4.8, where Figure 4.9 shows the distribution of utterance-final lengthening in left-headed keywords.

Utterance-final locus hypothesis: the locus of utterance-final lengthening is the word-rhyme.

This hypothesis is supported, although lengthening does not occur on all parts of the word-rhyme. Where the stressed syllable is in utterance-final position, the nucleus and coda are lengthened: thus, /eɪs/ is longer in …*mace*‖ then in …*mace* … ‖. The stressed syllable coda is lengthened in utterance-antepenultimate position and utterance-penultimate position, as are the following unstressed syllables within the word (subsyllabic durations are not obtained for unstressed syllables): thus, /s/ and /ən/ are longer in …*mason*‖ than in …*mason* … ‖; likewise, /s/, /ən/ and /ɹɪ/ are longer in …*masonry*‖ then in …*masonry* … ‖.

Utterance-final locus distribution hypothesis: the distribution of utterance-final lengthening is progressive within the locus.

This hypothesis is supported: lengthening is greater on the coda than on the nucleus of an absolute-utterance-final stressed syllable; and lengthening is greater on an absolute-final unstressed syllable than on an utterance-penultimate unstressed syllable.

Utterance-final accent hypothesis: the magnitude of utterance-final lengthening is not affected by the presence of a pitch accent on the utterance-final word.

This hypotheses is supported: there is no interaction between accent and utterance position (medial vs final), although there is a non-significant trend towards attenuation of utterance-final lengthening in accented words.

Utterance-span hypothesis

Utterance-span results are described in Section 4.5, where Figure 4.1 shows the lack of a systematic effect of utterance length on test syllable duration.

Utterance-span hypothesis: primary stressed syllable duration is inversely related to the number of syllables in an utterance.

This hypothesis is not supported: there is no systematic shortening of stressed syllable duration in longer utterances, in either accent condition.

Pitch accent hypotheses

Pitch accent results are described in detail in Section 4.9, where Figure 4.11 shows the distribution of accentual lengthening in left-headed and right-headed keywords.

Word-rhyme accent hypothesis: the locus of accentual lengthening is the word-rhyme.

Bimodal accent hypothesis: the locus of accentual lengthening is the primary stressed syllable and the word-final syllable.

These hypotheses are not supported: although there is accentual lengthening within the word-rhyme—on all parts of the accented syllable and on subsequent unstressed syllables—there is also lengthening in unstressed syllables preceding the word-rhyme, suggesting that the locus of accentual lengthening is the word. Thus, the syllables /ən/ and /ɹɪ/ are lengthened when *masonry* is accented (although this effect does not attain significance); similarly, the syllables /ɹɛ/ and /kəm/ are lengthened when *recommend* is accented. The magnitude of lengthening tends to be greater at word edges than word-medially.

Word-span accent hypothesis: the magnitude of accentual lengthening on the primary stressed syllable is inversely related to word-length.

The word-span accent hypothesis is supported: accentual lengthening on the stressed syllable is greatest in monosyllables and progressively less in disyllables and trisyllables. Total accentual lengthening is no greater in polysyllables than in monosyllables but is distributed between more syllables. The effect of this is what has previously been described as polysyllabic shortening, and may be re-interpreted as the polysyllabic accent effect: an inverse relationship between stressed syllable duration and word length in accented words only.

Locus hypotheses

The results of all parts of Experiment 2 inform the concept of the locus, which is discussed in Section 4.10.

Domain-edge locus hypothesis: each domain-edge process has a characteristic phonologically-defined locus.

The domain-edge locus hypothesis is supported: in particular, word-initial lengthening has a syllable onset locus and utterance-final lengthening affects certain constituents of the word-rhyme.

Domain-span locus hypothesis: a domain-span compression process shortens only the phonological head of the domain.

The domain-span locus hypothesis is partially supported. There is no support for word-span compression or utterance-span compression, but word-rhyme-span compression is supported and found to be localised within the stressed syllable on the nucleus. Unstressed syllables within the word-rhyme also appear to be affected, however, and it may be that the effect should be interpreted as word-final lengthening.

Summary

Mean test syllable durations[15] are reported in Table F.1 in Appendix F for the right-headed keywords *main*, *mend* and *send*, and in Table F.2 in Appendix F for the left-headed keywords *fish*, *mace*, *sense* and *ten*. The trends discussed above are discernible in the patterns of syllable durations according to length of the word and the utterance, and according to position within these domains.

Detailed results, statistical analysis and discussion are presented now for each set of experimental hypotheses. Utterance-span results are presented first, because the absence of an utterance-span effect affects the interpretation of the data for other analyses: in particular, it allows comparisons between different keyword series to be made without any allowance for utterance length. The discussion of results in each section focuses primarily on the interpretation of the present experiment; comparisons with previous results, particularly where these suggest different conclusions, are made in Chapter 5.

4.5 Utterance-span results

The utterance-span hypothesis predicts that primary stressed syllable duration is inversely related to the number of syllables in an utterance. As stated above, this hypothesis is not supported in the three sets of analyses presented in Section 4.5.1. The primary test of the hypotheses is provided by Keyword Series B, where keywords remain monosyllabic whilst utterance length varies. The durations of test syllable subconstituents in Series B are also compared with their durations in Series D, where monosyllabic keywords are in shorter utterances with different syntactic structures: evidence from these comparisons indicates some durational differences that appear to arise from domain-edge effects rather than utterance-span effects. The duration of test syllable subconstituents are also compared between Series A and Series C where disyllables and trisyllables are in utterances of varying length: evidence indicates no differences between the shorter Series A and the longer Series C utterances, allowing

[15]Total syllable durations cannot be reported for all keywords in all experimental conditions for reasons outlined in Section 4.3.3. The means in the summary tables are calculated without tokens for which both repetitions are missing, as also described in Section 4.3.3.

both to be used for the analysis of word-level effects in Section 4.6.

Section 4.5.2 discusses the lack of evidence for an utterance-span effect and the processes underlying the apparent domain-edge effects observed in the Series B vs Series D comparison.

4.5.1 Results and analysis

Keyword Series B

Example sentences in Keyword Series B are illustrated in Table 4.8. For the analysis of the effects of utterance length, left-headed and right-headed keywords are analysed together because there is no systematic difference between the two sets of monosyllables with respect to the utterance-span hypotheses[16].

Right-headed keywords	
$\|\ldots\sigma\sigma\sharp\sigma\sharp\ldots\|$	JOHN saw Jessica **mend** it AGAIN.
$\|\ldots\sigma\sigma\sigma\sharp\sigma\sharp\ldots\|$	JOHNNY saw Jessica **mend** it AGAIN.
$\|\ldots\sigma\sigma\sigma\sigma\sharp\sigma\sharp\ldots\|$	JONATHAN saw Jessica **mend** it AGAIN.
Left-headed keywords	
$\|\ldots\sharp\sigma\sharp\sigma\sigma\ldots\|$	I SAW the **mace** unreclaimed AGAIN.
$\|\ldots\sharp\sigma\sharp\sigma\sigma\sigma\ldots\|$	I SAW the **mace** unreclaimed once AGAIN.
$\|\ldots\sharp\sigma\sharp\sigma\sigma\sigma\sigma\ldots\|$	I SAW the **mace** unreclaimed by them AGAIN.

Table 4.8: Example experimental sentences for Keyword Series B.

Figure 4.1 shows mean syllable duration in Keyword Series B. There is no effect of Utterance Length on syllable duration by Subjects: $F(2,10.2) = 0.62$, $p = .556$ [by Items: $F(2,22.4) = 1.11$, $p = .348$]. The lengthening effect of Pitch Accent is highly significant by Subjects: $F(1,5) = 30.91$, $p < .005$ [by Items: $F(1,5) = 264.81$, $p < .001$]. There is no interaction between Utterance Length and Pitch Accent by Subjects: $F(2,10.2) = 0.21$, $p = .817$ [by Items: $F(2,24.3) = 0.10$, $p = .901$].

Although the lack of support for the utterance-span hypothesis is clear at the syllable level, it may be that some subsyllabic constituent shows an effect which is masked by variation in the other subsyllabic constituents and so the results for onset, nucleus and coda are shown in Table 4.9. This confirms that there is no relationship between the number of syllables in the utterance and the duration of test syllable onset, nucleus or coda: ANOVAs show no significant effect of Utterance Length, and no sig-

[16] As already stated, the left-headed keyword *part* is excluded from all analyses here because its phonetic environment is not consistent throughout Series B; other keywords are excluded for certain analyses because of inconsistently measurable codas.

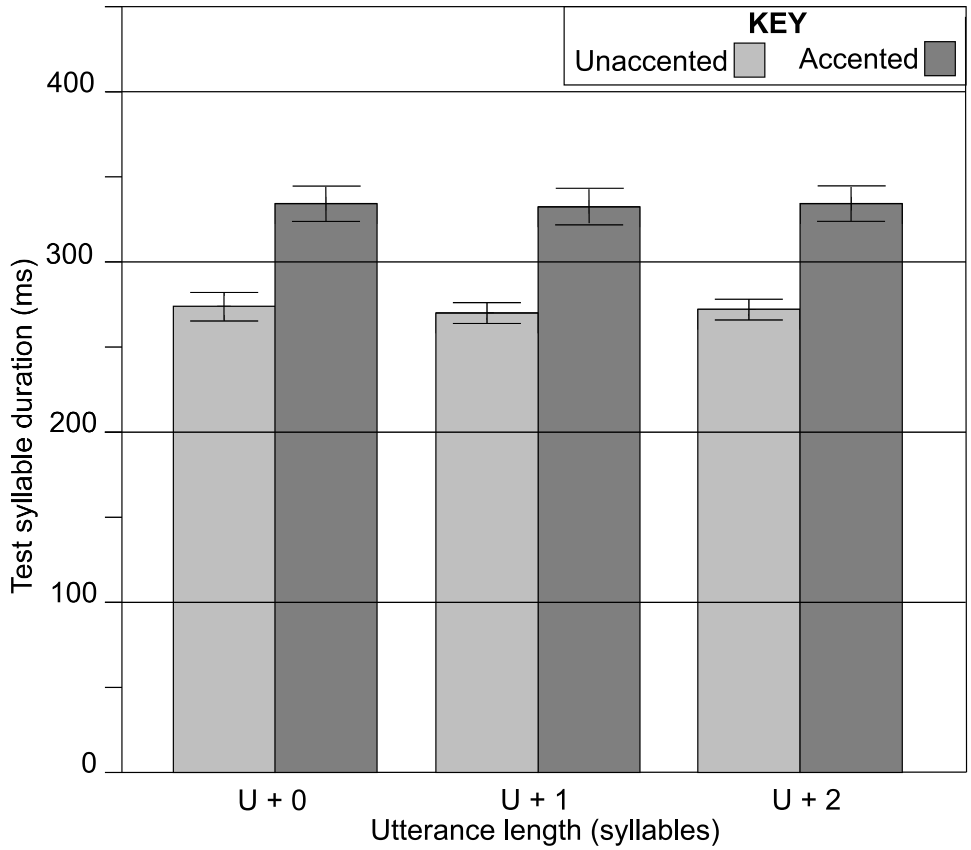

Figure 4.1: Mean test syllable duration (ms) in Keyword Series B for all keywords, excluding *part*, *cap*, *dog*, *speck* and *port*. Data points = 396; missing = 3.8%. Here and throughout, error bars represent two standard errors either side of the mean: this interval contains the population mean with 95% confidence.

nificant interaction between Utterance Length and Pitch Accent, for all subsyllabic constituents.

Therefore, all analyses of Series B data indicate no support for the utterance-span hypothesis.

Keyword Series B vs Keyword Series D

One possible reason for the lack of an utterance-span effect in Keyword Series B is that the difference in utterance length examined, only one or two syllables, might be insufficiently large relative to utterance length to cause a significant difference in test syllable duration. There are, however, other comparisons within the full set of experimental materials which provide a greater difference in utterance length: in particular, for some monosyllabic keywords, the longest sentences in Series B are four syllables

	Syllables added in utterance		
	0	1	2
Onset			
Unaccented	102	101	103
Accented	128	128	129
Nucleus			
Unaccented	91	90	90
Accented	105	107	105
Coda			
Unaccented	82	81	81
Accented	101	97	99

Table 4.9: Mean duration (ms) of subsyllabic constituents of the test syllable in Keyword Series B for right-headed and left-headed keywords. Means for onset and nucleus exclude keyword *part*: data points = 540; missing = 3.5%. Means for coda exclude keywords *part*, *cap*, *dog*, *speck* and *port*: data points = 396; missing = 3.8%.

longer than the longest sentences in Series D[17], as discussed in Section 4.2.1.

There are three such left-headed keywords examined, shown in Table 4.10. The utterance-span hypothesis predicts that the duration of the test syllable should be greater in the shorter Series D utterance than in the longer Series B utterance. It is possible, however, that proximity to the utterance boundary could also cause lengthening in the Series D test syllables: thus the locus of any effect should be examined to determine if the durational difference is greater closer to the boundary.

Series B.3 sentence	Series D.3 sentence	Difference in syllables
John THREW the **cap** to the big red BED again.	John DESIGNED the **cap** today	4
Kate GAVE the **sense** of the latest SCRIPT away.	Kate EXPLAINED the **sense** again.	4
I SAW the **mace** unreclaimed by them AGAIN.	Albert THREW the **mace** again.	4

Table 4.10: Sentences from Series B and Series D, containing left-headed keywords and differing in utterance length by four syllables.

Table 4.11 shows mean duration of the onset, nucleus and coda[18] for these three

[17] Although the shortest D.1 sentences from Series D provide a greater contrast in utterance length, they have keywords utterance-finally, where they are likely to be subject to final lengthening, and the D.2 sentences of intermediate length have keywords in utterance-penultimate position: as well as the possibility of lengthening due to proximity to the utterance boundary, the keywords are followed by full vowel syllables which could also cause lengthening of the test syllable.

[18] Although *cap* has an inconsistently measurable coda, in this data-set there are only two tokens for which neither repetition has a measurable coda.

keywords. There is little evidence of an utterance-span effect, even though the difference in utterance length is four syllables. Indeed, the direction of the durational difference in the syllable onset and nucleus is the opposite to that predicted by the utterance-span hypothesis.

	Keyword Series	
	B	D
Onset		
Unaccented	95	91
Accented	120	108
Nucleus		
Unaccented	88	83
Accented	98	96
Coda		
Unaccented	118	130
Accented	136	144

Table 4.11: Mean duration (ms) of subsyllabic constituents of the test syllable for left-headed keywords in Series B.3 and Series D.3 utterances: utterance length is four syllables greater in Series B than in Series D. Keywords used are *cap*, *sense* and *mace*: data points = 72; missing = 3 for onset and nucleus; missing = 5 for coda.

For syllable onsets, the effect of Utterance Length is significant by Subjects: $F(1,5) = 17.51$, $p < .01$ [by Items: $F(1,2.2) = 67.57$, $p < .05$]. For syllable nuclei, the effect of Utterance Length is not significant by Subjects: $F(1,5) = 0.34$, $p = .584$ [by Items: $F(1,2) = 16.91$, $p = .053$]. For syllable codas, the effect of Utterance Length approaches significance by Subjects: $F(1,5) = 4.43$, $p = .089$ [by Items: $F(1,2.1) = 32.17$, $p = .026$]. For onsets and nuclei, the effect of Accent is significant or highly significant; for codas, the effect is almost is significant by Subjects ($p = .051$) [by Items: not significant]. For neither onsets, nuclei nor codas is there a significant interaction between Utterance Length and Pitch Accent.

This pattern of results is somewhat surprising, with only coda durations showing any evidence of the durational effect predicted by the utterance-span hypothesis. It seems likely, however, that none of the results are actually related to utterance length as such. This contention is supported by a comparison between the Series B.1 utterances for the same keywords and the Series D.3 utterances used in the above comparison, as shown in Table 4.12: although the difference in utterance length is only two syllables, for onset, nucleus and coda, a very similar pattern of results emerges, the only difference being that the greater duration of test syllables codas in Series D is significant by Subjects ($p < .005$). If these effects were directly due to utterance length, a similar pattern should be seen in the comparison within Series B, where there is also an utterance length difference of two syllables.

Series B.1 sentence	Series D.3 sentence	Difference in syllables
John THREW the **cap** to the BED again.	John DESIGNED the **cap** today	2
Kate GAVE the **sense** of the SCRIPT away.	Kate EXPLAINED the **sense** again.	2
I SAW the **mace** unreclaimed AGAIN.	Albert THREW the **mace** again.	2

Table 4.12: Sentences from Series B and Series D, containing left-headed keywords and differing in utterance length by two syllables.

The result for test syllable onsets is the clearest and most unexpected: they have greater duration in the longer utterances. The difference may be related to the structure of the utterance, with a prosodic phrase boundary being more likely to precede the test syllables in the longer utterances. Examination of the Series B sentences in Table 4.10 suggests that this is unlikely, as the keywords are all preceded by *the*: the existence of a phrase boundary between a determiner and a noun would not be expected according to current theoretical accounts of prosodic structure. An alternative explanation for this observation, as what might be called a compensatory effect, is suggested in Section 4.5.2.

The nucleus shows least evidence of any utterance length effect, despite the fact that, as discussed in Section 4.1.2, domain-span effects might be expected to affect the nucleus maximally, as the phonological head of the syllable. There is a very slight lengthening of the nucleus in Series B compared with Series D, but this is not significant. Certainly, there is no evidence of an utterance-span compression effect.

Syllable codas, however, show a tendency, approaching significance, to be longer in the shorter utterance. Given the absence of any other support for the utterance-span hypothesis, and the fact that the same effect is obtained in the comparison between Series B.1 and D.3 utterances, with only two syllables difference in length, an interpretation in terms of utterance-final lengthening seems more plausible. In the Series D sentences, the test syllable is antepenultimate in the utterance: it is possible that the syllable coda may be lengthened in this position as well as in utterance-penultimate and utterance-final position: evidence for utterance-final lengthening is discussed further in Section 4.8.

Comparison of the right-headed keywords in Series B and Series D provides a further test of the effects of utterance length. Here, however, there are only two keywords—*suppose* and *send*—for which the longest sentences in Series B are four syllables longer than those in Series D; this comparison is therefore expanded to include keywords with three syllables difference in utterance length. Of these further four keywords, two—*dispose* and *juice*—have keywords in utterance-antepenultimate position in the Series B utterance: given the evidence just found for lengthening of the syllable coda in this position, these keywords are excluded from the analysis.

Table 4.13 shows the longest sentences from Series B and Series D for the keywords *suppose*, *send*, *main* and *port*. It should be noted that phonetic environment of the test syllables differs between these Series B and Series D utterances, raising the possibility of microprosodic effects influencing test syllable duration: such effects are unlikely, however, to induce a systematic bias in the results over a range of test syllables.

Series B.3 sentence	Series D.3 sentence	Difference in syllables
I LET the ballet dancer **pose** it TODAY.	Can you **pose** it TODAY please.	4
I MADE Peter Burgundy **send** to them ALL.	Will you **send** it TODAY please.	4
You MUST really continue **main** treatment NOW.	All the **main** roads SCARE me a lot.	3
I CHECKED each one in every **port** for TOM.	Can you **port** some QUICKLY please.	3

Table 4.13: Sentences containing right-headed keywords from Keyword Series B and Keyword Series D that differ in utterance length by three or four syllables.

Table 4.14 shows mean subsyllabic durations for keywords *suppose*, *send*, *main* and *port*. Both the nucleus and coda show some lengthening in the shorter Series D utterances compared with the longer Series B utterances. As for the left-headed keywords, syllable onset duration is greater in the longer utterances.

	Keyword Series	
	B	D
Onset		
Unaccented	108	99
Accented	134	124
Nucleus		
Unaccented	92	96
Accented	114	118
Coda		
Unaccented	60	65
Accented	74	85

Table 4.14: Mean duration (ms) of subsyllabic constituents of the test syllable for right-headed keywords in Series B.3 and D.3. Utterances are three or four syllables longer in Series B than Series D. Keywords used are *suppose*, *send*, *main* and *port*, the latter being excluded from the syllable coda duration means: data points for onset and nucleus = 96, missing = 1; data points for coda = 72, missing = 1.

For syllable onset, the effect of Utterance Length is significant by Subjects: $F(1,5) = 19.20$, $p < .01$ [by Items: $F(1,3) = 9.34$, $p = .055$]. For syllable nucleus, the effect of Utterance Length is not significant by Subjects: $F(1,5) = 1.58$, $p = .264$ [by Items: $F(1,3.1) = 23.32$, $p < .05$]. For syllable coda, the effect of Utterance Length is significant by Subjects: $F(1,5.1) = 15.85$, $p < .05$ [by Items: $F(1,2) = 4.98$, $p = .155$]. For onset and nucleus, the effect of Accent is significant or highly significant; for coda, the effect is significant by Subjects but not by Items. For neither onset, nucleus nor coda is there a significant interaction between Utterance Length and Pitch Accent.

As in the left-headed keyword results, there is little evidence of a direct relationship between utterance length and test syllable duration. This is supported by a comparison between the Series B.1 utterances and the Series D.3 utterances used in the above comparison, shown in Table 4.15, where the difference in utterance length between the two series is only one or two syllables: the pattern of results is very similar to that shown in Table 4.14, and the differences in onset and coda duration remain statistically significant. Because the durational effects are preserved, despite the smaller difference in syllable number, it must be concluded that the effects relate to the different structures in the two sets of utterances, rather than to their different lengths.

Series B.1 sentence	Series D.3 sentence	Difference in syllables
I LET the dancer **pose** it TODAY.	Can you **pose** it TODAY please.	2
I MADE Burgundy **send** to them ALL.	Will you **send** it TODAY please.	2
You MUST continue **main** treatment NOW.	All the **main** roads SCARE me a lot.	1
I CHECKED each one in every **port** for TOM.	Can you **port** some QUICKLY please.	1

Table 4.15: Sentences containing right-headed keywords from Keyword Series B and Keyword Series D that differ in utterance length by one or two syllables. Keywords are in bold.

The syllable onset, as for left-headed keywords, has greater duration in the longer utterance, but the phrase-initial lengthening explanation seems to be better motivated for right-headed keywords: examination of the Series B sentences in Tables 4.13 and 4.15 suggests that a prosodic boundary, such as a phonological phrase boundary, could occur preceding the keyword in some of the utterances. This seems most likely for the keywords *send* and *suppose*, where the test syllable is preceded by a noun phrase/verb phrase boundary; possible also for *main*, which follows a verb/noun phrase boundary; but unlikely for *port*, which is preceded by a noun-phrase-medial boundary. In the Series D sentences, syntactic structure and the fact that only two syllables precede the test syllables would tend to preclude the placement of phrase boundaries. The patterns of results for each keyword tends to support this analysis: *send* and *suppose* have at onsets at least 10 ms longer in Series B than in Series D, for both accented and unaccented keywords; *main* has 7 ms difference when accented and no difference when unaccented (where a preceding phrase boundary might be considered less likely); *port* has 10 ms difference when unaccented, but only 2 ms difference when accented. Thus, apart from *port* in the unaccented condition, the interpretation of the results as due to phrase-initial lengthening is supported. The relation between syntax and the occurrence of prosodic phrase boundaries is apparently probabilistic: that is, phrase boundaries are more likely preceding keywords in Series B than in Series D. The magnitude of the observed durational difference thus does not represent the true magnitude of phrase-initial lengthening, because only a proportion of the keywords in Series B will be phrase-initial. The evidence for phrase-edge processes is discussed further in Section 4.5.2.

For right-headed keywords, there is a small lengthening of the syllable nucleus in Series D compared with Series B, contrasting with the left-headed keywords, for which the trend was reversed. In neither case does the difference approach significance, however, and it must be concluded that there is no strong evidence of an utterance-span effect on test syllable nucleus duration.

The results for test syllable coda for right-headed keywords, as for left-headed keywords, are in the direction to support the utterance-span hypothesis, with greater duration in the shorter Series D utterances, but the lack of other evidence in favour of this, and the fact that the effect is comparable when the utterance length difference is one or two syllables to when it is three or four syllables, suggest that the explanation must lie elsewhere. For left-headed keywords, the utterance-antepenultimate position of the longer syllable codas suggests an utterance-final effect, but this explanation is not available for the right-headed syllables. Another possibility is that the effect is caused by utterance-medial phrase boundaries following the test syllables in the Series D utterances but not in the Series B utterances. The slight—but not significant—lengthening of the test syllable nucleus in Series D compared with Series B supports this explanation, as phrase-final lengthening would be expected to affect the syllable rhyme, but probably the coda more than the nucleus. Examination of the Series B sentences in Table 4.13 does not, however, provide compelling reasons to favour this interpretation: *pose* and *send* are followed by object pronouns which should show close prosodic attachment to the preceding verb; *main* is an adjective qualifying the following noun. A possible interpretation of this result as a compensatory effect is discussed in Section 4.5.2.

Keyword Series A vs Keyword Series C

As there appears to be no direct effect of utterance length on test syllable duration, Series A and Series C ought to show equivalent patterns of durational variation. In both series, word length is varied in utterance-medial position; the primary difference is that in Series A utterance length is fixed and in Series C utterance length covaries with word length.

For disyllabic keywords, the Series C utterance contains one more syllable than the Series A utterance, for example:

Series A.2 I saw Jessie commend it again.

Series C.2 I saw Alison commend it again.

For trisyllabic keywords, the Series C utterance contains two more syllables than the Series A utterance, for example:

Series A.3 I saw Jess recommend it again.

Series C.3 I saw Alison recommend it again.

Table 4.16 shows mean syllable durations for polysyllables in Series A and C, where no systematic difference is evident. For both disyllabic and trisyllabic comparisons in left-headed and right-headed contexts, analyses of variance confirm that there is no significant effect of Utterance Length and no interaction between Utterance Length and Accent. Furthermore, there are no such effects for the durations of onset, nucleus and coda analysed separately, except for onset duration in right-headed trisyllables, where there is a significant interaction between Utterance Length and Accent[19].

Given the lack of an utterance-span effect, Series C is used in addition to Series A in Section 4.6.1 to examine the effects of word length on test syllable duration.

4.5.2 Discussion

The utterance-span hypothesis predicts that primary stressed syllable duration is inversely related to utterance length. In the comparisons within Keyword Series B and between Keyword Series A and C, there is no significant effect of utterance length on test syllable duration. In the comparison between Series B and D, different parts of the syllable are affected in different ways by utterance length, suggesting that the observations may best be interpreted as arising from phrase-initial and utterance-final lengthening: furthermore, the structure of the sentences in question, rather than their length as such, appears to be the important factor.

This may underlie the observations by Lehiste (1974) and Rakerd *et al.* (1987) of a link between utterance length and durational variation: as observed in Chapter 2,

[19] Interaction by Subjects: $F(1,6.3) = 10.20$, $p < .05$ [by Items: $F(1,5.2) = 0.47$, $p = .521$]. In the unaccented condition, test syllable onsets from Series C right-headed trisyllables are 1 ms longer than those from Series A; in the accented condition they are 2 ms shorter: the magnitude of this interaction, together with the fact of it being entirely exceptional, indicate an anomalous result rather than an effect demanding further consideration.

	Keyword Series	
	A	C
Right-headed disyllables		
Unaccented	244	248
Accented	292	295
Right-headed trisyllables		
Unaccented	238	238
Accented	267	266
Left-headed disyllables		
Unaccented	286	286
Accented	331	327
Left-headed trisyllables		
Unaccented	279	276
Accented	306	302

Table 4.16: Mean test syllable duration (ms) in Series A and Series C. Series C utterances are longer by one syllable in the disyllable comparison, and by two syllables in the trisyllable comparison. All keywords except *port* are included for the right-headed disyllables: data points = 168; missing = 2.4%. All keywords except *port* and *dispose* (missing data) are included for the right-headed trisyllables: data points = 144; missing = 4.2%. Keywords *fish*, *mace*, *sense* and *ten* are included for left-headed disyllables and trisyllables: data points = 192; missing, for disyllables = 6.3%, for trisyllables = 2.1 %.

prosodic phrasing is influenced by the length of sentences and syntactic phrases. Thus sentence length may indirectly influence duration by affecting the number and placement of boundaries at which lengthening processes may occur. In general, longer sentences are likely to contain more prosodic boundaries rather than fewer, thus causing more aggregate lengthening, so the general trend would be in the opposite direction to that predicted by the utterance-span hypothesis.

The loci of variation, in the comparison between Series B and D, suggest domain-edge rather than domain-span interpretations: there is no significant durational variation on the test syllable nucleus—the phonological head of the syllable—but durational effects are seen on the onset and coda. The variations in test syllable onset and coda durations are considered in across the full set of keywords in Appendix G.

Three types of effects are suggested by this analysis: phrase-initial lengthening, utterance-final lengthening and compensatory shortening. Compensatory shortening is suggested to occur in association with both of the lengthening effects: the term "compensatory" is used here to characterise durational effects in which some constituent shortens or lengthens apparently as a result of an opposite durational variation elsewhere, whatever the underlying interpretation for the effect.

In Appendix G, there is a comparison of test syllable subconstituent duration between Series B.3 and Series D.3 utterances for right-headed keywords, such as:

Series B.3 I MADE Peter Burgundy **send** to them ALL.

Series D.3 Will you **send** it TODAY please.

There is evidence of lengthening of test syllable onsets in Series B compared with Series D, suggesting that in some cases the test syllable may be preceded by a phrase boundary[20]. There is also some evidence of lengthening of the coda for certain keywords in the Series D sentences, although this result is not significant across all keywords. The Series D sentences do not appear likely to have a phrase boundary following the test syllable, thus final lengthening cannot explain the greater length of the coda; rather, the observation of phrase-initial lengthening in the Series B onset and shortening of the Series B coda suggest that there may be a compensatory relationship between onset duration and coda duration.

In Appendix G, there is also a comparison between Series B.3 and Series D.3 for left-headed keywords, such as:

Series B.3 I SAW the **mace** unreclaimed by them AGAIN.

Series D.3 Albert THREW the **mace** again.

There is evidence of lengthening of the coda in Series D, which may be due to the utterance-antepenultimate position of the syllable. There is also evidence of lengthening of the onset in Series B; the structure of the sentences suggests that this is unlikely to be phrase-initial lengthening. The explanation may be compensatory shortening of the onset in Series D due to lengthening of the coda.

There is also some evidence of a compensatory effect associated with word-initial lengthening reported in 4.6.2. Possible interpretations of apparent compensatory effects are discussed in Chapter 5, as is the absence of evidence for utterance-span compression in relation to previous studies.

[20]As noted in Appendix G, the occurrence of a phrase boundary at a given point in a particular utterance is a matter of probability: syntactically more important boundaries are more likely to be realised prosodically. As keyword-adjacent intonational phrase boundaries are excluded from the final data-set, the phrases associated with these boundaries will be below the intonational phrase: for example, the phonological phrase. The question of (phonological) phrase-initial lengthening is considered further in Section 4.6 in relation to word-level results.

4.6 Word-edge and word-span results

As an overview of the durational effects of word length, primary stressed syllable durations are presented in Section 4.6.1 for monosyllables, disyllables and trisyllables. These results indicate that the word-span hypothesis—primary stressed syllable duration is inversely related to word length—is strongly supported only for accented keywords. Word-level effects are then examined in detail for subsyllabic constituents.

Results are reported first for right-headed keywords. Onset durations indicate support for the word-initial hypothesis: the duration of the primary stressed syllable onset is greater word-initially than word-medially in utterance-medial words. The hypotheses regarding the interaction of word-initial lengthening and accent are then examined. The word-initial accent hypothesis is not supported: thus, once the effects of word length in accented words are taken into account, word-initial lengthening of stressed syllable onsets is not significantly greater in accented syllables than unaccented syllables. The word-initial aspiration accent hypothesis is also not supported: onset aspiration duration is longer word-initially in both unaccented and unaccented syllables. The possible influence of phrase-initial position on syllable onset duration, suggested in Section 4.5, is also examined. The results for right-headed keywords for nucleus and coda duration are reported, in general indicating support for the word-span hypothesis in accented keywords only.

Results for left-headed keywords are then reported. Onset durations suggest that word-initial lengthening may be greater in monosyllables than in polysyllables. Nucleus duration suggest support for the word-span hypothesis and also for word-rhyme-span hypothesis: primary stressed syllable duration is inversely related to word-rhyme length. Coda duration indicates support for the word-span hypothesis in accented words only, and does not offer support for the word-final hypothesis—that the duration of the primary stressed syllable rhyme is greater word-finally than word-medially in utterance-medial words—because in unaccented words, there is no effect of word position on the coda.

Unstressed syllable durations are also reported. The results for right-headed keywords offer some support for word-initial lengthening, plus a word-span effect in accented keywords only. The results for left-headed keywords could be taken as support for word-rhyme-span compression or for word-final lengthening .

Section 4.6.2 discusses the implications of the results for the four types of process considered at the word-level: word-span compression; word-rhyme-span compression; word-final lengthening; and word-initial lengthening.

4.6.1 Results and analysis

Primary stressed syllable duration

Example sentences in Series A, where the number of syllables in the word varies but the total number of syllables in the utterance is fixed, are shown in Table 4.17.

Right-headed keywords	
$\|\ldots\sigma\sigma\sharp\boldsymbol{\sigma}\sharp\ldots\|$	JOHN saw Jessica **mend** it AGAIN.
$\|\ldots\sigma\sharp\sigma\boldsymbol{\sigma}\sharp\ldots\|$	JOHN saw Jessie **commend** it AGAIN.
$\|\ldots\sharp\sigma\sigma\boldsymbol{\sigma}\sharp\ldots\|$	JOHN saw Jess **recommend** it AGAIN.
Left-headed keywords	
$\|\ldots\sharp\boldsymbol{\sigma}\sharp\sigma\sigma\ldots\|$	I SAW the **mace** unreclaimed AGAIN.
$\|\ldots\sharp\boldsymbol{\sigma}\sigma\sharp\sigma\ldots\|$	I SAW the **mason** reclaimed it ALL.
$\|\ldots\sharp\boldsymbol{\sigma}\sigma\sigma\sharp\ldots\|$	I SAW the **masonry** cleaned AGAIN.

Table 4.17: Example sentences for Keyword Series A.

Mean test syllable duration for right-headed keywords in Series A is shown in Figure 4.2. The effect of Word Length is highly significant by Subjects: F(2,10.1) = 37.43, p < .001 [by Items: F(2,12.4) = 71.12, p < .001]. The effect of Accent is highly significant by Subjects: F(1,5) = 29.38, p< .005 [by Items: F(1,6.2) = 308.99, p< .001]. There is a highly significant interaction between Word Length and Accent by Subjects: F(2,10.2) = 23.99, p < .001 [by Items: F(2.62) = 11.90, p < .01]. Planned comparisons indicate that the difference in test syllable duration between monosyllables and disyllables is highly significant for both accented and unaccented keywords; the difference between disyllables and trisyllables is highly significant for accented keywords but not significant for unaccented keywords. Two processes are suggested by these results: a word-initial lengthening effect in accented and unaccented keywords, contributing to the difference in, for example, *mend* vs *commend*; and a word-span effect in accented keywords only, contributing to the difference in *mend* vs *commend* and *commend* vs *recommend*. Examination of subsyllabic durations below supports these conclusions.

Mean stressed syllable duration for left-headed keywords in Series A is shown in Figure 4.3. The effect of Word Length is highly significant by Subjects: F(2,10.1)= 12.84, p < .005 [by Items: F(2,6) = 9.97, p < .05]. The effect of Accent is significant by Subjects: F(1,5) = 15.81, p < .05 [by Items: F(1,3) = 57.06, p = .005]. The interaction between Word Length and Accent is also highly significant by Subjects: F(2,10.2) = 7.71, p < .01 [by Items: F(2,6.2) = 11.90, p < .01]. Planned comparisons indicate that the difference in test syllable duration between monosyllables and disyllables approaches significance for accented keywords (p = .057) but not significant for unaccented keywords;

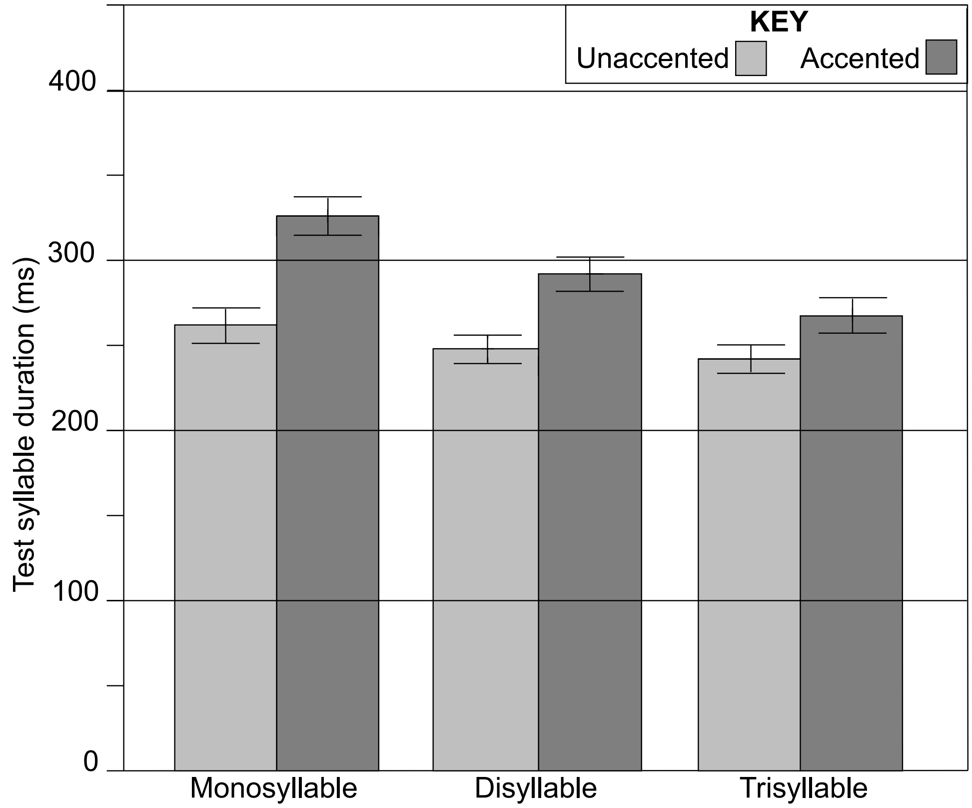

Figure 4.2: Mean test syllable duration (ms) in Series A for right-headed keywords excluding *port*: data points = 252; missing = 3.8%.

the difference between disyllables and trisyllables is highly significant for accented keywords but not significant for unaccented keywords. The difference between monosyllables and trisyllables is, however, significant for unaccented keywords as well as for accented keywords. As for right-headed keywords, there is evidence of a word-span effect in accented keywords only. The slight shortening effect in unaccented keywords, significant in, for example, *mace* vs *masonry* suggests a word-rhyme-span effect, because there is no comparable difference in right-headed keywords. Analysis of subsyllabic durations below indicates that the locus of this effect is the syllable nucleus.

The interaction between word length and accent for left-headed and right-headed keywords arises because the effect of word length is greater in accented keywords than in unaccented keywords. This is illustrated in Table 4.18: the absolute and proportional shortening of the test syllable due to an additional syllable in the word is substantially greater in the accented condition. An alternative view of this effect is that accentual lengthening of the test syllable is greater in words of fewer syllables, as discussed in more detail later. Apart from the monosyllable vs disyllable (and monosyllable vs trisyllable) comparison for right-headed keywords and the monosyllable vs

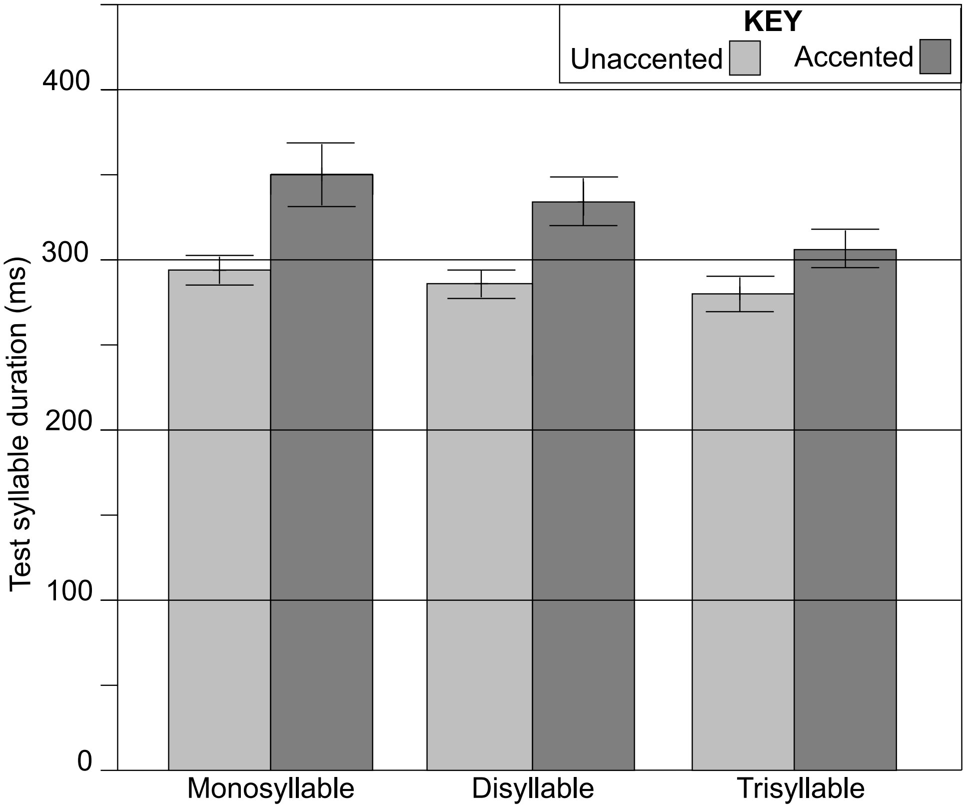

Figure 4.3: Mean test syllable duration (ms) in Series A for left-headed keywords *fish*, *mace*, *mend* and *send*: data points = 144; missing = 2.0%.

trisyllable for left-headed keywords, none of the differences in unaccented keywords are significant.

Table 4.18 also shows that for the comparison between monosyllables and disyllables, the effect of word length is much greater in right-headed keywords than in left-headed keywords, due to the large word-initial lengthening effect: analysis of subsyllabic durations, reported below, indicates that the locus of this effect is the syllable onset. Thus, /m/ is longer in *mend* than in *commend* or *recommend*.

The magnitude of the effect between disyllabic and trisyllabic keywords is comparable in Table 4.18 in left-headed and right-headed accented keywords, suggesting a word-span effect. Right-headed unaccented keywords show very little effect of word length, beyond that explicable as word-initial lengthening. Left-headed unaccented keywords show a slightly larger effect, comparable between monosyllables vs disyllables and disyllables vs trisyllables. This suggests that the word-final hypothesis is not supported: the loss of word-final lengthening in, for example, *fissure* vs *fish*, should cause a large shortening effect in /fɪʃ/, whereas there should be little or no difference in syllable duration between *fisherman* vs *fissure*.

	Disyllable vs Monosyllable		Trisyllable vs Disyllable	
Right-headed keywords	18 ms 6.9%	**34 ms** **10.4%**	3 ms 1.2%	**24 ms** **8.2%**
Left-headed keywords	7 ms 2.4%	**18 ms** **5.2%**	7 ms 2.4%	**25 ms** **7.6%**

Table 4.18: The absolute and proportional shortening of the test syllable in disyllables compared with monosyllables, and trisyllables compared with disyllables. Figures on the left in each cell are for the unaccented condition; figures on the right in bold are for the accented condition.

All of the hypotheses are now considered further by examining the distribution of durational variation in the subsyllabic constituents, for right-headed keywords and for left-headed keywords. The primary test of these hypotheses is Keyword Series A, where word length varies as utterance length remains fixed. As the results presented in Section 4.5.1 indicate no direct effect of utterance length on test syllable duration, Keyword Series C, in which word length and utterance length covary, is used as an additional test of the word-level hypotheses. Series C is illustrated in Table 4.19: the first sentence in each set, which contains the monosyllabic keyword, is also in to Series A, and so results reported for monosyllabic keywords are identical, except where a different subset of the data is used.

Right-headed keywords	
$\|\ldots\sigma\sigma\sharp\Sigma\sharp\ldots\|$	JOHN saw Jessica **mend** it AGAIN.
$\|\ldots\sigma\sigma\sharp\sigma\Sigma\sharp\ldots\|$	JOHN saw Alison **commend** it AGAIN.
$\|\ldots\sigma\sigma\sharp\sigma\sigma\Sigma\sharp\ldots\|$	JOHN saw Alison **recommend** it AGAIN.
Left-headed keywords	
$\|\ldots\sharp\Sigma\sharp\sigma\sigma\ldots\|$	I SAW the **mace** unreclaimed AGAIN.
$\|\ldots\sharp\Sigma\sigma\sharp\sigma\sigma\ldots\|$	I SAW the **mason** disinclined it ALL.
$\|\ldots\sharp\Sigma\sigma\sigma\sharp\sigma\sigma\ldots\|$	I SAW the **masonry** disinterred AGAIN.

Table 4.19: Example experimental sentences for Keyword Series C.

In the analysis of subsyllabic durational variation, results are presented for Series A. The results for Series C are in Appendix H: subsyllabic mean durations are given in Table H.1 for right-headed keywords and in Table H.3 for left-headed keywords; ANOVA results for Series C are shown in Table H.2 for right-headed keywords and Table H.4 for left-headed keywords. Results for Series A and C are compared in the following discussion, but the details of statistical tests for Series C are not given where the pattern of results is equivalent to that for Series A (this includes cases where the difference is merely in the level of significance).

Right-headed keywords: onset duration

Table 4.20 shows mean test syllable onset duration for right-headed keywords in Series A. There is a highly significant effect of Word Length by Subjects: $F(2,10.1) = 64.49$, $p < .001$ [by Items: $F(2,14.1) = 44.93$, $p < .001$]. The effect of Accent is highly significant by Subjects: $F(1,5) = 30.13$, $p < .005$ [by Items: $F(1,7.2) = 231.03$, $p < .001$]. There is also a highly significant interaction between Word Length and Accent by Subjects: $F(2,10.1) = 21.62$, $p < .001$ [by Items: $F(2,14.7) = 47.00$, $p < .001$].

Planned comparisons reveal that the difference in onset duration between monosyllables and disyllables is highly significant for both accented and unaccented contexts. Thus, for example, /m/ is shorter in *commend* than in *mend*, and the effect is greater in accented keywords (31 ms, 24%) than in unaccented keywords (17 ms, 17%). There is no significant difference in onset duration between unaccented disyllables and trisyllables, but there is a highly significant shortening effect (13 ms, 13%) between accented disyllables and trisyllables: thus, for example, /s/ is shorter in *condescend* than *descend*.

	Number of syllables in word		
	1	2	3
Unaccented	99	82	81
Accented	128	97	84

Table 4.20: Mean test syllable onset duration (ms) for all right-headed keywords in Series A: data points = 288; missing = 4.5%.

The data-set for Series C for syllable onset excludes the keyword *port* (missing data), but the pattern of results (Appendix H) is very similar to that for Series A: a large shortening effect between monosyllables and disyllables for both accent conditions and a further shortening effect between disyllables and trisyllables for accented keywords only. As in Series A, the effects of Word Length, Accent and the interaction between Word Length and Accent are all highly significant.

The results for onset duration support the word-initial lengthening hypothesis: the duration of the syllable onset is increased by adjacency to the initial boundary of an utterance-medial word. The further shortening, in accented keywords only, between disyllables and trisyllables indicates a word-span effect which appears dependent on the presence of pitch accent. An alternative view of this interaction is that accentual lengthening on the syllable onset is greater in words of fewer syllables.

Interaction between word-initial lengthening and accent: onset duration

The word-initial accent hypothesis predicts that word-initial lengthening of stressed syllable onsets is greater in accented syllables. This hypothesis is apparently supported: word-initial lengthening occurs in the primary stressed syllable onset of both accented and unaccented keywords—thus, /m/ is longer in *mend* than in *commend*—but the effect is greater in accented keywords. Not all of the durational difference between accented monosyllables and disyllables may be due to the word-initial effect, however: a proportion may result from the word-span compression effect. The evidence from the disyllable vs trisyllable comparison suggests a word-span effect on test syllable onsets only in the accented context: thus, /m/ is longer in *commend* than in *recommend* in the comparison between accented keywords but not between unaccented keywords. This word-span effect in accented words could account for the apparently greater word-initial effect in the presence of accent. If so, word-initial lengthening as such is independent of pitch accent: in an accented word, an onset consonant seems to gain extra duration due to word-initial position which is actually attributable to its being in a monosyllable rather than a disyllable (for example: /m/ in *mend* rather than *commend*). If this interpretation is correct, then the word-initial accent hypothesis is not in fact supported, and there is no interaction between word-initial lengthening and accent.

Interaction between word-initial lengthening and accent: voiceless stop closure and aspiration duration

The word-initial aspiration accent hypothesis states that word-initial lengthening of aspiration in stressed-syllable-onset voiceless stops only occurs in unaccented syllables; in accented syllables, onset aspiration duration may be longer word-medially. Table 4.21 shows the mean test syllable closure and aspiration duration in Series A for the right-headed keywords which have voiceless stops as their test syllable onset: *compose*, *port* and *suppose*[21]. The evidence for both a word-initial effect and a word-length effect is comparable to that found for syllable onset duration.

For closure duration, the effect of Word Length is highly significant by Subjects: $F(2,10.5) = 45.45$, $p < .001$ [by Items: $F(2,4) = 7.20$, $p = .047$]. The effect of Accent is significant by Subjects: $F(1,5) = 6.70$, $p < .05$ [by Items: $F(1,2.1) = 139.06$, $p < .01$]. The interaction between Word Length and Accent is highly significant by Subjects: $F(2,10.9) = 23.08$, $p < .001$ [by Items: $F(2,4.5) = 32.93$, $p < .005$]. Planned comparisons indicate that the shortening in closure duration between monosyllables and disyllables is significant for unaccented words (9 ms, 13%) and highly significant for accented words

[21]The keyword *dispose* is excluded because the test syllable onset is unaspirated in disyllabic and trisyllabic contexts, indicating the syllabification /dɪ.spəʊz/.

	Number of syllables in word		
	1	2	3
Closure duration			
Unaccented	69	60	61
Accented	85	69	58
Aspiration duration			
Unaccented	43	36	33
Accented	56	44	34

Table 4.21: Mean test syllable onset closure and aspiration duration (ms) in Keyword Series A for keywords *compose*, *suppose* and *port*: data points = 108; missing = 6.

(16 ms, 19%). Between disyllables and trisyllables, unaccented keywords show no significant difference and accented keywords show a highly significant shortening effect (11 ms, 16%).

The pattern of results for aspiration duration is very similar. The effect of Word Length is highly significant by Subjects: $F(2,10.1) = 20.19$, $p < .001$ [by Items: $F(2,4.1) = 18.63$, $p < .01$]. The effect of Accent is significant by Subjects: $F(1,5) = 9.25$, $p < .05$ [by Items: $F(1,2.1) = 38.62$, $p < .05$]. The interaction between Word Length and Accent is significant by Subjects: $F(2,10.2) = 6.50$, $p < .05$ [by Items: $F(2,4.2) = 5.98$, $p = .059$]. Planned comparisons indicate that the shortening in aspiration duration between monosyllables and disyllables is significant for unaccented words (7 ms, 16%) and highly significant for accented words (12 ms, 21%). Between disyllables and trisyllables, unaccented keywords show no significant difference and the accented keywords show a highly significant shortening effect (10 ms, 23%).

For both onset closure and aspiration duration for *compose*, *suppose* and *port*, the pattern of results shown in Table 4.21 closely resembles that seen for onset duration in the full data-set: a shortening effect between monosyllables and disyllables which is somewhat greater in accented keywords and a shortening effect between disyllables and trisyllables only evident in accented keywords. This suggests that, as discussed above, the word-initial effect is complemented in the accented context by a word-span compression effect, thus increasing manifest size of word-initial lengthening. The present results suggest that either the previously-observed word-initial shortening of aspiration duration in accented syllables is not robust, or it is not observed here because word-span shortening between monosyllables and disyllables in the accented condition serves to mask the effect of word position.

Word-initial effect: influence of phrase boundaries.

Results reported in Section 4.5.1 suggest that monosyllabic keywords in utterance-medial position may in some cases be preceded by phrase boundaries which are not present when the keywords are near the start of the utterance; thus, the apparent word-initial lengthening effect could actually be a result of phrase-initial lengthening.

To test the effect of word-initial position in the absence of phrase boundaries, test syllable onsets are examined in Series D, where they are near the start of the utterance and unlikely to be immediately preceded by a phrase boundary, and compared with Series E, which has polysyllables in similar utterances. Series B utterances, where test syllables in monosyllabic keywords appear to have a higher probability of occurring in phrase-initial position, are included for reference. Example utterances in these experimental conditions are shown in Table 4.22.

B.2	JOHNNY saw Jessica **mend** it AGAIN.
D.2	Now **mend** it AGAIN for me please.
E.2	**Commend** it AGAIN for me please.
B.3	JONATHAN saw Jessica **mend** it AGAIN.
D.3	Will you **mend** it AGAIN for me please.
E.3	**Recommend** it AGAIN for me please.

Table 4.22: Example utterances in Keyword Series B, D and E.

Table 4.23 shows the mean test syllable onset duration (ms) for right-headed keywords in Series B, D and E, excluding those in the shortest utterance length conditions (B.1, D.1, E.1). A number of trends may be observed, apart from the clear lengthening effect of pitch accent throughout. Firstly, the comparison within Series E illustrates the effect of word length discussed above: onsets are shorter in trisyllables than in disyllables, and this effect is greater in accented keywords. Secondly, the comparison between Series B.3 and Series D.3 shows the influence of phrase boundaries indicated in Section 4.5.1: test syllable onsets in monosyllables are slightly longer utterance-medially, where they seem more likely to be preceded by a phrase boundary, such as that between phonological phrases; this effect does not depend on accent[22]. Thirdly, the comparisons between Series D and Series E show that there is a large difference in test syllable onset duration between monosyllables and disyllables (D.3 vs E.2), and between monosyllables and trisyllables (D.3 vs E.3), even when the monosyllabic keyword is unlikely to be phrase-initial; this effect is greater in accented keywords but still large in unaccented keywords.

[22]The difference between word-initial and potentially phrase-initial syllable onsets is not evident in the B.2 vs D.2 comparison in Table 4.23. Comparison within Series D suggests that onsets are slightly lengthened in the D.2 utterances, possibly because they are preceded by the full vowel syllable *now* in all

	Keyword Series		
	B	D	E
	B.2	*D.2*	*E.2*
Unaccented	97	98	79
Accented	129	127	90
	B.3	*D.3*	*E.3*
Unaccented	100	95	76
Accented	129	122	83

Table 4.23: Mean test syllable onset duration (ms) for right-headed keywords in Series D and Series E. All keywords are included for the U+1 comparison: data points = 192; missing = 2.1%. All keywords except *dispose* (missing data) are included for the U+2 comparison: data points = 168; missing = 4.2%.Test syllable onset duration (ms) for right-headed keywords in Series B is included for reference, for the same keywords in each comparison.

The difference in onset duration between Series D.2 and Series E.2, an effect of Word Length, is highly significant by Subjects: $F(1,5) = 128.12$, $p < .005$ [by Items: $F(1,7) = 26.41$, $p < .005$]. The effect of Accent is highly significant by Subjects: $F(1,5) = 34.61$, $p < .005$ [by Items: $F(1,7) = 149.95$, $p < .001$]. The interaction between Word Length and Accent is highly significant by Subjects: $F(1,5) = 40.87$, $p < .005$ [by Items: $F(1,7.1) = 66.53$, $p < .001$]. The effect of Word Length evident between Series D.3 and Series E.3 is highly significant by Subjects: $F(1,5) = 112.08$, $p < .001$ [by Items: $F(1,7) = 30.17$, $p < .005$]. The effect of Accent is highly significant by Subjects: $F(1,5) = 22.57$, $p < .01$ [by Items: $F(1,7.5) = 443.59$, $p < .001$]. The interaction between Word Length and Accent is highly significant by Subjects: $F(1,5) = 19.25$, $p < .01$ [by Items: $F(1,7.3) = 59.17$, $p < .001$].

The evidence strongly indicates word-initial lengthening as well as phrase-initial lengthening. The word-initial effect is greater in accented keywords; as discussed in Section 4.5.1, the phrase-initial effect does not show such an interaction. Given that word-initial and phrase-initial processes might be expected to manifest similar interactions, this observation supports the interpretation of the word-level effects discussed above: word-initial lengthening comparable in accented and unaccented keywords, plus word-span compression in accented keywords only.

Right-headed keywords: nucleus duration

Table 4.24 shows mean test syllable nucleus duration for the right-headed keywords in Series A, where there is no strong evidence for either a word-initial effect or a word-

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cases, except for *main*, preceded by *the*.

span effect.

	Number of syllables in word		
	1	2	3
Unaccented	97	97	97
Accented	114	118	111

Table 4.24: Mean nucleus duration (ms) in the test syllable for right-headed keywords in Series A: data points = 288; missing = 4.5%.

The effect of Word Length is not significant by Subjects: $F(2,10.2) = 2.22$, $p = .159$ [by Items: $F(2,14.6) = 1.89$, $p = .187$]. The effect of Accent is significant by Subjects: $F(1,5) = 13.08$, $p < .05$ [by Items: $F(1,7) = 23.82$, $p < .005$]. The interaction between Word Length and Accent is not significant by Subjects: $F(2,10.2) = 2.63$, $p = .119$ [by Items: $F(2,14.5) = 3.72$, $p = .05$]. Planned comparisons indicate that none of the differences in vowel duration are significant for either accented or unaccented keywords, although in the accented condition the difference in vowel length between disyllabic and trisyllabic context approaches significance ($p = .077$).

These results strongly suggest that the word-initial lengthening seen for onset duration does not extend to the vowel of the word-initial syllable. Furthermore, there is little evidence of the word-span effect suggested by previous results for accented words, except for a non-significant difference between disyllables and trisyllables. Nucleus duration is actually slightly shorter in accented monosyllables than accented disyllables : a possibly compensatory relationship between this effect and word-initial lengthening is discussed in Section 4.6.2.

The results for nucleus duration in Series C (Appendix H) are similar, with little clear evidence of a word-span effect: nucleus duration is slightly longer in disyllables than monosyllables, and shorter in trisyllables than disyllables, particularly for accented keywords. The effect of Word Length is, however, significant in a By-Subjects analysis: $F(2,10.2) = 5.79$, $p < .05$ [by Items: $F(2,12.2) = 3.70$, $p = .055$]. The effect of Accent is significant and the interaction between Word Length and Accent not significant. The results of planned comparisons are equivalent to those for Series A: for both accented and unaccented keywords, there is no significant durational difference in pairwise comparisons of Word Length; once again, only the difference between accented disyllables and trisyllables approaches significance ($p = .067$).

Right-headed keywords: coda duration

Table 4.25 shows mean test syllable coda duration for right-headed keywords in Series A. Although differences in coda duration according to word length are small, particularly for the unaccented keywords, they are in the direction predicted by the word-span hypothesis.

	Number of syllables in word		
	1	2	3
Unaccented	69	68	66
Accented	85	80	75

Table 4.25: Mean test syllable coda duration (ms) for right-headed keywords in Series A excluding keyword *port*: data points = 252; missing = 3.8%.

The effect of Word Length illustrated in Table 4.25 is significant by Subjects: $F(2, 10.1) = 4.92$, $p < .05$ [by Items: $F(2,13.1) = 11.75$, $p = .001$]. The effect of Accent is highly significant by Subjects: $F(1,5) = 27.07$, $p < .005$ [by Items: $F(1,6) = 8.01$, $p < .05$]. The interaction between Word Length and Accent is highly significant by Subjects: $F(2,10.8) = 7.55$, $p < .01$ [by Items: $F(2,14) = 4.92$, $p < .05$]. Planned comparisons indicate that none of the differences in coda duration due to Word Length are significant in the unaccented condition, but coda duration is significantly greater in monosyllables than trisyllables in the accented condition.

The pattern of variation of coda duration is similar in Series C (Appendix H), with evidence of a small word-span effect, greater in accented keywords. The effect of Word Length is highly significant in Series C, as is the effect of Accent. For Series C, however, the interaction between Word Length and Accent is not found to be significant by Subjects: $F(2,10.2) = 2.40$, $p = .131$.

Right-headed keywords: summary

The results for the subsyllabic constituents of test syllables in right-headed keywords suggest two durational processes. Firstly, a large word-initial lengthening effect, with a syllable onset locus. Secondly, a smaller word-span effect only present, or only of significant magnitude, in accented words. The locus of the word-span effect appears to be the whole syllable, but durational variation is more evident on the onset and coda than on the nucleus, where evidence for a word-span effect is slight. These results are discussed further in Section 4.6.2.

Left-headed keywords: onset duration

Table 4.26 shows mean test syllable onset duration for left-headed keywords in Series A. There is a significant effect of Word Length by Subjects: $F(2,10.1) = 5.97$, $p < .05$ [by Items: $F(2,10.1) = 7.71$, $p < .01$]. The effect of Accent is also significant by Subjects: $F(1,5) = 10.8$, $p < .05$ [by Items: $F(1,5) = 188.85$, $p < .001$]. The interaction between

Word Length and Accent is not significant by Subjects: $F(2,10.4) = 1.48$, $p = .271$ [by Items: $F(2,10.5) = 7.02$, $p < .05$]. Planned comparisons indicate that for both unaccented and accented keywords, the difference between monosyllables and disyllables is significant.

	Number of syllables in word		
	1	2	3
Unaccented	112	104	106
Accented	133	124	121

Table 4.26: Mean duration (ms) of test syllable onset for all left-headed keywords in Series A except *dog* and *part*: data points = 216; missing = 1.4%.

For left-headed keywords in Series C (Appendix H), mean test syllable onset durations are very similar to those for Series A: the effects of Word Length and Accent are significant, and the interaction between Word Length and Accent is not significant. The difference between monosyllables and disyllables approaches significance for unaccented keywords ($p = .063$) and is significant for accented keywords.

The results for onset duration offer some support for the word-final hypothesis, because the source of the significant effect of word length appears to be the difference between monosyllables and disyllables/trisyllables, in both accented and unaccented keywords: for example, /m/ is longer in *mace* than in *mason* or *masonry*. There is no evidence of a shortening effect between disyllables and trisyllables in unaccented keywords and only a very slight, non-significant effect in accented keywords. Paradoxically, although this result offers some support for a binary distinction between word-final and non-final stressed syllables, the syllable onset is not generally believed to manifest domain-final lengthening. An alternative interpretation, discussed further in Section 4.6.2, is that the results indicate that the magnitude of word-initial lengthening is greater in monosyllables than in polysyllables.

Left-headed keywords: nucleus duration

Table 4.27 shows mean test syllable nucleus duration for left-headed keywords in Series A. The effect of Word Length is highly significant by Subjects: $F(2,10.3) = 27.27$, $p < .001$ [by Items: $F(2,10.1) = 32.81$, $p < .001$]. The effect of Accent approaches significance by Subjects: $F(1,5) = 4.87$, $p = .078$ [by Items: $F(1,5.1) = 68.94$, $p < .001$]. The interaction between Word Length and Accent is highly significant by Subjects: $F(2,11.8) = 10.92$, $p < .005$ [by Items: $F(2,10.2) = 3.19$, $p = .084$]. Planned comparisons show that the durational difference between monosyllables and disyllables is only significant in accented keywords, but the difference between disyllables and trisyllables is significant in both accented and unaccented keywords. The difference between monosyllables and trisyllables is highly significant in both accent conditions.

	Number of syllables in word		
	1	2	3
Unaccented	79	76	67
Accented	89	79	72

Table 4.27: Mean test syllable nucleus duration (ms) for left-headed keywords in Series A except *dog* and *part*: data points = 216; missing = 1.4%.

The results for nucleus duration are very similar for Series C (Appendix H): for both accented and unaccented words, there is shortening between monosyllables and disyllables and further shortening between disyllables and trisyllables. The effect of Word Length is highly significant, the effect of Accent is significant and the interaction between Word Length and Accent is significant. The results of planned comparisons are very similar, although for Series C the difference between disyllables and trisyllables only approaches significance in the accented condition.

The results for nucleus duration provide support for the word-span hypothesis. The interaction indicates that the word-span compression effect on the nucleus is differently distributed in unaccented and accented keywords. For Series A, disyllabic shortening compared with the monosyllabic context is 3 ms (4%) for unaccented words and 10 ms (11%) for accented words; trisyllabic shortening compared with the disyllabic context is 9 ms (12%) for unaccented words and 7 ms (9%) for accented words. The fact that the differences between disyllables and trisyllables are comparable with those between monosyllables and disyllables favours the word-span hypotheses rather than the word-final hypothesis, as the latter predicts no difference in stressed syllable duration in disyllables vs trisyllables, or a much smaller difference than between monosyllables and disyllables. The results show that, for example, the vowel /eɪ/ in /meɪs/ is shorter in *mason* than in *mace* and shorter still in *masonry*. This constitutes good evidence for a word-span effect; however, unlike most of the foregoing results, the evidence suggests an effect in both accented and unaccented keywords.

If the word-span effect does only affect accented words, then the presence of a difference in the unaccented left-headed keywords for nucleus duration could be taken to indicate support for the word-rhyme-span hypothesis: this states that primary stressed syllable duration is inversely related to the word-rhyme length, and the results here suggest that the effect is localised on the syllable nucleus, as discussed further in Section 4.6.2.

Left-headed keywords: coda duration

Table 4.28 shows mean test syllable coda duration for left-headed keywords in Series A. The effect of Word Length is not significant by Subjects: $F(2,10.3) = 2.00$, $p = .184$ [by Items: $F(2,6.1) = 0.65$, $p = .557$]. The effect of Accent is significant by Subjects: $F(1,5) = 9.60$, $p < .05$ [by Items: $F(1,3) = 10.48$, $p < .05$]. There is a significant interaction between Word Length and Accent according to a By Subjects analysis: $F(2,10.5) = 5.31$, $p < .05$ [by Items: $F(2,6.2) = 5.66$, $p < .05$]. Planned comparisons reveal that the only significant difference in coda duration according to Word Length for either Accent condition is between monosyllables and trisyllables in the accented condition ($p < .05$).

	Number of syllables in word		
	1	2	3
Unaccented	104	105	105
Accented	131	126	116

Table 4.28: Mean test syllable coda duration (ms) for the left-headed keywords *fish*, *mace*, *sense* and *ten* in Series A: data points = 144; missing = 3%.

The results for coda duration are very similar for Series C (Appendix H): there is no evidence of a word-span effect in the unaccented context, but good evidence for a word-span effect in the accented context. The effect of Word Length approaches significance in Series C, as does the effect of Accent, and the interaction between Word Length and Accent is significant. The difference between monosyllables and trisyllables in the accented condition is significant in planned comparisons.

Because of the significant interaction and the apparent word-span effect which it indicates in accented keywords only, the data from the accented condition are analysed separately: for Series A, the effect of Word Length approaches significance by Subjects: $F(2,11.1) = 3.70$, $p = .059$ [by Items: $F(2,6.2) = 2.16$, $p = .194$]; For Series C, the effect of Word Length is significant by Subjects: $F(2,14.3) = 5.08$, $p < .05$ [by Items: $F(2,6.1) = 1.83$, $p = .239$]. These analyses support the conclusion that there is a word-span effect in accented keywords only. The word-final hypothesis is not supported as this predicts as shortening of the syllable rhyme—including the coda—in left-headed monosyllables vs disyllables: however, /s/ is no longer in *mace* than in *mason* in the unaccented condition.

Left-headed keywords: summary

In general, the results for left-headed keywords support the word-span hypothesis, but the nature of the effect apparently varies throughout the syllable. Coda duration suggests that the word-span effect only operates in the presence of pitch accent, as appeared to be the case for right-headed keywords, but nucleus duration indicates a word-span effect both in the presence and the absence of pitch accent. The results for onset duration apparently favour a word-final lengthening interpretation, both in the presence and absence of pitch accent, but previous research suggests that the syllable onset is less likely than the nucleus or coda to manifest final lengthening.

The processes underlying these results are discussed further in Section 4.6.2.

Unstressed syllable duration

As described in Section 4.3.3, the additional syllables in polysyllabic keywords are measured for Series C, but not for Series A: because there is no evidence of an utterance-span effect, the decision to use Series C was made because it has more consistent syntactic structure between sentences. The effect of word length on unstressed syllables may be examined by looking at the duration of syllable-2. For right-headed keywords, this is to the immediate left of the stressed syllable in utterances such as:

Series C.2 JOHN saw Alison **commend** it AGAIN.

Series C.3 JOHN saw Alison **recommend** it AGAIN.

For left-headed keywords, syllable-2 is to the immediate right of the stressed syllable in utterances such as:

Series C.2 I SAW the **mason** disinclined it ALL.

Series C.3 I SAW the **masonry** disinterred AGAIN.

As these examples illustrate, the phonetic environment of syllable-2 is not consistent between disyllables and trisyllables; this may cause microprosodic variations in duration, which are unlikely to be systematic with respect to the experimental hypotheses.

Table 4.29 shows syllable-2 duration for right-headed keywords[23]. The effect of Word Length is significant by Subjects: $F(1,5.1) = 10.98$, $p < .05$ [by Items: $F(1,5) = 3.09$, $p = .139$]. The effect of Accent is significant by Subjects: $F(1,5) = 12.10$, $p < .05$ [by Items: $F(1,5.1) = 36.69$, $p < .005$]. The interaction between Word Length and Accent approaches significance by Subjects: $F(1,5.1) = 5.30$, $p = .069$ [by Items: $F(1,5.1) = 12.47$, $p < .05$].

Unstressed syllables in accented keywords are 17ms (13%) shorter in trisyllables than in disyllables—thus, /kə/ is shorter in *recommend* than in *commend*—but the equivalent difference in unaccented keywords is only 4 ms (3%). There is clearly a

[23] As described in Section 4.3.3, the keyword *main* is excluded because the onset of /hju/ is not comparably articulated in the two contexts *develop humane* and *inhumane*.

	Number of syllables in word	
	2	3
Unaccented	132	128
Accented	151	134

Table 4.29: Mean syllable-2 duration (ms) for all right-headed keywords except *port* (missing data) and *main* in Series C: data points = 144; missing = 4.2%.

word-level effect: one interpretation, in line with the results for test syllable duration, is that there is a word-initial lengthening effect in accented and unaccented keywords, together with a word-span compression effect in accented keywords only. The small magnitude of apparent word-initial lengthening may reflect the fact that it has a syllable onset locus, and variation in the rest of the syllable may mask the effect in the onset.

Table 4.30 shows syllable-2 duration for left-headed keywords[24]. The effect of Word Length is significant by Subjects: $F(1,5.3) = 50.37$, $p < .005$ [by Items: $F(1,5) = 15.23$, $p < .05$]. The effect of Accent approaches significance by Subjects: $F(1,5.3) = 5.48$, $p = .063$ [by Items: $F(1,5.1) = 5.79$, $p = .061$]. The interaction between Word Length and Accent is not significant by Subjects: $F(1,5) = 3.48$, $p = .115$ [by Items: $F(1,5.5) = 0.16$, $p = .707$].

	Number of syllables in word	
	2	3
Unaccented	95	70
Accented	108	75

Table 4.30: Mean syllable-2 duration (ms) for all left-headed keywords in Series C except *dog* and *part*: data points = 144; missing = 5.6%.

Unstressed syllables in left-headed keywords show a large word-level effect: 25 ms (26%) shorter in trisyllables than disyllables in the unaccented condition, and 33 ms (31 %) shorter in trisyllables than disyllables in the accented condition. There is no interaction with pitch accent, unlike the results for test syllable duration, most of which indicate a word-span effect only in accented keywords. The comparison for unstressed syllables confounds the effects of word-length and position-in-word: for example, /ən/ is word-final in the disyllable *mason* but not word-final in the trisyllable *masonry*. Thus, these results could be interpreted as evidence for word-span or

[24] As noted in Section 4.2.1, the syllable following the keyword in Series C for *dog* and *part* is likely to contain a full vowel and thus may have durational influence on the preceding syllable. Although this seems particularly unlikely where the preceding syllable is unstressed, these keywords are excluded from the following analysis.

word-rhyme-span compression or word-final lengthening, although the latter is not supported by most of the results for stressed syllable duration, and word-span compression of stressed syllables appears only to be significant in accented words.

4.6.2 Discussion

Results for whole test syllable duration, illustrated in Figures 4.2 and 4.3, indicate two main effects:

- word-initial lengthening;
- word-span compression, much greater in pitch-accented words.

The proportion of shortening between monosyllables and disyllables and between disyllables and trisyllables is illustrated in Figure 4.4 for subsyllabic constituents in Series A; for the purposes of comparison, results are shown for the same data-sets for all constituents.

The experimental hypotheses are here considered with regard to the patterns of durational variation of subsyllabic constituents.

Word-span hypothesis

Figure 4.4 shows that all subsyllabic constituents in accented keywords manifest some evidence of word-span compression except for nuclei in the right-headed monosyllable vs disyllable comparison. In contrast, constituents in unaccented keywords do not show strong evidence of word-span compression except for the onset in the monosyllable vs disyllable comparison for right-headed and left-headed keywords and the nucleus in both comparisons for left-headed keywords. These apparently anomalous results for unaccented keywords are discussed below.

Regarding the word-span effect, the comparison between disyllables and trisyllables is the more transparent because the monosyllable vs disyllable comparison may be influenced by word-edge effects. Word-span compression is quite clear in accented keywords between disyllables and trisyllables: thus /mɛnd/ is shorter in *recommend* than *commend* and /meɪs/ is shorter in *masonry* than *mason*. The word-span compression interpretation is supported because the effect is evident in left-headed and right-headed keywords, and in all subsyllabic constituents, rather than being confined to a specific locus.

Most of the evidence suggests that word-span compression is confined to accented words. In unaccented keywords, according to this interpretation, primary stressed syllable duration is constant, all other factors being equal. When the word is accented, all

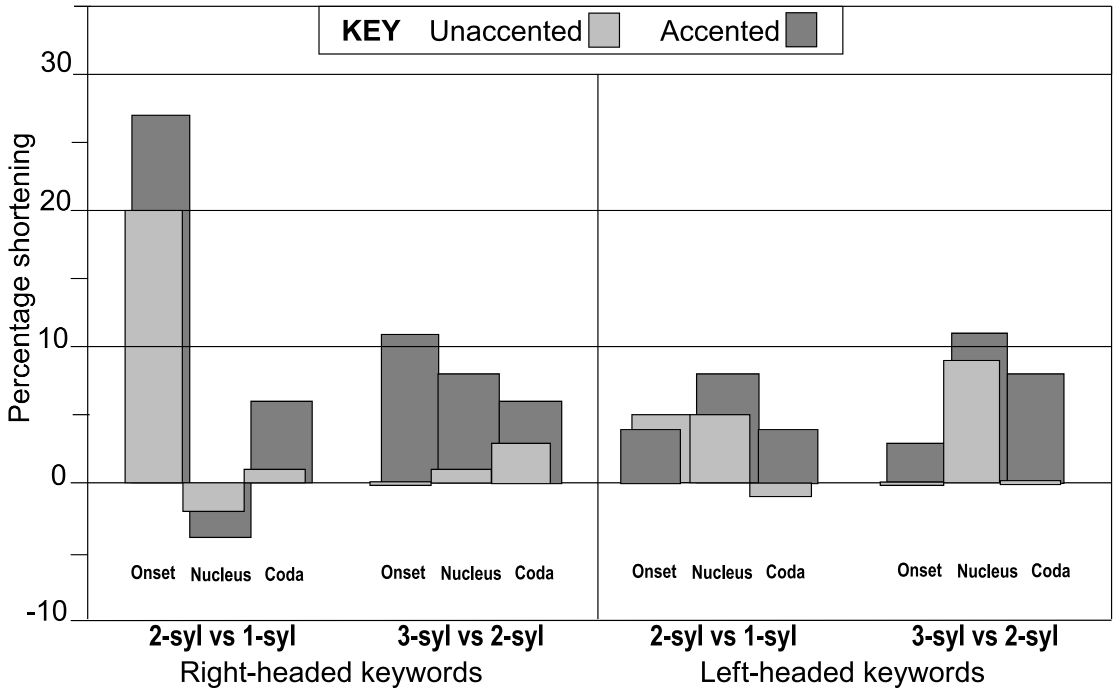

Figure 4.4: Proportional word-level shortening in monosyllabic, disyllabic and trisyllabic keywords in Series A. Proportional shortening is the difference in duration expressed as a percentage of syllable duration in the longer context. All right-headed keywords are included except *port*: data points = 252; missing = 3.8%. Left-headed keywords are *fish*, *mace*, *mend* and *send*: data points = 144; missing = 2.0%.

parts of the primary stressed syllable are lengthened, by a large amount in the monosyllable, less in the disyllable and less still in the trisyllable. This produces an apparent word-span compression effect in the comparison of constituent duration between accented keywords. Given its origin, however, it is more straightforward to describe it as an effect of word length on the magnitude of accentual lengthening. What may be called the "polysyllabic accent effect" simply encapsulates the fact that:

Accentual lengthening of the primary stressed syllable is greater in words of fewer syllables.

Because accentual lengthening affects all parts of the syllable, the locus of the polysyllabic accent effect is the whole syllable. The relative shortening effect on the different constituents should be a function of the amount of accentual lengthening they receive. If this is the case, the results shown in Figure 4.4 here suggest that the distribution of accentual lengthening is different in right-headed and left-headed words: this is examined further in Section 4.9. How previous evidence for polysyllabic shortening may be interpreted in the light of these results is discussed in Chapter 5.

Word-rhyme-span hypothesis

The word-rhyme-span hypothesis predicts an effect of word length in left-headed words, but not in right-headed words. This is not supported by onset and coda duration, where the effect of word length is at least as great in right-headed keywords. The pattern of results for nucleus duration is somewhat different, however. In both comparisons for unaccented keywords, monosyllable vs disyllable and disyllable vs trisyllable , the nucleus shows evidence of a word-span compression effect in left-headed keywords but not in right-headed keywords. Furthermore, in the accented condition, the nucleus shows the greatest effect of word-length for left-headed keywords, whereas for right-headed keywords the onset shows the greatest effect of word-length. These results suggest a process, which may be called "word-rhyme compression", independent of pitch accent and with a syllable nucleus locus.

Results for unstressed syllable duration indicate that the locus may extend to subsequent syllables within the word-rhyme. For left-headed keywords, the word-final syllable in the disyllable is shorter when word-medial in the trisyllable: for example, /ən/ is shorter in *masonry* than in *mason*. This effect appears to be independent of accent, although the proportional shortening is slightly greater in accented keywords.

The polysyllabic accent effect could explain the unstressed syllable result in left-headed accented keywords. The fact that there is an almost comparable effect in unaccented left-headed keywords requires a further mechanism which could be word-rhyme compression. Subsyllabic durations are not available for unstressed syllables, but it may be hypothesised that the locus of the effect may be the syllable nucleus, as for stressed syllables. Thus, a full statement of word-rhyme compression is:

There is an inverse relationship between the number of syllables in the word-rhyme and the duration of the nuclei of those syllables, both stressed and unstressed.

In accented keywords, of course, the unstressed syllable is likely to be influenced also by the polysyllabic accent effect, thus it appears that the two effects combine sub-additively, as the shortening in the disyllable vs trisyllable comparison is little greater than in the unaccented condition.

Two alternative interpretations of the effect observed in left-headed keywords are available: word-final lengthening, as discussed below, and syllable ratio equalisation, proposed by Turk & Shattuck-Hufnagel (2000). Syllable ratio equalisation is discussed with regard to Experiment 1 in Chapter 3, where it is suggested to be supererogatory; it is reassessed in Chapter 5 with regard to the results of Experiment 2.

Word-final lengthening

As shown in Figure 4.4, the results for left-headed accented keywords indicate that all parts of the syllable are affected by word-length, with the syllable nucleus showing the greatest effect. This supports the polysyllabic accent effect discussed above: a word-final process would be expected to affect the nucleus and coda, and probably the latter more than the former. The results for unstressed syllables in left-headed keywords could be interpreted as support for word-final lengthening: in both accented and unaccented contexts, the unstressed word-final syllable in the disyllable is longer then when placed word-medially in the trisyllable: thus, for example, /ən/ is longer in *mason* than in *masonry*.

The results for stressed syllables in unaccented keywords seem, however, to suggest a domain-span compression interpretation, for a number of reasons. The word-length effect in unaccented left-headed keywords is primarily manifest on the nucleus, and the coda is unaffected, contrary to previous observations of domain-edge effects. Furthermore, the magnitude of the word-length effect on the unaccented nucleus is actually greater in the disyllable vs trisyllable comparison than in the monosyllable vs disyllable comparison: there is greater shortening of /eɪ/ in *mason* vs *masonry* than in *mace* vs *mason*. A word-final effect would be expected to cause a large difference in test syllable duration in the latter comparison, but little or no difference in the former.

Word-rhyme compression is not, therefore, simply an alternative statement of a word-final effect. The locus of domain-final lengthening at higher-level boundaries is known to include the syllable rhyme, and tends to be progressive; that is, greater closer to the boundary. The effect observed here has a syllable nucleus locus and is not progressive. For theoretical consistency, it does not appear appropriate to describe it as a word-final effect.

Because of the lack of support for the utterance-span hypotheses, and the interpretation of the word-span effect as resulting from variations in accentual lengthening—the polysyllabic accent effect—the word-rhyme compression is the only domain-span effect for which Experiment 2 provides evidence. For reasons of parsimony, an interpretation which posits a demonstrated process in a new domain is to be preferred to an interpretation which requires an new type of process. It is clear that final lengthening exists at the intonational-phrase-level and/or the utterance-level; to extend this process to the word-level would be theoretically more satisfying than suggesting a single domain-span process, that is, word-rhyme compression.

Results presented in Section 4.8.1 indicate that utterance-final lengthening is localised on certain subconstituents of the word-rhyme; this suggests parallels with the effects observed here in left-headed keywords which leave open the possibility of a word-final characterisation of the process. This is explored further in Chapter 5.

Finally, there does not appear in Experiment 2 to be any evidence of phrase-final lengthening below the level of the intonational phrase. Lower-level phrase boundaries were not controlled, and as seen below, there is some evidence of phrase-initial lengthening, suggesting some right-headed keywords may be preceded by boundaries such as those between phonological phrases. For left-headed keywords, however, the lack of support for the word-final hypothesis also indicates an absence of evidence of phrase-final lengthening in utterance-medial context, a conclusion supported by the comparisons between utterance-medial and near-utterance-final words in Section 4.5. Possible levels of final lengthening are discussed further in Chapter 5.

Word-initial lengthening

The results for word-initial lengthening are fairly clear: the syllable onset, including aspiration duration in onset voiceless stops, has greater duration word-initially than word-medially. The apparently greater lengthening in accented words is probably due to the polysyllabic accent effect, as described above. This interpretation is supported by the evidence relating to phrase-initial lengthening, which does not indicate an interaction with accent.

The results for unstressed syllables provide some support for the word-initial lengthening hypothesis: for example, /kə/ is longer in *commend* than in *recommend*, although the effect is very small in the unaccented condition. Thus, if word-initial lengthening does not interact with accent, then the results for unstressed syllables must also be interpreted as a combination of word-initial lengthening, with a syllable onset locus, and the polysyllabic accent effect, affecting the whole syllable.

The finding, observed in the results of Oller (1973) and Cooper (1991), of differential interactions with pitch accent (or lexical stress) in the closure and aspiration duration of syllable onset voiceless stops is not supported here. Such effect cannot be ruled out by this evidence, however, because in Experiment 2 the polysyllabic accent effect may prove a confounding factor: for example, the duration of aspiration of /p/ is compared in *pose* and *suppose*, where possible word-medial lengthening of aspiration in accented syllables may be masked by shortening due to word length.

The results for phrase-initial lengthening are only suggestive, given that boundaries below the intonational phrase have not been controlled: it appears that, for example, /m/ in *mend* is slightly longer in utterance-medial context (for example: *Johnny saw Jessica mend it again*), where it may be preceded by a phrase boundary, than near the utterance-edge (for example: *Will you mend it again for me please*), where a preceding phrase boundary is less likely. Experiment 2 thus supports Fougeron & Keating's (1997) finding of three levels of syllable onset durational variation below the intonational phrase: word-medial; word-initial; phrase-initial.

There are two outstanding anomalies in the results illustrated in Figure 4.4, both of which may relate to word-initial lengthening. Firstly, the syllable onset in unaccented left-headed keywords shows an effect of word-length in the monosyllable vs disyllable comparison; thus, /m/ is shorter in *mason* than in *mace*: this may be interpreted as indicating that word-initial lengthening has lesser magnitude in polysyllables than in monosyllables. This is an analogue of the polysyllabic accent effect: the degree of lengthening is inversely proportional to word length. For word-initial lengthening, however, this seems to be a binary distinction between monosyllables and polysyllables, as there is no evidence of shortening of /m/ in *masonry* compared with *mason*, except in the accented condition, for which the polysyllabic accent effect already provides an explanation.

The second outstanding result is the slight lengthening of the syllable nucleus in the monosyllable vs disyllable comparison for right-headed accented and unaccented keywords. The durational difference between, for example, /ɛ/ in *mend* and *commend* is not significant, but does run contrary to the trend of the other results. If the interpretations of Experiment 2 are correct, then the syllable nucleus in this comparison ought to show no durational variation in unaccented keywords and show word-span compression in accented keywords; in fact, the nucleus is slightly longer in the disyllable. This could be interpreted as a compensatory effect: as can be seen in Figure 4.4, word-initial lengthening is very large in comparison with the other durational effects, including accentual lengthening. The magnitude of word-initial lengthening may induce an opposite adjustment in nucleus duration in the direction of maintaining a constant syllable duration; this could also underlie the relatively small word-initial lengthening effect apparent in the durations for whole unstressed syllables. This interpretation of the small observed effect is speculative, but evidence presented in Section 4.5 suggests similar effects may be associated with phrase-initial syllables and utterance-antepenultimate syllables. Possible compensatory effects are discussed further in Chapter 5.

4.7 Utterance-initial results

The utterance-initial hypothesis predicts that word-initial syllable onsets are shorter utterance-initially than utterance-medially. Only right-headed keywords are used in the analyses presented in Section 4.7.1—left-headed keywords are not placed utterance-initially in the experimental materials—and there are two different groups of right-headed keywords analysed, as described below. The utterance-initial hypothesis is supported for those keywords in which the test syllable onset is fully measurable utterance-initially.

The experimental comparison for the utterance-initial hypothesis is between Series B (utterance-medial) and Series D (utterance-initial). For example, the utterance-initial hypothesis predicts that /m/ is shorter in D.1 than B.1, thus:

Series B.1 JOHN saw Jessica **mend** it AGAIN.

Series D.1 **Mend** it AGAIN for me please.

Results are reported first for test syllable onset duration in Series B and Series D: although fully-measurable onsets show utterance-initial shortening, partial-onset (aspiration/frication) duration shows slight utterance-initial lengthening in unaccented context. Nucleus and coda durations are also reported, indicating some evidence of compensatory durational effects, tending to counter the utterance-initial effects on the syllable onset.

The interpretation of observed utterance-initial effects is discussed in Section 4.7.2, as are explanations for the apparent compensatory effects.

4.7.1 Results and analysis

Keyword grouping

Utterance-initial shortening has only been observed in nasal onset consonants; thus, keywords with different test syllable onset consonants are treated separately in the first analysis. In the right-headed monosyllables, as discussed in Section 4.3.3, only *main*, *mend* and *send* have onsets which are entirely measurable utterance-initially. The monosyllable *juice* begins with the voiced affricate /dʒ/ for which the duration of closure cannot be measured utterance-initially; thus, the duration of frication is compared utterance-initially and utterance-medially. The keywords *port*, *compose*, *dispose* and *suppose* have the voiceless stop /p/ as their test syllable onset, for which closure duration cannot be measured in utterance-initial position; thus, aspiration duration is examined to test the utterance-initial hypothesis.

Table 4.31 shows mean onset duration for *mend* and *main*, and separately for *send*; mean onset frication duration for *juice*; mean test syllable onset aspiration duration (ms) for *compose*, *dispose*, *port* and *suppose*. The keywords with fully-measurable onsets show the same trend: *send*, and *main* and *mend* together, have greater onset duration utterance-medially than utterance-initially. In contrast, *juice* has onset frication duration longer utterance-initially than utterance-medially, although the difference is small compared with the utterance-initial shortening shown by *main*, *mend* and *send*. The keywords *compose*, *dispose*, *port* and *suppose* show no effect of utterance position on aspiration duration in accented keywords, but aspiration duration is slightly longer utterance-initially in unaccented keywords.

	Utterance position	
	Initial	Medial
/m/ duration: *main* and *mend*		
Unaccented	43	69
Accented	66	103
/s/ duration: *send*		
Unaccented	97	115
Accented	124	143
/dʒ/ frication duration: *juice*		
Unaccented	55	50
Accented	62	58
/p/ aspiration duration: *compose, dispose, port* and *suppose*		
Unaccented	46	41
Accented	54	55

Table 4.31: Mean test syllable onset duration (ms) for right-headed keywords in Series B and Series D: data points for each keyword = 24; missing = 0 for *mend* and *main*; missing = 1 for keyword *send*; missing = 0 for *juice*; missing = 4 for *compose*, *dispose*, *port* and *suppose*.

Thus, *main*, *mend* and *send* are analysed together, as all three show utterance-initial shortening in the onset. For the remaining keywords, *juice* may reasonably be grouped with the keywords *compose*, *dispose*, *port* and *suppose* as all have partially-measurable onsets, with closure duration unmeasurable utterance-initially; furthermore, these keywords do not show utterance-initial shortening, but rather manifest slight utterance-initial lengthening, at least in the unaccented condition[25].

Test syllable onset duration

Figure 4.5 shows mean test syllable onset duration for *main*, *mend* and *send*. The effect of Utterance Position is highly significant by Subjects: $F(1,5.1) = 150.61$, $p < .001$ [by Items: $F(1,2) = 40.38$, $p < .05$]. The effect of Accent is significant by Subjects: $F(1,5) = 13.88$, $p < .05$ [by Items: $F(1,2) = 2228.57$, $p < .001$]. There is no significant interaction between Utterance Position and Accent by Subjects: $F(1,5) = 0.91$, $p = .384$ [by Items: $F(1,2) = 4.19$, $p = .177$]. For unaccented monosyllables, the onset is 25 ms (30%) shorter utterance-initially; for accented monosyllables, the onset is 31 ms (27 %)

[25]Because *port* has an inconsistently measurable coda, it is excluded from further analysis to provide a consistent keyword set between all subsyllabic constituents.

shorter utterance-initially.

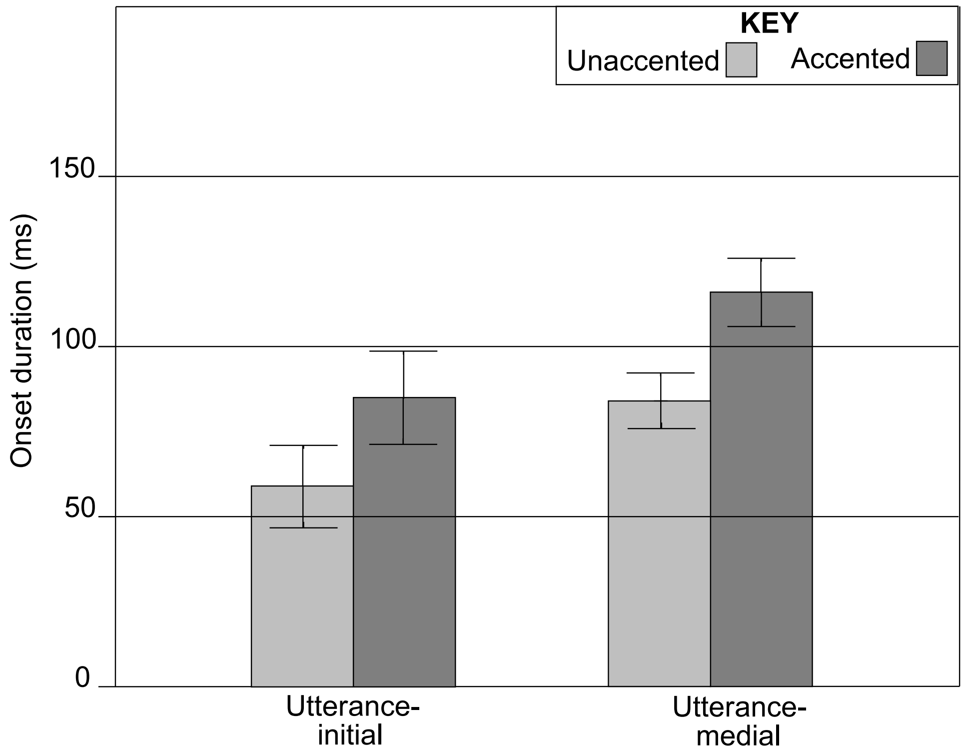

Figure 4.5: Mean test syllable onset duration (ms) for monosyllables *main*, *mend* and *send* in Series B and Series D: data points = 72; missing = 1.

Figure 4.6 shows mean duration of test syllable onset aspiration/frication for *compose*, *dispose*, *suppose* and *juice*. The effect of Utterance Position is not significant by Subjects: $F(1,5) = 0.67$, $p = .449$ [by Items: $F(1,3) = 1.69$, p .283]. The effect of Accent is significant by Subjects: $F(1,5) = 9.36$, $p < .05$ [by Items: $F(1,3.2) = 105.89$, $p = .002$]. The interaction between Utterance Position and Accent is significant by Subjects: $F(1,5.1) = 8.03$, $p < .05$ [by Items: $F(1,3.1) = 5.09$, $p = .108$]. The nature of this interaction is indicated by two-tailed t-tests: the effect of Utterance Position is significant for unaccented keywords, where aspiration/frication duration is 6 ms (13%) shorter utterance-medially, but not for accented keywords.

The results for *main*, *mend* and *send* clearly support the utterance-initial hypothesis, for both accented and unaccented keywords: onset duration is shorter utterance-initially. The results for partial-onset duration for *compose*, *dispose*, *suppose* and *juice* do not support the utterance-initial hypothesis: unaccented keywords manifest a small utterance-initial lengthening effect and accented keywords show no effect of utterance-position. Because of these differences, nucleus and coda durations are analysed according to the keyword groupings used for onset and partial-onset duration.

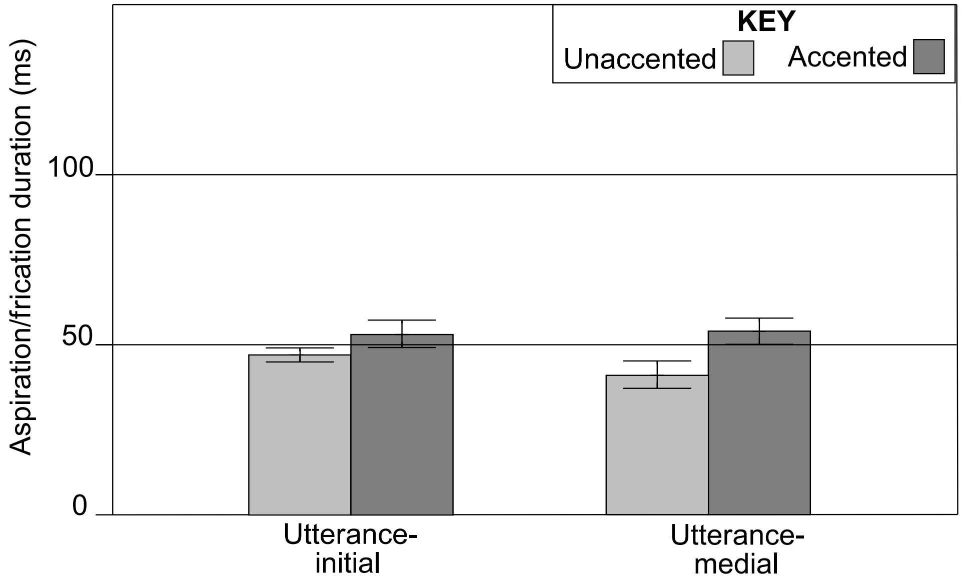

Figure 4.6: Mean test syllable onset aspiration/frication duration (ms) for monosyllables from keywords *compose*, *dispose*, *suppose* and *juice* in Series B and Series D: data points = 96; missing = 4.

Test syllable nucleus duration

Table 4.32 shows mean nucleus duration for *main*, *mend* and *send*, which demonstrate a large utterance-initial shortening effect in their onsets. For nucleus duration there is no effect of Utterance Position by Subjects: F(1,5) = 0.03, p = .875 [by Items: F(1,2) = 0.02, p = .910]. There is a highly significant effect of Accent by Subjects: F(1,5) = 20.43, $p < .01$ [by Items: F(1,2) = 4.31, p = .173]. There is no significant interaction between Utterance Position and Accent by Subjects: F(1,5.1) = 0.51, p = .505 [by Items: F(1,2) = 0.26, p = .660]. Thus, for these keywords, the effect of utterance-initial position does not extend beyond the test syllable onset.

	Utterance position	
	Initial	Medial
Unaccented	82	82
Accented	99	97

Table 4.32: Mean test syllable nucleus duration (ms) for monosyllables *main*, *mend* and *send* in Series B and Series D: data points = 72; missing = 1.

Table 4.33 shows the mean test syllable nucleus duration for the keywords *compose*, *dispose*, *suppose* and *juice*. The effect of Utterance Position is not significant by Subjects: F(1,5) = 3.72, p = .111 [by Items: F(1,3) = 5.31, p = .104]. The effect of Accent is highly significant by Subjects: F(1,5) = 18.15, $p < .01$ [by Items: F(1,3) = 39.33, $p < .01$]. The interaction between Utterance Position and Accent is significant by Subjects: $F(1,5.4) = 23.13$, $p < .005$ [by Items: $F(1,3) = 3.34$, $p = .164$]. The nature of this interaction is indicated by two-tailed t-tests: in the unaccented context, the effect of Utterance Position is highly significant, with 13 ms (12%) shortening utterance-initially; in accented context, the effect of Utterance Position is not significant.

	Utterance position	
	Initial	Medial
Unaccented	98	111
Accented	133	134

Table 4.33: Mean test syllable nucleus duration (ms) for monosyllables from keywords *compose*, *dispose*, *port* and *suppose* in Series B and Series D: data points = 96; missing = 4.

The utterance-initial shortening of nucleus duration for unaccented monosyllables contrasts with the utterance-initial lengthening of onset aspiration/frication duration shown in Figure 4.6 for the same unaccented monosyllables. The interpretation of this compensatory relationship between aspiration duration and vowel duration is discussed in Section 4.7.2.

Test syllable coda duration

Table 4.34 shows mean test syllable coda durations for *main*, *mend* and *send*. The effect of Utterance Position is highly significant by Subjects: $F(1,5.1) = 20.89$, $p < .01$ [by Items: $F(1,2) = 3.18$, $p = .216$]. The effect of Accent is also highly significant by Subjects: $F(1,5) = 20.57$, $p < .01$ [by Items: $F(1,2) = 13.67$, $p = .066$]. The interaction between Utterance Position and Accent is not significant by Subjects: $F(1,5.2) = 1.91$, $p = .224$ [by Items: $F(1,2) = 0.54$, $p = .541$]. Thus, coda duration is shorter utterance-medially, by 10 ms (13%) for unaccented keywords and by 7ms (7%) for accented keywords,

	Utterance position	
	Initial	Medial
Unaccented	75	65
Accented	94	87

Table 4.34: Mean test syllable coda duration (ms) for monosyllables *main*, *mend* and *send* in Series B and Series D: data points = 72; missing = 1.

The finding of an utterance-initial lengthening effect on coda duration for keywords *main*, *mend* and *send* is surprising, particularly as the syllable nucleus for these keywords, which is closer to the start of the utterance, shows no sign of any durational effect; however, the utterance-initial codas are compared with utterance-medial codas which show evidence of a possible compensatory shortening effect, as reported in Section 4.5.1. Such shortening would be sufficient explanation of the durational difference, without proposing a further utterance-initial effect.

Table 4.35 shows the mean test syllable coda duration for *compose*, *dispose*, *suppose* and *juice*. There is no significant effect of Utterance Position by Subjects: $F(1,51) = 0.14$, $p = .723$ [by Items: $F(1,3.2) = 1.90$, $p = .258$]. The effect of Accent is significant by Subjects: $F(1,5.1) = 8.78$, $p < .05$ [by Items: $F(1,3) = 3.55$, $p = .156$]. The interaction between Utterance Position and Accent approaches significance by Subjects: $F(1,5.3) = 5.31$, $p = .067$ [by Items: $F(1,3.1) = 0.70$, $p = .462$]. The tendency towards an interaction reflects the slight utterance-initial lengthening of the coda in unaccented keywords and the even smaller utterance-initial shortening of the coda in accented keywords.

	Utterance position	
	Initial	Medial
Unaccented	76	72
Accented	81	83

Table 4.35: Mean test syllable coda duration (ms) for monosyllables from keywords *compose*, *dispose*, *suppose* and *juice* in Series B and Series D: data points = 96; missing = 4.

4.7.2 Discussion

The comparison between utterance-initial and utterance-medial syllables suggests two trends: firstly, utterance-initial durational variation in the stressed syllable onset, either shortening or lengthening according to the composition of the onset; secondly, compensatory shortening, whereby lengthening in the onset is balanced by the opposite effect in the nucleus.

Utterance-initial durational processes

The utterance-initial shortening found by Fougeron & Keating (1997) for nasals in unstressed syllables is found here in stressed syllables and a similar effect is found for the fricative /s/ in stressed syllable onsets. Stressed syllable onsets containing stops or affricates do not demonstrate utterance-initial shortening, however: the duration of aspiration or frication which follows the stop release is longer utterance-initially in unaccented words, and shows no effect of position in accented words.

Evidence presented in Section 4.6.1 shows that syllable onsets are longer word-initially than word-medially, and also indicates further lengthening (phonological-) phrase-initially. These results agree with Fougeron & Keating's finding of hierarchical lengthening of syllable onsets, which they find to be further lengthened intonational-phrase-initially. This raises the question of why utterance-initial boundaries, at the highest level of putative prosodic hierarchies, do not show consistent evidence for further domain-initial lengthening.

A possible explanation for the absence of an utterance-initial lengthening effect is that there is no reason for utterance-initial boundaries to be signalled suprasegmentally, at least not when the utterance is spoken in isolation. If hierarchical initial-lengthening effects are cues to juncture, they are superfluous utterance-initially: the listener will know that the first syllable spoken is utterance-initial because it is preceded by silence. This interpretation predicts that utterance-initial onset duration should be comparable to that found word-medially, as the lowest level of the hierarchy of onset lengthening. The results of Fougeron & Keating (1997) for one speaker show exactly this pattern; for the second speaker, onset duration is slightly longer utterance-initially than word-medially, but shorter than word-initially[26].

This interpretation of utterance-initial shortening may be tested by examining test syllable onset duration in Keyword Series E, where the onset is utterance-initial in the monosyllable and word-medial in the disyllable and trisyllable, for example:

E.1 **Mend** it AGAIN for me please.

E.2 **Commend** it AGAIN for me please.

E.3 **Recommend** it AGAIN for me please.

Table 4.36 shows mean test syllable onset duration for *main*, *mend* and *send* in Series E. The effect of Word Length is not significant by Subjects: $F(2,10.1) = 0.07$, $p = .931$ [by Items: $F(2,4) = 0.10$, $p = .904$]. The effect of Accent is significant by Subjects and by Items. The interaction between Word Length and Accent approaches significance by Subjects: $F(2,10.2) = 3.64$, $p = .064$ [by Items: $F(2,4) = 9.75$, $p < .05$].

The usual word-initial lengthening, as described in Section 4.6.1 is not evident, as the small word-length effect in the accented condition may be attributed to the polysyllabic accent effect. The onset is actually slightly shorter word-initially than word-medially in the unaccented condition. The almost significant interaction may be attributable to one or both of these trends, although none of the differences due to Word Length are significant in t-tests for either accented or unaccented keywords.

[26] As mentioned in Section 4.1.3, the third speaker did not show an utterance-initial shortening effect: onset duration utterance-initially was comparable to that found intonational-phrase-initially.

	Word length		
	Monosyllable	Disyllable	Trisyllable
Unaccented	59	68	67
Accented	85	80	77

Table 4.36: Mean test onset syllable duration (ms) for the keywords *main*, *mend* and *send* in Series E: data points = 108; missing = 3.

The pattern of onset duration according to word length may be contrasted with that found utterance-medially; in Series C, for example:

C.1 JOHN saw Jessica **mend** it AGAIN.

C.2 JOHN saw Alison **commend** it AGAIN.

C.3 JOHN saw Alison **recommend** it AGAIN.

Table 4.37 shows mean test syllable onset duration for *main*, *mend* and *send* in Series C. Word-initial lengthening is evident, as is the additional word-span compression in accented keywords attributable to the polysyllabic accent effect. In a comparison of Series C and Series E, the interaction between Utterance Position and Word Length is highly significant by Subjects: $F(2,10.1) = 20.98$, $p < .001$ [by Items: $F(2,4) = 15.59$, $p < .05$]. This supports the conclusion that the word-initial lengthening evident in the utterance-medial Series C is absent in the utterance-initial Series E.

	Word length		
	Monosyllable	Disyllable	Trisyllable
Unaccented	84	69	70
Accented	116	90	76

Table 4.37: Mean test onset syllable duration (ms) for the right-headed keywords *main*, *mend* and *send* in Series C: data points = 108; missing = 1.

Therefore, the hypothesis that utterance-initial shortening represents an absence of any domain-initial hierarchical lengthening is quite well supported by the data for keywords *main*, *mend* and *send*, which have fully-measurable test syllable onsets utterance-initially.

The results for the other keywords, where stop closure cannot be measured at the start of the utterance, show a somewhat different pattern. There is no utterance-initial shortening of aspiration or frication following the stop release in accented keywords, and in unaccented keywords the partial onset—for example, the aspiration of /p/ in /pəʊz/—is slightly longer utterance-initially than utterance-medially. This could be an articulatory effect: aspiration or frication following a stop release may be more forceful and thus longer where this is initiating phonation than in the middle of the speech stream; the difference may be masked in accented keywords because of their generally greater gestural magnitude and duration. Utterance-initial processes are discussed further in Chapter 5.

Compensatory effects

A compensatory effect, similar to those discussed in Section 4.7.1, is suggested by one of the results in Section 4.7. In the test syllables for the keywords *compose*, *dispose*, *suppose* and *juice* in the unaccented condition, the partial-onset—aspiration or frication following the stop release—shows a small utterance-initial lengthening effect, and the nucleus shows a slightly larger utterance-initial shortening effect; the coda is also slightly longer utterance-initially, although the effect is not significant. The sum of these effects produces a whole syllable duration which is not significantly different utterance-initially and utterance-medially. In the accented condition, there is no significant effect of utterance position in either the whole syllable or in the subsyllabic constituents.

Compensatory shortening of the nucleus following lengthening of the partial-onset is predictable if the articulatory gestures involved are considered. The vowel durations reported in Experiment 2 are taken from the onset of voicing, because, as discussed in Section 4.3, aspiration duration shows a similar pattern of word-initial lengthening to consonant closure duration: thus, onset duration for voiceless stops includes closure and aspiration duration. As shown in Figure 4.7, however, the vocalic gesture begins in the oral cavity with the release of the stop, at which point the articulator begin moving towards its steady state position for the vowel. In voiceless stops, the vocalic gesture does not begin in the larynx until the onset of voicing. Thus, if the onset of voicing is delayed, aspiration duration increases and vowel duration decreases. Conversely, an earlier onset of voicing will mean shorter aspiration duration and longer vowel duration.

It is, of course, possible for aspiration duration and vowel duration to increase concurrently; such an effect would be expected, for example, in a pitch-accented syllable. The inverse relationship between vowel duration and aspiration duration observed here would arise when there is a durational process that affects only the onset, such as initial lengthening, or only the nucleus, such as word-rhyme compression or phrase-final lengthening (the latter affecting also the syllable coda).

Thus, the evidence of a compensatory relationship within utterance-initial stressed syllables appears to be explicable as an effect of articulatory overlap in the case of *compose*, *dispose* and *suppose*. There is, however, some direct evidence of compen-

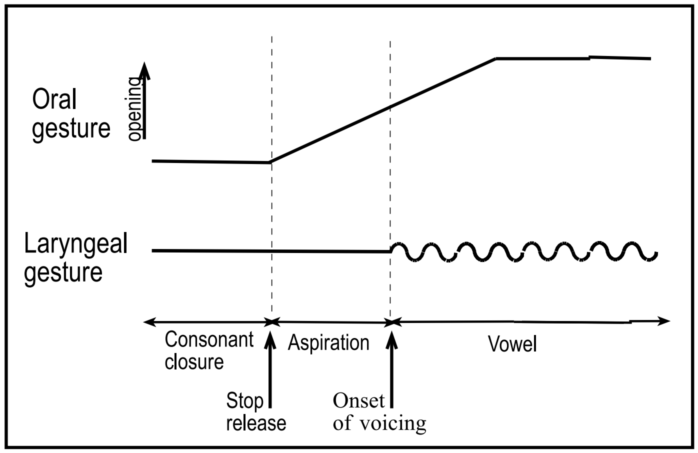

Figure 4.7: Schematic diagram of the relationship between aspiration duration and vowel duration.

satory relationships at three levels of prosodic structure: word-initial, phrase-initial and utterance-final. The interpretation of these effects is discussed further in Chapter 5.

4.8 Utterance-final results

The principal test of utterance-final lengthening is the comparison between the two left-headed keyword series in which the length of the keyword covaries with the length of the utterance: Series C, where the keyword is utterance-medial, and Series E, where the keyword is utterance-final. This is the utterance-final within-word analysis: results for the primary stressed syllable and for additional syllables in polysyllabic keywords support the utterance-final hypothesis that the locus of lengthening is the word-rhyme, although not all subconstituents of the word-rhyme are lengthened. The utterance-final locus distribution hypothesis, that lengthening is progressive within this locus, is supported. The utterance-final accent hypothesis, that the magnitude of lengthening is not affected by the presence of a pitch accent on the utterance-final word, is also supported, although there is non-significant attenuation of lengthening in accented words. Results are reported first for whole test syllable duration, then separately for the onset, nucleus and coda of the test syllable, and then for unstressed syllables in disyllables and trisyllables.

Series D contains test syllables in monosyllabic keywords, separated from the utterance-final boundary by zero, one or two syllables. The utterance-final cross-word analysis compares Series D with Series B, which contains utterance-medial monosyllabic keywords, to determine the pattern of utterance-final durational variation where word boundaries intervene between the test syllable and the utterance edge. These results are only suggestive, however, because there are potentially confounding influences in the experimental materials; in particular, full-vowel syllables immediately follow the test syllables when in utterance-penultimate position[27].

The experimental support for the three utterance-final hypotheses is discussed in Section 4.8.2.

4.8.1 Results and analysis

Within-word results: full stressed syllable duration

Table 4.38 shows example sentences from Series C and Series E; the experimentally-important difference between the two series being the proximity of the utterance-final boundary in Series E. Differences in test syllable duration should be directly comparable between the two series because, as seen in Section 4.5.1, there is no direct effect of utterance length on test syllable duration.

Series C: utterance-medial keywords	
$\|\ldots\sharp\sigma\sharp\sigma\sigma\ldots\|$	I SAW the **mace** unreclaimed AGAIN.
$\|\ldots\sharp\sigma\sigma\sharp\sigma\sigma\ldots\|$	I SAW the **mason** disinclined it ALL.
$\|\ldots\sharp\sigma\sigma\sigma\sharp\sigma\sigma\ldots\|$	I SAW the **masonry** disinterred AGAIN.
Series E: utterance-final keywords	
$\|\ldots\sharp\sigma\|$	Albert THREW the **mace**.
$\|\ldots\sharp\sigma\sigma\|$	Albert THREW the **mason**.
$\|\ldots\sharp\sigma\sigma\sigma\|$	Albert THREW the **masonry**.

Table 4.38: Example experimental sentences for Series C and Series E.

Figure 4.8 shows mean duration of utterance-final and utterance-medial test syllables in monosyllables, disyllables and trisyllables. The effect of Utterance Position is highly significant by Subjects: $F(1,5) = 75.10$, $p < .001$ [by Items: $F(1,3) = 28.34$, $p < .05$. This indicates that test syllables are longer utterance-finally than utterance-medially.

The effect of Word Length is highly significant by Subjects: $F(2,10.1) = 153.84$, $p < .001$ [by Items: $F(2,6) = 91.80$, $p < .001$]; this is attributable to the polysyllabic accent effect and the word-rhyme-span compression effect, as discussed in Section 4.6.1. The effect of Accent is significant by Subjects: $F(1,5) = 14.83$, $p < .05$ [by Items: $F(1,3) = 98.84$, $p < .005$].

The interaction between Utterance Position and Word Length is highly significant by Subjects: $F(2,10,5) = 230.70$, $p < .001$ [by Items: $F(2,6) = 13.34$, $p < .01$]. This indi-

[27] In the reporting of these results, the phrase "utterance-final" generally refers to the experimental condition, wherein the measured syllable itself could be "absolute-final", "utterance-penultimate" or "utterance-antepenultimate".

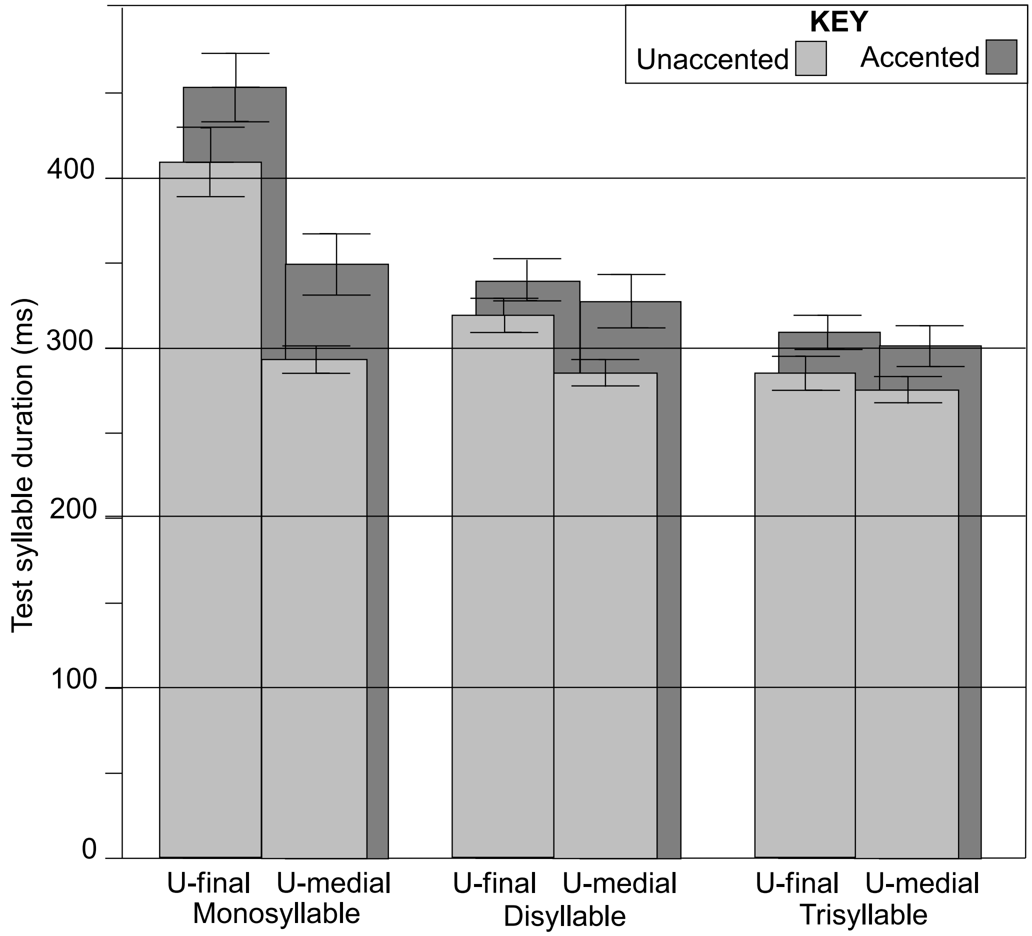

Figure 4.8: Mean test syllable duration (ms) for the left-headed keywords *fish*, *mace*, *sense* and *ten* in Series C and Series E: data points = 288; missing = 2.8%.

cates that the magnitude of utterance-final lengthening is greatest in monosyllables, where the stressed syllable is in absolute-final position; utterance-final lengthening is less when there are one or two syllables in the keyword between the stressed syllable and the end of the utterance. The magnitude and locus of the effect in each case is examined in more detail below.

The interaction between Accent and Utterance Position is not significant by Subjects: $F(1,5) = 2.43$, $p = .179$ [by Items: $F(1,3) = 4.54$, $p = .122$], indicating support for the utterance-final accent hypothesis. The interaction between Word Length and Accent is highly significant by Subjects: $F(2,11.1) = 24.00$, $p < .001$ [by Items: $F(2,6.1) = 18.90$, $p < .005$], indicating that word-span shortening is greater for accented keywords. As proposed in Section 4.6.1, this is due to the polysyllabic accent effect, which affects all parts of the test syllable; in addition, both accented and unaccented left-headed keywords are affected by word-rhyme-span shortening, which has a syllable nucleus locus. There is no significant three-way interaction between Accent, Utterance Position and Word Length by Subjects: $F(2,10.6) = 2.03$, $p = .179$ [by Items: $F(2,6.1) = 1.47$, $p = .301$].

Figure 4.8 shows clearly that test syllable duration is greater utterance-finally than utterance-medially, particularly when it immediately precedes the utterance boundary. The distribution of the effect within the test syllable is examined now.

Within-word results: stressed syllable onset duration

Table 4.39 shows mean test syllable onset duration for left-headed keywords in Series C and Series E[28]. The effect of Word Length is highly significant by Subjects: $F(2,10.1) = 22.22$, $p < .001$ [by Items: $F(2,14) = 17.31$, $p < .001$]. Both utterance-final and utterance-medial keywords show small but consistent word-level shortening effects; as discussed in Section 4.6.2, the evidence from Experiment 2 indicates that word-initial lengthening may be attenuated in polysyllables, both when accented and unaccented, in addition to the shortening due to the polysyllabic accent effect .

	Number of syllables in word					
	1	2	3	1	2	3
	Utterance-final			*Utterance-medial*		
Unaccented	109	101	99	105	101	98
Accented	128	117	115	128	119	115

Table 4.39: Mean test syllable onset duration (ms) for all left-headed keywords in Series C and Series E: data points = 576; missing = 2.1%.

There is no significant effect of Utterance Position by Subjects: $F(1,5) = 0.01$, $p = .931$ [by Items: $F(1,7) = 0.10$, $p = .757$]. For unaccented and accented keywords, onset duration at each word length is comparable utterance-finally and utterance-medially. This is true even in monosyllables, where the test syllable in Series E is in absolute-final position in the utterance: in unaccented keywords, the onset is 4 ms longer utterance-finally; in accented keywords, the onset is the same duration utterance-finally and utterance-medially.

There is a significant effect of Accent by Subjects: $F(1,5) = 9.65$, $p < .05$ [by Items: $F(1,7) = 151.46$, $p < .001$]. The interaction between Utterance Position and Word

[28] As discussed in Section 4.2.1, the left-headed keywords *dog* and *part* are followed in monosyllabic utterance-medial context by potentially full-vowel syllables; thus they are excluded from certain analyses, because of the possibility of stress-adjacent lengthening. There are included in the utterance-final analysis, however: firstly, any stress-adjacent lengthening in the utterance-medial series would bias the results towards the null hypothesis; secondly, any such effect is likely to be small relative to utterance-final lengthening, and distributed throughout the syllable rather than having a particular subsyllabic locus; finally, this possible confound only relates to the comparison between monosyllables. The keywords *dog* and *part* are not, however, included in the above analysis of full syllable duration, because of their inconsistently-measurable codas.

Length is not significant by Subjects: $F(2,10.1) = 0.49$, $p = .628$ [by Items: $F(2,14) = 3.48$, $p = .058$]; nor is the interaction between Utterance Position and Accent: $F(1,5.1) = 1.18$, $p = .326$ [by Items: $F(1,7) = 1.21$, $p = .308$]. The interaction between Word Length and Accent does approach significance by Subjects: $F(2,10.3) = 3.37$, $p = .075$ [by Items: $F(2,14.2) = 5.81$, $p = .014$], indicating that the greatest effect of Word Length is between accented monosyllables and disyllables/trisyllables. There is no evidence of any three-way interaction between Utterance Position, Word Length and Accent by Subjects: $F(2,10.3) = 0.17$, $p = .849$ [by Items: $F(2,14.4) = 3.06$, $p = .078$].

These results indicate that the test syllable onset is not lengthened utterance-finally. Previous results generally observe final lengthening on the rhyme of the preboundary syllable, so this result is in accordance with expectations.

Within-word results: stressed syllable nucleus duration

Table 4.40 shows mean test syllable nucleus duration in Series C and Series E. The effect of Word Length is highly significant by Subjects: $F(2,10.1) = 88.63$, $p < .001$ [by Items: $F(2,14) = 100.21$, $p < .001$], indicating the polysyllabic accent effect and the word-rhyme span effect.

	Number of syllables in word					
	1	2	3	1	2	3
	Utterance-final			*Utterance-medial*		
Unaccented	126	87	75	88	83	75
Accented	133	90	81	100	90	82

Table 4.40: Mean test syllable nucleus duration (ms) for all left-headed keywords in Series C and Series E: data points = 576; missing = 2.1%.

The effect of Utterance Position is significant by Subjects: $F(1,5) = 16.48$, $p < .05$ [by Items: $F(1,7) = 33.88$, $p < .005$]. There is a highly significant interaction between Utterance Position and Word Length by Subjects: $F(2,10.1) = 62.65$, $p < .001$ [by Items: $F(2,14) = 51.49$, $p < .001$], indicating that utterance-final lengthening is greatest for monosyllables: where the test syllable is in absolute-final position in the utterance, the nucleus is 38 ms (43%) longer in the unaccented condition and 33 ms (33%) longer in the accented condition.

Because of the interaction between Utterance Position and Word Length, the effect of Utterance Position on nucleus duration is analysed separately for monosyllables, disyllables and trisyllables, as shown in Table 4.41: this indicates that utterance-final lengthening only occurs when the test syllable immediately precedes the utterance boundary. In disyllables and trisyllables, where there are one or two unstressed syllables between the test syllable and the utterance boundary, there is no evidence of final lengthening of the test syllable nucleus. It may also be noted that there is no evidence of an interaction between Utterance Position and Accent, even in monosyllables, suggesting that the effects of final lengthening are similar whether the keyword is unaccented or accented.

	By-Subjects analysis			By-Items analysis		
Source of variation	Degrees of freedom	*F Ratio*	Significance level	Degrees of freedom	*F Ratio*	Significance level
Monosyllables						
Position	1,5	44.11	$< .005$	1,7	49.41	$< .001$
Accent	1,5.1	18.95	$< .01$	1,7	15.86	$< .01$
Interaction	1,5.1	0.90	.386	1,7	2.32	.171
Disyllables						
Position	1,5.1	0.11	.750	1,7	2.76	.141
Accent	1,5	6.24	.054	1,7	3.52	.103
Interaction	1,5.1	2.68	.161	1,7.2	1.34	.284
Trisyllables						
Position	1,5.1	0.64	.460	1,7.1	0.37	.564
Accent	1,5.1	12.51	$< .05$	1,7	10.92	$< .05$
Interaction	1,5.1	0.12	.746	1,7.2	2.46	.160

Table 4.41: Analyses of variance of test syllable nucleus duration according to word length for all left-headed keywords in Series C and Series E. There are 192 data points in each analysis, with 1.0% missing data for monosyllables and disyllables and 4.2% missing data for trisyllables.

In the analysis of the full data set for all three levels of Word Length, the interaction between Utterance Position and Accent is not significant by Subjects: $F(1,5) = 1.07$, $p = .348$ [by Items: $F(1,7) = 5.32$, $p = .054$], nor is the interaction between Accent and Word Length: $F(2,10.2) = 1.14$, $p = .358$ [by Items: $F(2,14.1) = 2.65$, $p = .105$]. The three-way interaction between Utterance Position, Accent and Word Length is not significant by Subjects: $F(2,10.6) = 1.77$, $p = .218$.

Within-word results: stressed syllable coda duration

Table 4.42 shows mean test syllable coda duration in Series C and Series E for keywords *fish*, *mace*, *sense* and *ten*. The effect of Word Length is highly significant by Subjects: $F(2,10.4) = 64.81$, $p < .001$ [by Items: $F(2,6) = 8.54$, $p < .05$]. The effect of Utterance Position is highly significant by Subjects: $F(1,5.1) = 100.18$, $p < .001$ [by Items: $F(1,3) = 13.15$, $p < .05$]. The interaction between Utterance Position and Word Length is also highly significant by Subjects: $F(2,11.6) = 185.41$, $p < .001$ [by Items: $F(2,6) = 5.55$, $p < .05$]. In contrast with nucleus duration, utterance-final lengthening of the coda extends to disyllables and trisyllables, although the effect is greatest in monosyllables, as indicated by the interaction: in monosyllables, final lengthening is 73 ms (70%) in unaccented keywords and 65 ms (50%) in accented keywords; in disyllables, final lengthening is 24 ms (22%) in unaccented keywords and 15 ms (12%) in accented keywords; in trisyllables, final lengthening is 8 ms (8%) in unaccented keywords and 7 ms (6%) in accented keywords.

	Number of syllables in word					
	1	2	3	1	2	3
	Utterance-final			*Utterance-medial*		
Unaccented	177	131	113	104	107	105
Accented	196	138	120	131	123	113

Table 4.42: Mean test syllable coda duration (ms) for left-headed keywords *fish*, *mace*, *sense* and *ten* in Series C and Series E: data points = 288; missing = 2.8%.

Because of the interaction between Utterance Position and Word Length, the effect of Utterance Position on coda duration is analysed separately for monosyllables, disyllables and trisyllables, as shown in Table 4.43[29].

For monosyllables and disyllables, Table 4.43 shows that the effect of Utterance Position is highly significant by Subjects. For trisyllables, the effect of Utterance Position on coda duration is almost significant by Subjects ($p = .052$). For neither monosyllables nor disyllables nor trisyllables is there a significant interaction between Utterance Position and Accent, indicating that—as for nucleus duration—the utterance-final lengthening effect is similar in unaccented and accented context. As discussed in Section 4.3.3, test syllable codas could be regarded as ambisyllabic or as onset consonants in left-headed polysyllables, such as *mason* or *masonry*: treating them here as coda consonants allows the results to be interpreted as a consistent pattern of lengthening on the coda in monosyllables, disyllables and trisyllables.

In the analysis of the full data-set for all three levels of Word Length, the interaction between Utterance Position and Accent is not significant by Subjects: $F(1,5.1) = 1.11$, $p = .338$ [by Items: $F(1,3) = 2.02$, $p = .249$]. There is, however, a significant interaction between Accent and Word Length by Subjects: $F(2,12.3) = 14.23$, $p < .005$ [by Items:

[29] These analyses use different subsets of the data according to the number of missing data points of the keywords *cap*, *dog* and *speck* due to coda glottalisation: they are included if the missing data is not unevenly distributed, and the proportion of missing data in the full data-set is not greater than about 5%.

	By-Subjects analysis			By-Items analysis		
Source of variation	Degrees of freedom	*F Ratio*	Significance level	Degrees of freedom	*F Ratio*	Significance level
Monosyllables						
Position	1,5.2	205.53	$p < .001$	1.6	10.45	$p < .05$
Accent	1,5.1	11.74	$p < .05$	1,6	19.50	$p < .005$
Interaction	1,5.6	1.71	.242	1,6.1	0.44	$p = .533$
Disyllables						
Position	1,5.1	16.85	$p < .01$	1,5	26.28	$p < .005$
Accent	1,5.1	5.28	$p < .01$	1,5.1	6.93	$p < .05$
Interaction	1,5.2	0.27	.624	1,5.2	7.00	$p < .05$
Trisyllables						
Position	1,5.1	6.40	.052	1,3.1	16.24	$p < .05$
Accent	1,5	3.12	.137	1,3.6	87.39	$p < .005$
Interaction	1,5.1	0.00	.950	1,3.1	0.00	.984

Table 4.43: Analyses of variance of test syllable coda duration according to word length for all left-headed keywords in Series C and Series E. For monosyllables, all keywords are included except *part*: data points = 168; missing data = 3.0%. For disyllables, all keywords are included except *part* and *speck* : data points = 144, missing data = 4.2%. For trisyllables, the keywords used are *fish*, *mace*, *sense* and *ten*: data points = 96, missing data = 2.

$F(2,6.1) = 8.17$, $p < .05$], in contrast with the findings for nucleus duration. This reflects the finding, discussed in Section 4.6.1, of a word-span effect on the coda in accented keywords only.

The three-way interaction between Utterance Position, Accent and Word Length is not significant by Subjects: $F(2,10.6) = 1.77$, $p = .218$.

Within-word results: final unstressed syllable duration in disyllables

In disyllables such as *captain* and *partner*, the effect of utterance position on the word-final unstressed syllable (syllable-2) may be examined by comparing Series C and Series E utterances, as for stressed syllable duration. The full data-set is not used for this analysis, however, for a reason indicated in Table I.1 in Appendix I, which gives mean syllable-2 duration keyword-by-keyword. Five keywords show some utterance-final lengthening in accented and unaccented keywords; for *captain*, the effect is only evident in unaccented keywords. Keywords *dogma* and *tendon*, in contrast, both show an utterance-final shortening effect, of between 15 ms and 25 ms for *tendon* and between 4 ms and 26 ms for *dogma*.

The anomalous behaviour of these two keywords may be due to the context in which they are spoken utterance-medially:

Series C.2 Tim knew the **dogma** may decline again

Series C.2 I heard the **tendon** denied again.

In both cases, syllable-2 is followed by another very similar syllable (both underlined), which may cause speakers to take particular care over enunciation in this iterative sequence[30]. Given this account of the anomalous results for *dogma* and *tendon*, they are excluded from the analysis of syllable-2 duration in disyllables.

Mean syllable-2 duration is shown in Table 4.44. The effect of Utterance Position is significant by Subjects: $F(1,5) = 12.55$, $p < .05$ [by Items: $F(1,5) = 13.65$, $p < .05$]. The utterance-final lengthening is 29 ms (35%) in unaccented disyllables and 20 ms (21%) in accented disyllables. The effect of Accent is not significant by Subjects: $F(1,5.1) = 2.99$, $p = .144$ [by Items: $F(1,5.2) = 9.31$, $p < .05$], and the interaction between Utterance Position and Accent is not significant by Subjects: $F(1,5.1) = 2.23$, $p = .195$ [by Items: $F(1,5.9) = 4.33$, $p = .083$].

	Utterance position	
	Final	Medial
Unaccented	112	83
Accented	114	94

Table 4.44: Mean syllable-2 duration (ms) in Series C and Series E for left-headed disyllables excluding *dogma* and *tendon*: data points = 144; missing = 3.5%.

Thus, both syllables in trochaic words such as *captain*, *fissure*, *mason* and *censor* manifest significant utterance-final lengthening. The absolute magnitude of the effect is comparable between the two syllables, but the proportional effect is greater on the shorter unstressed syllable. The distribution of final lengthening within polysyllables is examined further below.

[30]Cutler (1990:213) makes a similar point concerning Beckman & Edwards (1990): "It is not particularly far-fetched to suggest that the difficulty of articulating such [an iterative] sequence with clarity might have been a contributory factor in rendering speakers more prone to produce lengthening effects." Elsewhere in the Experiment 2, slight modifications to materials within particular keyword series have been made to avoid such clashes, as outlined in Section 4.2.

Within-word results: penultimate unstressed syllable duration in trisyllables

Syllable-2 is word-medial in trisyllables, for example: /tɪn/in *captaincy* and /ən/in *masonry*. In utterance-final trisyllables, syllable-2 is in utterance-penultimate position.

Table 4.45 shows mean syllable-2 duration for the trisyllables of left-headed keywords. The effect of Utterance Position is significant by Subjects: $F(1,5.2) = 10.71$, $p < .05$ [by Items: $F(1,7) = 4.61$, $p = .069$]. The utterance-final lengthening of syllable-2 is 6 ms (9%) in unaccented dss and 7 ms (10%) in accented disyllables. The effect of Accent approaches significance by Subjects: $F(1,5.2) = 4.70$, $p = .081$ [by Items: $F(1,7.1) = 9.02$, $p < .05$]. There is no significant interaction between Utterance Position and Accent by Subjects: $F(1,5.2) = 0.16$, $p = .708$ [by Items: $F(1,7.1) = 0.10$, $p = .761$].

	Utterance position	
	Final	Medial
Unaccented	74	68
Accented	79	72

Table 4.45: Mean syllable-2 duration (ms) in Series C and Series E for all left-headed trisyllables: data points = 192; missing = 2.6%.

Utterance-penultimate unstressed syllables, like stressed syllables, show significant lengthening relative to utterance-medial syllables, but the effect is small for unstressed syllables. This may be due to the distribution of the effect: in the test syllable only the coda undergoes significant lengthening in utterance-penultimate position. Subsyllabic constituent durations were not obtained for unstressed syllables, but the importance of subsyllabic structure may be inferred from the pattern of the results for each keyword, shown in Table I.2 in Appendix I. Where syllable-2 is an open syllable, there is little consistent evidence of utterance-final lengthening: only *spectacle* of open syllable-2 keywords shows utterance-final lengthening for both unaccented and accented context, 8 ms (16%) for the former and 4ms (7%) for the latter. By contrast, three keywords have large and consistent utterance-final lengthening effects: *captaincy*, *masonry* and *tendency*, and for these syllable-2 is closed (that is, contains a coda consonant). Keyword *captaincy* has 13 ms (11%) lengthening in unaccented context and 13 ms (10%) in accented context; keyword *masonry* has 18ms (27%) in unaccented context and 21 ms (31%) in accented context; keyword *tendency* has 34ms (31%) in unaccented context and 4 ms (3%) in accented context. This result supports the conclusion from the results for stressed syllables, that the locus of final lengthening in utterance-penultimate position is the coda, rather than some arbitrary set of segments at the end of the syllable.

Within-word results: final unstressed syllable duration in trisyllables

Syllable-3 is word-final in trisyllables, for example: /sɪ/in *captaincy* and /ɹɪ/in *masonry*. In utterance-final trisyllables, syllable-3 is in absolute-final position.

Table 4.46 shows mean duration of syllable-3 in left-headed trisyllables[31]. The effect of Utterance Position is highly significant by Subjects: $F(1,5) = 52.00$, $p < .005$ [by Items: $F(1,7) = 18.53$, $p < .005$]. There is a large utterance-final lengthening effect in word-final unstressed syllables: 40 ms (25%) in unaccented keywords and 35 ms (20%) in accented keywords. The effect of Accent approaches significance by Subjects: $F(1,5) = 5.74$, $p = .062$ [by Items: $F(1,7.5) = 89.44$, $p < .001$]. There is no interaction between Utterance Position and Accent by Subjects: $F(1,5.1) = 0.38$, $p = .563$ [by Items: $F(1,7.3) = 2.32$, $p = .170$].

	Utterance position	
	Final	Medial
Unaccented	203	163
Accented	212	177

Table 4.46: Mean final unstressed syllable duration (ms) for the trisyllables of all left-headed keywords in Series C and Series E: data points = 192; missing = 2.6%.

Thus, as for the test syllable in monosyllabic context, and for the word-final unstressed syllable in disyllabic context, there is a large lengthening effect in the absolute-final syllable relative to utterance-medial position. Also, for syllable-3 in trisyllables shown in Table 4.46, as for syllable-2 in disyllables shown in Table 4.44, the lengthening effect of accent is attenuated utterance-finally and does not attain significance; however, in neither instance is the interaction between utterance position and accent statistically significant.

Cross-word results: utterance-penultimate position

In utterance-penultimate position when followed by an unstressed syllable within the same word, the test syllable coda is lengthened relative to utterance-medial position . A comparison of the U+1 conditions in Series B and Series D, for example:

Series B.2 I SAW the **fish** again here TODAY.

Series D.2 Bob said he SAW the **fish** off.

[31] The keywords *dogmatist* and *partnership* have coda stop consonants in syllable-3 that are not always released; for these keywords syllable-3 duration is measured up to the point of closure of the coda stop consonant.

may indicate whether this effect also holds when the utterance-penultimate syllable is followed by another syllable which comprises a separate word.

As described in Section 4.2.1, the test syllables in Series D.2 sentences are necessarily followed by full-vowel syllables, because function words are not reduced phrase-finally. This could result in stress-adjacent lengthening of the test syllables, so this comparison contains a possible confound; as already noted, the utterances for the keywords *dog* and *part* also contain full vowel syllables following the test syllable in the Series B.2 utterances. The locus of any effect within the syllable may indicate its origin, however.

Table 4.47 shows mean onset, nucleus and coda durations in Series B.2 and D.2 utterances for left-headed keywords.

	Utterance position	
	Final	Medial
Onset		
Unaccented	107	105
Accented	127	130
Nucleus		
Unaccented	90	88
Accented	104	102
Coda		
Unaccented	123	105
Accented	135	131

Table 4.47: Mean duration (ms) of subsyllabic constituents of the test syllable in Series B.2 and Series D.2 utterances (U+1 condition) for left-headed keywords. Means for onset and nucleus include all keywords: data points = 196; missing = 6. Means for coda include keywords *fish*, *mace*, *sense* and *ten*: data points = 96; missing = 5.

The syllable onset shows no effect of Utterance Position by Subjects: $F(1,5.2) = 0.02$, $p = .894$ [by Items: $F(1,7.1) = 0.00$, $p = .992$] and no interaction between Utterance Position and Accent by Subjects: $F(1,5.3) = 1.24$, $p = .314$ [by Items: $F(1,7.3) = 6.37$, $p = .038$]. Thus, there is no evidence of either final lengthening or of the tendency towards utterance-medial lengthening of test syllable onsets in Series B noted in Section 4.5.1.

The syllable nucleus shows no effect of Utterance Position by Subjects: $F(1,5.1) = 0.06$, $p = .812$ [by Items: $F(1,7) = 0.82$, $p = .397$] and no interaction between Utterance Position and Accent by Subjects: $F(1,5.1) = 0.12$, $p = .747$ [by Items: $F(1,7.2) = 1.08$, $p = .334$]. The lack of a difference between Series B and Series D in nucleus duration suggests that the effect of stress-adjacency is not a factor in this comparison. The result mirrors that found for utterance-penultimate test syllables in trochaic disyllables such as *mason*, which show no effect of utterance position on the nucleus.

The syllable coda shows no effect of Utterance Position by Subjects: $F(1,5.2) = 2.59$, $p = .166$ [by Items: $F(1,3) = 3.63$, $p = .153$]; the interaction between Utterance Position and Accent approaches significance by Subjects, however: $F(1,5.2) = 4.74$, $p = .079$ [by Items: $F(1,3.1) = 3.16$, $p = .170$]. Because of this, unaccented and accented keywords are also analysed separately. Unaccented keywords show a significant effect of Utterance Position on coda duration by Subjects: $F(1,5.1) = 7.47$, $p < .05$ [by Items: $F(1,3) = 3.34$, $p = .165$]. Accented keywords show no significant effect of Utterance Position on coda duration by Subjects: $F(1,6.2) = 0.78$, $p = .409$ [by Items: $F(1,3.1) = 6.73$, $p = .079$].

The lengthening of the coda in unaccented keywords seems likely to be attributable to utterance-finality, rather than stress-adjacency, given the lack of effect of utterance position for onset and nucleus. If so, this result is somewhat anomalous, as none of the previous results for utterance-final lengthening indicate an interaction between utterance position and accent.

Cross-word results: utterance-antepenultimate position

In utterance-antepenultimate position, there is evidence of lengthening of the test syllable coda when followed by two unstressed syllables within the word. A comparison of Series B.3 and Series D.3 utterances, for example:

Series B.3 I SAW the **fish** again with it TODAY.

Series D.3 Bob said he SAW the **fish** again.

may indicate if this effect also holds when the utterance-antepenultimate syllable is followed by two syllables which comprise a separate word.

Table 4.48 shows mean onset, nucleus and coda durations in Series B.3 and D.3 utterances for left-headed keywords.

The syllable onset shows a significant effect of Utterance Position by Subjects: $F(1,5.1) = 10.72$, $p < .05$ [by Items: $F(1,7.2) = 5.94$, $p < .05$] and no interaction between Utterance Position and Accent by Subjects: $F(1,5.1) = 0.58$, $p = .481$ [by Items: $F(1,7.1) = 0.04$, $p = .854$]. This results indicates utterance-medial lengthening of test syllable onsets in Series B, as already noted in Section 4.5.1. It is unlikely to be influenced by stress-adjacent lengthening in Series B, as the effect is very similar when *dog* and *part* are excluded.

The syllable nucleus shows no effect of Utterance Position by Subjects: $F(1,5) = 0.76$, $p = .423$ [by Items: $F(1,7.1) = 14.07$, $p < .01$] and no interaction between Utterance Position and Accent by Subjects: $F(1,5.1) = 0.62$, $p = .467$ [by Items: $F(1,7.1) = 0.04$, $p = .844$] (and the results are very similar when *dog* and *part* are excluded). Thus, as for

	Utterance position	
	Final	Medial
Onset		
Unaccented	101	105
Accented	122	129
Nucleus		
Unaccented	84	90
Accented	97	100
Coda		
Unaccented	113	104
Accented	128	124

Table 4.48: Mean duration (ms) of subsyllabic constituents of the test syllable in Series B and Series D U+1 condition for left-headed keywords. Means for onset and nucleus include all keywords: data points = 192; missing = 4.7%. Means for coda include keywords *fish*, *mace*, *sense* and *ten*: data points = 120; missing = 7.5%.

the within-word analysis, utterance-antepenultimate test syllables show no evidence of final lengthening on the nucleus.

The effect of Utterance Position on the syllable coda approaches significance by Subjects: $F(1,5.1) = 4.22$, $p = .094$ [by Items: $F(1,4) = 2.85$, $p = .166$]. There is no interaction between Utterance Position and Accent by Subjects: $F(1,5.1) = 2.94$, $p = .145$ [by Items: $F(1,4.1) = 0.62$, $p = .473$]. Here there is no possibility of a confound due to stress-adjacency, as all test syllables are followed by reduced syllables in Series B and Series D, but the analysis should be treated with caution due to the relatively high proportion of missing data (7.5%).

This caveat notwithstanding, the pattern of apparent utterance-final lengthening in test syllables followed by another monosyllabic or disyllabic word before the utterance boundary resembles that for within-word final lengthening effects: the coda, but not the onset or the nucleus, may be lengthened in utterance-penultimate and utterance-antepenultimate position, but by much less than when in absolute-final position. The within-word results regarding this effect are fairly clear; the cross-word results are more equivocal, with the possibility that other durational processes may, in some cases, influence the observed durations.

4.8.2 Discussion

Experiment 2 tests three specific hypotheses relating to utterance-final lengthening:

Utterance-final locus hypothesis: the locus of utterance-final lengthening is the word-rhyme.

Utterance-final locus distribution hypothesis: the distribution of utterance-final lengthening is progressive within the locus.

Utterance-final accent hypothesis: the magnitude of utterance-final lengthening is not affected by the presence of a pitch accent on the utterance-final word.

The evidence relating to each of these hypotheses is considered now.

The locus of final lengthening

Experiment 2 finds that an utterance-final stressed syllable undergoes a large amount of lengthening, and an utterance-penultimate stressed syllable undergoes a significant but substantially smaller amount of lengthening relative to utterance-medial position. Furthermore, there is some evidence of lengthening of a stressed syllable in utterance-antepenultimate position when followed by two unstressed syllables. The unstressed syllables following the final stressed syllable also show lengthening; in all cases, the syllable in absolute-final position, whether stressed or unstressed, shows the greatest amount of lengthening. Thus, for example, all three syllables in *fisherman* are longer utterance-finally than utterance-medially, with the greatest effect seen on the absolute-final syllable /mən/.

These results support the utterance-final hypothesis, indicating that the locus of lengthening is the word-rhyme. This constituent begins with the primary stressed syllable within a word and extends to the word boundary. Unstressed syllables preceding the word-rhyme are not measured in this study; however, Turk (1999) shows that the unstressed first syllable of words such as *Tibet* is not lengthened intonational-phrase-finally. The present results could also be taken to indicate that the locus of final lengthening is the within-word foot, defined in Chapter 2 as beginning with a stressed syllable and continuing to a word boundary or another stressed syllable onset, whichever is the sooner; however, Turk (1999) also shows intonational-phrase-final lengthening on both syllables in words such as *Woodstock*, which comprises two within-word feet. For this reason, the word-rhyme interpretation is preferred.

Not all parts of the word-rhyme are affected by final lengthening, however: where the stressed syllable is in absolute-final position, the syllable rhyme shows significant lengthening but the onset does not. For utterance-penultimate and utterance-antepenultimate stressed syllables, only the syllable coda shows significant utterance-final lengthening[32]. The results for unstressed syllables also suggest this distribu-

[32]The lengthening of the coda in utterance-antepenultimate stressed syllables is appraoches significance ($p = .052$) in the analyses for Experiment 2.

tion: only those unstressed syllables which have codas show consistent lengthening in utterance-penultimate position, although, as subsyllabic durations were not obtained for unstressed syllables, the actual distribution of lengthening may only be inferred.

There is some evidence that the stressed syllable coda may also be lengthened in utterance-penultimate and utterance-antepenultimate position where there is a separate word intervening before the boundary. Thus, for example, /s/ in /meɪs/ may be longer in *mace up*|| and *mace again*|| than utterance-medially, although the effect of utterance position does not attain significance in these cases. Furthermore, stress-adjacent lengthening may be a confounding factor in the utterance-penultimate analysis.

Thus, proposing the word-rhyme as the locus of utterance-final lengthening requires two qualifications. Firstly, lengthening occurs only on the syllable rhyme in absolute-final position, and only on the syllable coda in utterance-penultimate and utterance-antepenultimate position. There is no constituent which maps precisely to this locus, so its description necessarily entails two levels: at the syllabic level, the locus is the word rhyme; at the subsyllabic level, the locus is the syllable rhyme or the syllable coda, according to position. Secondly, the word-rhyme is by definition a within-word constituent; future research may yet reveal that the locus of utterance-final lengthening is a cross-word constituent.

The distribution of final lengthening within the locus

The utterance-final locus distribution hypothesis predicts that lengthening is progressive within the locus. As neither stressed nor unstressed syllables show an interaction between the durational effects of utterance position and pitch accent in Experiment 2, the mean durations may be pooled across accent conditions for the purposes of illustrating the distribution of lengthening effects. Table 4.9 shows the magnitude of utterance-final lengthening on all constituents which show any evidence of such an effect[33]: it is clear that greater lengthening is found nearer to the end of the utterance and the trend is particularly clear when the proportion of lengthening is considered. Thus, the utterance-final locus distribution hypothesis is strongly supported in the pooled data for a number of keywords.

Influence of pitch accent on utterance-final lengthening

The utterance-final accent hypothesis predicts that the magnitude of utterance-final lengthening is not affected by the presence of a pitch accent on the utterance-final word. Experiment 2 supports this hypothesis: in none of the statistical analyses of

[33]Lengthening is shown for illustrative purposes on the test syllable nucleus in all conditions, although, as noted above, the effect is only significant on the nucleus in absolute-final test syllables.

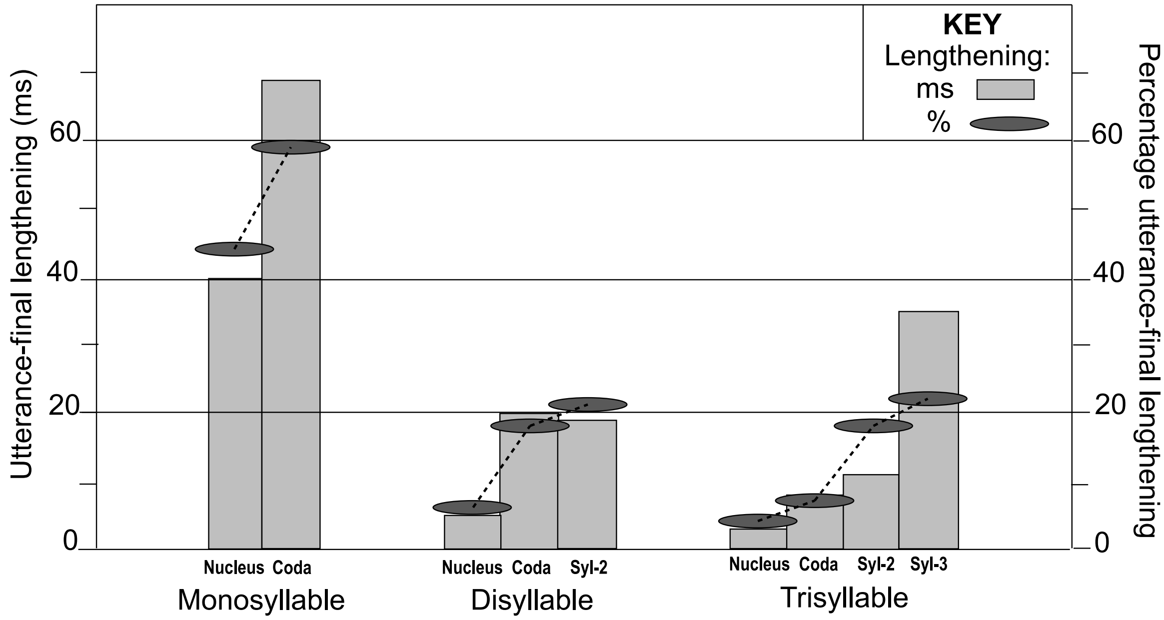

Figure 4.9: The magnitude and proportion of final lengthening (ms) for the left-headed keywords *fish*, *mace*, *sense* and *ten* in Series C and Series E on the test syllable nucleus and coda, and for the whole unstressed syllable(s) in disyllables and trisyllables.

utterance-final lengthening effects, for either stressed or unstressed syllables, is a significant interaction found between utterance position and pitch accent. Table 4.49 shows the mean and proportion of lengthening for stressed syllable subsyllabic durations and whole unstressed syllable durations.

Although there are no statistical interactions found between final lengthening and accentual lengthening, Table 4.49 clearly shows that for almost all comparisons, both the magnitude and proportion of final lengthening is greater in unaccented words. The difference in the proportion of lengthening is more marked because constituents are shorter in unaccented words, and thus a similar magnitude of final lengthening will be proportionally greater in the unaccented case. This result is quite similar to that reported in Cambier-Langeveld (2000) and may be interpreted as a ceiling effect, as discussed in Chapter 5.

This slight attenuation of final lengthening in accented keywords notwithstanding, it seems that the two effects are largely independent. This conclusion is supported by the observation that the locus of final lengthening is consistent between accented and unaccented words.

The results of Experiment 2 regarding utterance-final lengthening are discussed further in Chapter 5, and compared with previous findings.

	Stressed syllable				Unstressed syllable			
	Nucleus		Coda		Syllable-2		Syllable-3	
Monosyllables								
Unaccented	38 ms	43%	73 ms	70%				
Accented	33 ms	33%	65 ms	50%				
Disyllables								
Unaccented			24 ms	22%	29 ms	35%		
Accented			15 ms	15%	20 ms	21%		
Trisyllables								
Unaccented			8 ms	8%	6 ms	9%	40 ms	25%
Accented			7 ms	6%	7 ms	10%	35 ms	20%

Table 4.49: Magnitude and proportion of utterance-final lengthening in accented and unaccented keywords.

4.9 Accentual lengthening results

The lengthening effect of pitch accent is observed in many of the foregoing analyses of syllabic and subsyllabic durations, and is statistically significant in most instances. Two particular aspects of accentual lengthening are of interest here: the interaction between lengthening and the number of syllables in the word; and the distribution of lengthening in the stressed syllable and the rest of the accented word.

The word-span accent hypothesis, that the magnitude of accentual lengthening on the primary stressed syllable is inversely related to word length, is examined first in Section 4.9.1 and found to be supported.

The distribution of accentual lengthening is examined in left-headed and right-headed monosyllables, disyllables and trisyllables. The results for left-headed keywords provide some support for both the word-rhyme accent hypothesis, which states the locus is the word-rhyme, and the bimodal accent hypothesis, which states the locus is the primary stressed syllable and the word-final syllable. The results for right-headed keywords, however, show that the locus of accentual lengthening is the whole word.

The interpretation of these results is discussed further in Section 4.9.2.

4.9.1 Results and analysis

Accentual lengthening and word length

The word-span accent hypothesis predicts that the magnitude of accentual lengthening on the primary stressed syllable is inversely related to word length. The magnitude and proportion of accentual lengthening is shown in Figure 4.10 for keywords in Series A.

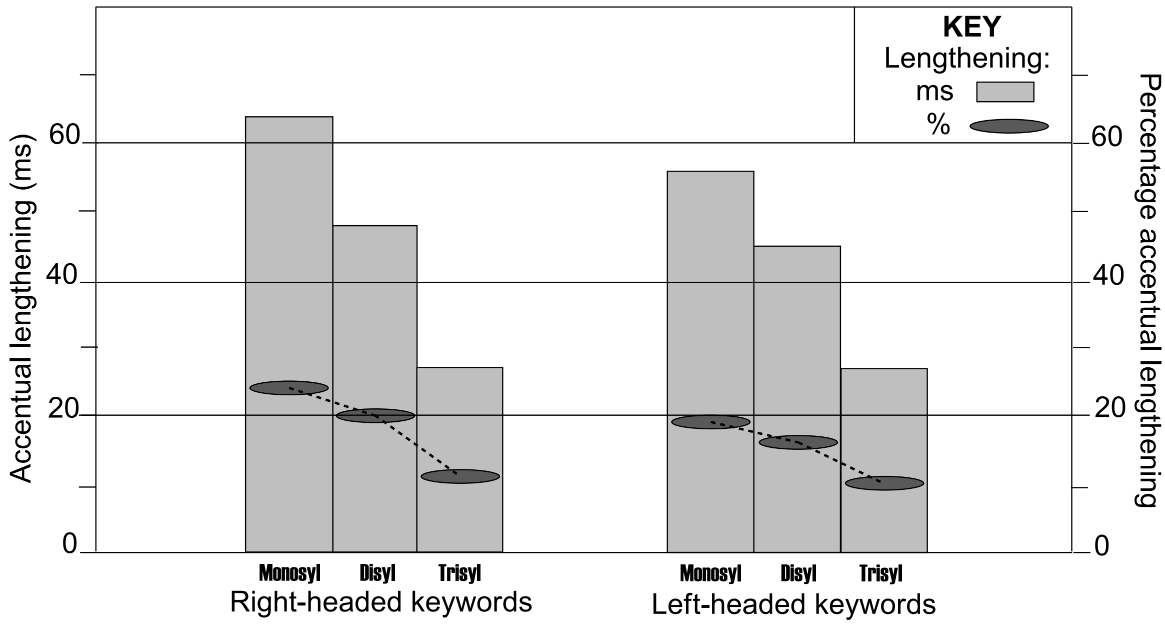

Figure 4.10: The magnitude and proportion of accentual lengthening (ms) of the test syllable in Series A. All right-headed keywords are included except *port* : data points = 252, missing = 3.8%. Left-headed keywords included are *fish*, *mace*, *sense* and *ten* : data points = 144, missing = 2.1%.

The analyses in Section 4.6.1 of test syllable duration show a significant interaction between word length and pitch accent for both right-headed and left-headed keywords: accentual lengthening of the stressed syllable is greatest in monosyllables and least in trisyllables. For right-headed keywords in Series A, the effect of Accent is highly significant by Subjects: $F(1,5) = 29.38$, $p < .005$ [by Items: $F(1,6.2) = 308.99$, $p < .001$], and the interaction between Word Length and Accent is highly significant by Subjects: $F(2,10.2) = 23.99$, $p < .001$ [by Items: $F(2,13) = 36.49$, $p < .001$]. For left-headed keywords in Series A, the effect of Accent is significant by Subjects: $F(1,5) = 15.81$, $p < .05$ [by Items: $F(1,3) = 57.06$, $p < .01$], and the interaction between Word Length and Accent is highly significant by Subjects: $F(2,10.2) = 7.71$, $p < .01$ [by Items: $F(2,6.2) = 11.90$, $p < .01$].

Details of the effect of accent and the interaction between accentual lengthening and word length for test syllable onset, nucleus and coda are given in Section 4.6.1 for Series A and in Appendix H for Series C. In most cases, subsyllabic constituents show the same pattern of durational variation as the full test syllable: significant accentual lengthening, and a significant interaction with word length such that accentual lengthening is greatest in monosyllables and least in trisyllables.

This pattern, termed the polysyllabic accent effect in Section 4.6.2, apparently underlies the finding here and in previous experiments of polysyllabic shortening that, in accented words, primary stressed syllables are longer in monosyllables, shorter in disyllables and shorter still in trisyllables; according to the polysyllabic accent hypothesis this is due to greater accentual lengthening in words of fewer syllables. The lack of strong evidence for a similar effect in unaccented keywords supports this finding: localised effects such as word-initial lengthening on the syllable onset and word-rhyme-span shortening on the syllable nucleus appear to arise from separate processes.

The reason that accentual lengthening is greater in words of fewer syllables appears to be that the additional syllables in polysyllables undergo some accentual lengthening themselves, as though there is a fixed amount of lengthening to be shared out amongst the syllables of the accented word. Because the interaction between accentual and word length is similar in right-headed and left-headed words, as shown in Figure 4.10, it is expected that the lengthening of unstressed syllables in polysyllables should show a similar degree of symmetry: that is, the effects should be similar on the additional syllables in left-headed and right-headed keywords. This is not always observed, however: studies such as Turk & White (1999) suggest there is more accentual lengthening on syllables following the primary stress than on those preceding it. The distribution of accentual lengthening in Experiment 2 is examined now.

The distribution of accentual lengthening

As just discussed, there may be a relationship between the magnitude of accentual lengthening in the test syllable and in the additional syllables in polysyllables. The durational effects of accent are examined for the subsyllabic constituents of the test syllable in monosyllables, disyllables and trisyllables, and for the additional syllables in polysyllabic keywords.

The distribution of accentual lengthening in monosyllables

Table 4.50 shows the durational effect of accent for test syllable onset, nucleus and coda of monosyllables from the right-headed keyword set. ANOVA details are shown in Table J.1 in Appendix J: in By-Subjects analyses, all subsyllabic constituents show highly significant effects of Accent. The onset shows the greatest amount of lengthening and the nucleus shows the least, although this is still a large effect.

	Onset	Nucleus	Coda
Unaccented	99	96	68
Accented	129	115	84
Lengthening	30%	20%	24%

Table 4.50: Duration (ms) of subsyllabic constituents of test syllables in right-headed monosyllables in Series B. For onset and nucleus duration, all keywords are included: data points = 288, missing = 1.4%; for coda duration, all keywords except *port* are included: data points = 252, missing = 1.6%.

Table 4.51 shows the durational effect of accent in test syllable onset, nucleus and coda for monosyllables from the left-headed keyword set. ANOVA details are shown in Table J.1 in Appendix J: the effect of Accent is significant by Subjects for onset and nucleus, and approaches significance for coda duration ($p = .065$)[34]. The pattern of lengthening resembles that for right-headed keywords, as would be expected given that for monosyllables there is no structural difference between the two groups of keywords (they are analysed separately for the purposes of comparison with the two groups of disyllables and trisyllables). Although the proportion of lengthening is slightly smaller in this set—presumably due to differences in segmental composition—the onset once again shows the largest effect of accent and the nucleus shows the smallest effect.

	Onset	Nucleus	Coda
Unaccented	105	89	114
Accented	129	100	138
Lengthening	23%	12%	21%

Table 4.51: Duration (ms) of subsyllabic constituents of test syllables in left-headed monosyllables in Series B. For onset and nucleus duration, all keywords are included: data points = 288, missing = 5.2%; for coda duration, keywords *fish*, *mace* and *sense* are included (*ten* is excluded because of missing data): data points = 108, missing = 4.6%.

The lesser lengthening of the nucleus is not attributable to the decision to include the duration aspiration of voiceless stop onset consonants within onset duration rather than within nucleus duration. Applying the alternative segmentation—that is, including aspiration within the nucleus—shows a slight lessening of the proportion of lengthening in the onset and a slight increase in the proportion in the nucleus, but

[34]The lack of a significant effect for coda duration may be due to the smaller data set used: *ten* is excluded because its inclusion creates a data-set with 7.6% missing data, greater than the conventionally-allowable proportion of 5%. If *ten* is included, however, the pattern of results is similar to that shown in Table 4.51, with unaccented duration of 105 ms and accented duration of 130 ms, a 24% accentual lengthening effect which is significant by Subjects: $F(1,5) = 9.64$, $p < .05$.

the trend remains the same. For right-headed keywords: accentual lengthening of the onset excluding aspiration is 29%; accentual lengthening of the nucleus including aspiration is 23%. For left-headed keywords: accentual lengthening of the onset excluding aspiration is 22%; accentual lengthening of the nucleus including aspiration is 16%.

The distribution of accentual lengthening in disyllables

Table 4.52 shows the durational effect of accent for test syllable constituents of right-headed disyllables. ANOVA details are shown in Table J.2 in Appendix J: the effect of Accent is highly significant by Subjects for onset and is significant for nucleus and coda. Thus the subsyllabic constituents of the stressed final syllables of words such as *compose*, *commend* and *humane* are all lengthened when the word is accented, but by less than in the equivalent monosyllables, such as *pose*, *mend* and *main*. Furthermore, the distribution of lengthening is different: in right-headed monosyllables, the nucleus shows less accentual lengthening than the onset or coda; in the right-headed disyllables, the proportion of lengthening is similar for onset, nucleus and coda.

	Syllable-2	Onset	Nucleus	Coda
Unaccented	120	83	98	68
Accented	138	98	117	81
Lengthening	15%	18%	19%	19%

Table 4.52: Duration (ms) of test syllable onset, nucleus and coda, and of syllable-2, in right-headed disyllables in Series A and C. For onset and nucleus duration, all keywords are included: data points = 192, missing = 2.1%; for coda duration, all keywords except *port* are included: data points = 168, missing = 2.4%; for syllable-2 duration, all Series C keywords are included: data points = 96, missing = 3.

Table 4.52 also shows mean duration of syllable-2, the initial unstressed syllable in right-headed disyllables: for example, /kə/ in *commend*. The effect of Accent is significant by Subjects: $F(1,5.1) = 14.28$, $p < .05$ [by Items: $F(1,7) = 29.62$, $p < .005$].

Table 4.53 shows the durational effect of accent for test syllable constituents of left-headed disyllables such as *fissure*, *mason* and *censor*. ANOVA details are shown in Table J.2 in Appendix J: the effect of Accent is significant by Subjects for onset and coda, and approaches significance for nucleus duration ($p = .077$). The lengthening effects are distributed differently compared to right-headed disyllables, and resemble the results for left-headed and right-headed monosyllables, where the onset and coda show greater proportional lengthening than the nucleus. The amount of lengthening is in all cases less than that found in equivalent monosyllables such as *fish*, *mace* and *sense*.

	Onset	Nucleus	Coda	Syllable-2
Unaccented	100	83	106	99
Accented	119	90	124	109
Lengthening	19%	8%	17%	10%

Table 4.53: Duration (ms) of test syllable onset, nucleus and coda, and of syllable-2, in left-headed disyllables in Series A and C. For onset and nucleus duration, all keywords are included: data points = 192, missing = 3.6%; for coda duration, keywords *fish*, *mace*, *sense* and *ten* are included: data points = 96, missing = 6.3%; for syllable-2 duration, all Series C keywords are included: data points = 96, missing = 4.

Table 4.53 also shows mean duration of syllable-2, the final unstressed syllable in left-headed disyllables: for example, /mə/ in *dogma*. The effect of Accent is not significant by Subjects: F(1,5.2) = 3.91, p = .103 [by Items: F(1,7.3) = 3.26, p = .113]. The lack of a significant effect of pitch accent for word-final unstressed syllables is somewhat surprising, given the magnitude of the effect and the results of previous experiments, and may reflect the relatively small size of the data-set. As discussed below, the effect of accent on syllable-2 more nearly attains significance when disyllables and trisyllables are analysed together.

The distribution of accentual lengthening in trisyllables

Table 4.54 shows the durational effects of accent for test syllable constituents of right-headed trisyllables, such as *recommend*, *inhumane* and *reproduce*. ANOVA details are shown in Table J.3 in Appendix J: for onset duration and for nucleus duration, the effect of Accent approaches significance by Subjects (p = .060 and p = .054 respectively); for coda duration, there is a highly significant effect of Accent by Subjects. The distribution of lengthening is different from that found in right-headed monosyllables and disyllables: here, the greatest amount of lengthening is on the coda; there is little lengthening on the syllable onset and an intermediate amount on the nucleus.

Table 4.54 also shows the effects of pitch accent on syllable-2 and syllable-3 in right-headed trisyllables: for example, in *recommend*, /kə/ is syllable-2 and /rə/ is syllable-3. For syllable-2, the effect of Accent is not significant by Subjects: F(1,5.1) = 3.88, p = .105 [by Items: F(1,6.3) = 10.14, $p < .05$], and the apparent accentual lengthening effect is smaller than for syllable-2 in disyllables. For syllable-3, the effect of Accent is significant by Subjects: F(1,5.1) = 9.31, $p < .05$ [by Items: F(1,6.1) = 7.66, $p < .05$].

Table 4.55 shows the durational effects of accent for test syllable constituents of left-headed trisyllables such as *captaincy*, *masonry* and *fisherman*. ANOVA details are shown in Table J.3 in Appendix J: the effect of Accent on onset duration is significant by Subjects; the effect of Accent approaches significance by Subjects for nucleus dura-

	Syllable-3	Syllable-2	Onset	Nucleus	Coda
Unaccented	140	129	76	98	66
Accented	161	135	80	110	76
Lengthening	15%	5%	5%	12%	15%

Table 4.54: Duration (ms) of test syllable onset, nucleus and coda, and of syllable-2 and syllable-3, in right-headed trisyllables in Series A and C. For the onset, nucleus and coda duration, all keywords except *port* are included: data points = 168, missing = 5.9%; for syllable-2 duration, all keywords in Series C except *port* are used, data points = 84, missing = 3; for syllable-3 duration, all keywords in Series C except *port* are used, data points = 84, missing = 3.

tion (p = .069) and coda duration (p = .088). The distribution of lengthening contrasts with the pattern seen for monosyllabic keywords and disyllabic left-headed keywords, where onset and coda showed more lengthening than nucleus. It also contrasts with the pattern seen for right-headed trisyllabic words, where the coda shows the greatest degree of lengthening. Here, the onset shows the greatest degree of lengthening, with lesser effects seen on the nucleus and coda.

	Onset	Nucleus	Coda	Syllable-2	Syllable-3
Unaccented	100	75	105	68	163
Accented	116	82	114	72	177
Lengthening	16%	9%	9%	6%	9%

Table 4.55: Duration (ms) of test syllable onset, nucleus and coda, and of syllable-2 and syllable-3, in left-headed trisyllables in Series A and C. For the onset and nucleus duration, all keywords are included: data points = 192, missing = 2.1%; for coda duration, keywords *fish*, *mace*, *sense* and *ten* are included: data points = 96, missing = 2; for syllable-2 and syllable-3 duration, all keywords in Series C are used, data points = 96, missing = 4.

Table 4.55 also shows the effects of pitch accent on syllable-2 and syllable-3 in left-headed trisyllables: for example, in *masonry*, /ən/ is syllable-2 and /rɪ/ is syllable-3. For syllable-2, the effect of Accent is not significant by Subjects: F(1,5.7) = 3.48, p = .114 [by Items: F(1,7.2) = 3.04, p = .124]. For syllable-3, the effect of Accent, although relatively large in terms of the mean durations, is not significant by Subjects: F(1,5) = 3.89, p = .105 [by Items: F(1.7.6) = 46.47, p < .001]. (The By-Items analysis shows a highly significant effect, which could indicate that it might also be significant by Subjects with additional data.)

Accentual lengthening of syllable-2 is more reliable when data for left-headed disyllables and trisyllables are pooled together. The full analysis is reported in Section

4.6.1, where the effect of Accent approaches significance by Subjects (p = .088) and there is no significant interaction between Word Length and Accent (p = .178). This suggests that the lack of a significant effect for either disyllables or trisyllables alone may be attributable to the relatively small data-set, combined with the relatively small size of the effect.

The effects of accent on subsyllabic durations of test syllables clearly vary in magnitude and distribution according to both word length and the position of the stressed syllable within the word. The results for syllable-2 and syllable-3 duration indicate that the effects of accent may extend beyond the primary lexically-stressed syllable, as previously found by Sluijter (1995), Turk & Sawusch (1997) and Turk & White (1999). The pattern of results does not suggest strong support for either the rightward accent hypothesis or the bimodal accent hypothesis. Both hypotheses predict more lengthening on syllables following the stressed syllable than on those preceding it, which was not the case: word-initial unstressed syllables, in particular, show large and reliable lengthening due to pitch accent.

4.9.2 Discussion

Accentual lengthening and word length

The word-span accent hypothesis predicts that the magnitude of accentual lengthening on the primary stressed syllable is inversely related to word length: the results for onset, nucleus and coda duration clearly demonstrate this in left-headed and in right-headed keywords. A similar effect is observed on the common unstressed syllable in disyllables and trisyllables: in right-headed keywords, syllable-2—for example, /kə/ in *commend* and *recommend*—shows 19ms (14%) accentual lengthening in disyllables and 6 ms (5%) in trisyllables; in left-headed keywords, syllable-2—for example, /ən/ in *mason* and *masonry*—shows 11ms (13%) accentual lengthening in disyllables and 6 ms (10%) in trisyllables.

Figure 4.11 shows the mean accentual lengthening for the whole word in monosyllables, disyllables and trisyllables: the absolute magnitude of accentual lengthening is, to a first approximation, comparable between words of different lengths. Certainly, there is no suggestion of greater accentual lengthening in polysyllables in proportion to their greater length. Accentual lengthening as a proportion of total word length clearly decreases from monosyllables to disyllables to trisyllables.

The data presented in Figure 4.11 suggest that accentual lengthening is a property of the word: thus, a certain amount of additional length due to accent is assigned to the word as a whole, and distributed amongst the constituent syllables. An alternative is to link the amount of accentual lengthening to fundamental frequency variation: for example, Beckman & Edwards (1992:374) suggest that accentual lengthening may

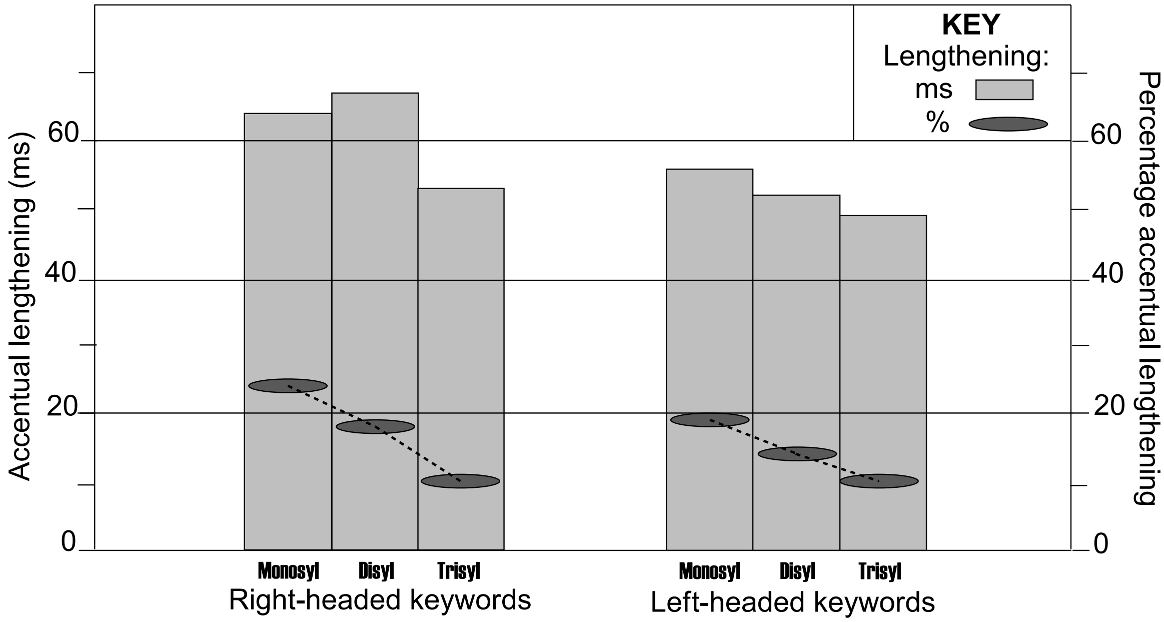

Figure 4.11: The magnitude and proportion of accentual lengthening (ms) of the whole keyword in Series C. All right-headed keywords are included except *port* : data points = 252, missing = 3.6%. Left-headed keywords included are *fish*, *mace*, *sense* and *ten* : data points = 144, missing = 4.9%.

occur "simply to make room for realising the associated pitch shapes in the intonation contour." This would suggest that words of fewer syllables require more lengthening, because in polysyllables the same pitch excursion could be accommodated without the need for much accentual lengthening; as Figure 4.11 indicates, however, there is not much attenuation of accentual lengthening across the word as a whole in polysyllables compared with monosyllables.

Research on the alignment of pitch accents also suggests a decoupling of accentual lengthening and the pitch excursion itself. Ladd *et al.* (1999) indicate that the slope and duration of a rising prenuclear pitch accent can vary to accommodate changes in speech rate or duration of the accented syllable. What is preserved under these manipulations is the alignment and F_0 level of the start and the end of the rise: the start is aligned with beginning of the stressed syllable onset and the end is aligned with the post-vocalic consonant; the F_0 levels of the start and end points differ between speakers but are fixed for individual speakers. This data is obtained for prenuclear rising accents, and it is possible that the alignment targets are different for nuclear accents— at least 94% of the accents on keywords in Experiment 2 are nuclear—-although Silverman & Pierrehumbert (1990) suggest that prenuclear and nuclear accents are not distinguished phonetically. It seems highly probable that other types of accent do have fixed alignment points, however: thus even if tonal targets are differently aligned in nuclear accents—for example, with the edges of the accented word rather then the accented syllable—variation in the duration of the word would only be required to accommodate the excursion if it had a fixed slope or fixed duration. Arvaniti *et al.* (1998), Ladd *et al.* (1999) and Ladd *et al.* (2000), for a number of languages, indicate that the slope and duration of the pitch excursion are subject to variation according to the structure of the accented syllable, and in some cases, adjacent syllables.

The evidence thus suggests that the amount of accentual lengthening within a word is not an accommodation of F0 movement, but rather a fundamentally durational property of the word as a whole; as discussed below, the structure of the word determines how accentual lengthening is distributed amongst its constituents.

The distribution of accentual lengthening

Figure 4.12 shows the mean accentual lengthening in the constituents of monosyllables and polysyllables[35], clearly indicating that neither the word-rhyme accent hypothesis nor the bimodal accent hypothesis are supported. The former predicts that the locus of accentual lengthening is the word-rhyme; the latter that the locus is the primary stressed syllable and the word-final syllable. Both these hypotheses have some support from the data for left-headed keywords; however, the unstressed syllables preceding the primary stress in right-headed keywords also show lengthening effects. Indeed, the only lengthening effects which attain significance for unstressed syllables are when syllable-2 or syllable-3 are word-initial in right-headed disyllables and trisyllables.

These results strongly suggest that the locus of accentual lengthening is the word itself. Variations in the distribution of lengthening within the word appear to derive from two main sources: segmental composition and word structure. The effect of segmental composition can be seen, for example, in the difference between left-headed and right-headed monosyllables, which have no structural differences: in the former, the coda shows the greatest accentual lengthening effect and in the latter, it is the onset. Similarly, Figure 4.12 may be compared with the results in Section 4.9.1, which have somewhat different data-sets: for left-headed keywords in the larger data-set used in the statistical analysis, the syllable onset shows the greatest degree of lengthening in monosyllables (24ms, 23%), whereas for the smaller data-set used in Figure 4.12 it is lengthened by less than the syllable coda. These differences may be attributed to segmental variation, in particular, the relative expandability of different phonemes.

[35]The mean durations from which Figure 4.12 is derived are taken, for the purposes of comparison, from the same subset of the data for all constituents; thus the proportion of accentual lengthening differs slightly for some constituents from that reported in Section 4.9.1, where the largest available data-set was used for each constituent.

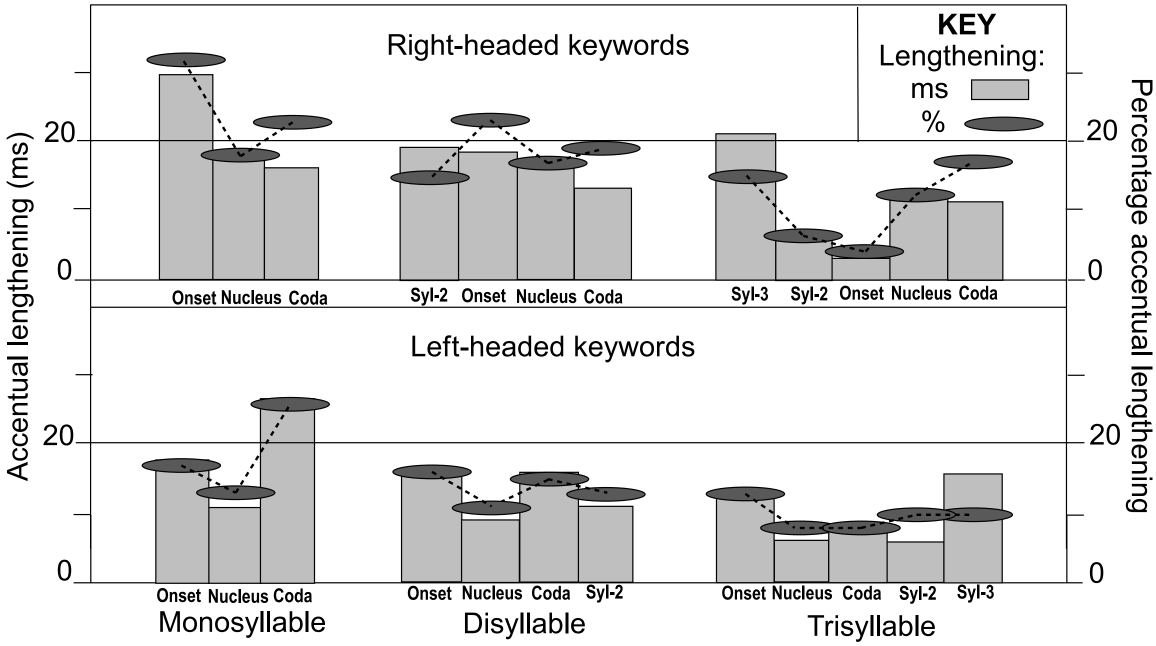

Figure 4.12: The magnitude and proportion of accentual lengthening (ms) for test syllable onset, nucleus and coda, and for syllable-2 and syllable-3 in Series C keywords. All right-headed keywords are included except *port* : data points = 252, missing = 3.6%. Left-headed keywords included are *fish*, *mace*, *sense* and *ten* : data points = 144, missing = 4.9%.

The clearest effect of word structure is the tendency for the most accentual lengthening to be evident at word edges, in both left-headed and right-headed keywords. Thus, in monosyllables the onset and coda show more lengthening than the nucleus. This pattern is also evident in disyllables, but the additional syllable reduces the accentual lengthening of the adjacent constituent by more than lengthening is reduced in the syllable as a whole: in right-headed disyllables, the accentual lengthening of the onset is 12 ms less than in the monosyllable, whereas the differences for nucleus and coda are only 1 ms and 3 ms respectively; in left-headed disyllables, the accentual lengthening of the coda is 11 ms less than in the monosyllable, whereas the onset and nucleus show only 2 ms less lengthening each. In trisyllables, the test syllable constituent on the same side as the additional syllables shows an even more marked reduction in accentual lengthening: in right-headed trisyllables, the accentual lengthening of the onset is 15 ms less than in the disyllable, whereas the differences for nucleus and coda are only 5 ms and 2 ms respectively; in left-headed trisyllables, the accentual lengthening of the coda is 8 ms less than in the disyllable, and the onset and nucleus both show 3 ms reduction in accentual lengthening.

As discussed in Section 4.6.2, the polysyllabic accent hypothesis predicts that durational differences between constituents of monosyllables, disyllables and trisyllables reflect the amount of accentual lengthening that the constituents receive in each context. Thus, according to the pattern in Figure 4.12 just described, right-headed keywords should manifest large polysyllabic shortening effects on the syllable onset and left-headed keywords on the syllable coda. Figure 4.4 in Section 4.6.2 shows word-level shortening effects in Series A[36], where the results for the disyllable vs trisyllable comparison particularly bear out this analysis: in right-headed keywords, the onset shows the greatest polysyllabic accent effect; in left-headed keywords, the coda shows a large effect. The fact that the nucleus shows the greatest polysyllabic accent effect in left-headed keywords may be attributed to the additional influence of word-rhyme-span shortening.

In the monosyllable vs disyllable comparison (see again Figure 4.4 in Section 4.6.2), the pattern of results is complicated by additional factors. For right-headed keywords, the onset does show the greatest word-level shortening effect, but word-initial lengthening clearly plays a large part in this: the effect is significantly greater in the accented condition, however, indicating the polysyllabic accent effect. For left-headed keywords, the difference in the coda is no greater than that in the onset and nucleus, contrary to the predictions based on the amount of accentual lengthening, as shown in Figure 4.12. As discussed in Section 4.6.2, however, both the other constituents may be subject to additional influences: firstly, the word-level shortening of the onset in the left-headed monosyllable vs disyllable comparison shown in Figure 4.4 may reflect an attenuation of word-initial shortening in polysyllabic words; secondly, the word-level shortening of the nucleus in the same comparison is influenced by word-rhyme-span shortening. Thus, processes which were hypothesised largely on the basis of word-level durational variation in unaccented keywords appear to have some corroboration in the pattern of word-level variation in accented keywords, insofar as they can explain why the magnitude of word-span compression for each constituent does not correspond to the predictions based on accentual lengthening.

The evidence thus appears strongly to indicate that the word itself is the locus of accentual lengthening. Possible reasons are discussed in Chapter 5 for differences between these results and those of previous studies which suggest a slightly different picture of the distribution of lengthening within the locus.

4.10 Discussion: the concept of the locus

There are two hypotheses which specifically relate to the concept of the locus.

Domain-edge locus hypothesis: each domain-edge process has a characteristic phonologically-defined locus.

[36]Figure 4.12 above shows accentual lengthening results for the same set of keywords in Series C.

Domain-span locus hypothesis: a domain-span compression process shortens only the phonological head of the domain.

How far the results of Experiment 2 support these hypotheses is discussed now.

4.10.1 Domain-edge processes

Experiment 2 finds evidence for domain-initial processes at the word-level and the phrase-level. Stressed syllable onsets are lengthened word-initially compared to word-medially, an effect which may be greater in monosyllables than in polysyllables. There also appears to be further lengthening word-initially when there is a phrase boundary preceding the word. Utterance-initially, the stressed syllable onset appears not to be subject to any lengthening, although it is also word-initial and phrase-initial: its duration is comparable to that found word-medially, at least when the whole onset is acoustically measurable.

In these cases, significant lengthening is restricted to the stressed syllable onset, strongly suggesting that this is a phonologically-defined locus. If the process was simply the lengthening of the initial part of the word by a certain amount, then the nucleus should also show some lengthening where the onset is intrinsically shorter or less expandable. This is not observed; indeed, the nucleus or coda of the word-initial syllable may be somewhat shorter following a word-initial or phrase-initial consonant: such compensatory effects are discussed further in Chapter 5.

The locus of utterance-final lengthening appears to extend from the final stressed syllable to the utterance boundary, at least where no word boundary intervenes: the absolute-final syllable, whether stressed or unstressed, shows lengthening in both the nucleus and coda; utterance-penultimate and utterance-antepenultimate syllables are only lengthened in the coda. Furthermore, the effect is progressive, with constituents closer to the boundary showing more lengthening. These observations strongly support the concept of a phonologically-defined locus, in this case the word-rhyme, although not all parts of the word-rhyme are affected. If utterance-final lengthening were a result of general deceleration over several syllables, then all constituents following the antepenultimate coda—the earliest to show lengthening—should be lengthened. Where the stressed syllable is in penultimate position, however, only the coda is lengthened: a general deceleration should also affect the onset and nucleus. Likewise in final position, the stressed syllable rhyme is lengthened but the onset is unaffected.

The concept of the locus manifested in these observations is less straightforward than that observed in domain-initial effects, as the description of the locus is not simply a matter of identifying a phonological constituent. Furthermore, it is not sufficient to say that all codas in the word-rhyme are lengthened, as the nucleus is also lengthened absolute-finally.

It is clear that the utterance-final lengthening observed in this experiment has a distinct locus; it may be questioned, however, whether the domain of the effect is actually the utterance. Wightman *et al.* (1992) for English and Cambier-Langeveld (2000) for Dutch find that intonational phrase boundaries and utterance boundaries are not distinguished by the magnitude of final lengthening on the preboundary syllable, a result which could be most simply interpreted by positing just one level of final lengthening, as all utterance boundaries are necessarily also intonational phrase boundaries. There are some problems with the interpretation of the results of Wightman *et al.* (1992), as discussed in Section 4.1.3, so it remains to be seen if the magnitude of final lengthening in English is greater utterance-finally than intonational-phrase-finally.

Whether or not the magnitude of the effect on the final syllable rhyme differs between the two constituents, the locus could distinguish the two domains if it is more extensive utterance-finally. Turk (1999) suggests that a penultimate stressed syllable may be lengthened intonational-phrase-finally, at least when accented, although she does not report which subsyllabic constituents are affected. Cambier-Langeveld (2000) finds no difference in the locus of final lengthening for Dutch between the intonational phrase and the utterance, at least within the final and penultimate syllables. It remains to be seen if the antepenultimate stressed syllable coda is also lengthened intonational-phrase-finally. If this is the case, there appears no reason for proposing two levels of domain-final lengthening, at least at and above the intonational-phrase.

In contrast, it seems clear that the utterance manifests a distinct durational effect at its initial boundary: lower-level boundaries show degrees of lengthening, but all lengthening appears to be absent utterance-initially, despite this boundary necessarily corresponding with the start of intonational and lower-level phrases. As discussed in Section 4.7.2, it may be that this effect is only observed when the utterance is spoken in isolation; where there are successive utterances separated by only short pauses, the need to indicate the onset of a new utterance may mean that an appropriate degree of lengthening of the utterance-initial onset is observed.

4.10.2 Domain-span processes

Two levels of linguistic structure are considered in Experiment 2 as possible domains of span compression processes: the utterance and the word. There is no strong evidence to suggest that the constituents of the utterance are shorter when the utterance contains more syllables; durational variations between utterances of different lengths appear much more likely to be due to timing processes at utterance-medial constituent boundaries. Similarly, most of the durational differences in stressed syllables between monosyllables, disyllables and trisyllables appear to relate either to word-initial lengthening, as discussed above, or to the effects of pitch accent: stressed syllables are longer in accented monosyllables than accented disyllables, and longer in accented disyllables than in accented trisyllables because accentual lengthening is greater in words of fewer syllables. Studies such as Turk & Shattuck-Hufnagel (2000), which find some evidence of polysyllabic shortening in unaccented words, are discussed in Chapter 5.

The observed word-span effect in accented words reflects the clear finding of Experiment 2 that the locus of accentual lengthening is the whole word, with word edges generally subject to more lengthening than word-medial constituents. The total magnitude of accentual lengthening within the whole word is, to a first approximation, similar in monosyllables, disyllables and trisyllables: the trend in most cases is for the total lengthening to be slightly less in longer words, the opposite of what would be expected if all constituents were subjected to a similar proportion of accentual lengthening. Because aggregate accentual lengthening does not increase in longer words, stressed syllable subconstituents show less lengthening in disyllables than in monosyllables, and less again in trisyllables compared with disyllables. This results in the polysyllabic accent effect, an inverse relation between stressed syllable duration and the number of syllables in accented words. This inverse relation does not appear to hold in unaccented words, however, and it is not necessary to postulate a distinct domain-span mechanism to explain the observation, because the facts about the distribution of accentual lengthening, in conjunction with word-initial lengthening and word-rhyme compression, account for the observed durational variation at the word-level.

The only clear evidence for a domain-span process in Experiment 2 is found in left-headed keywords such as *mace*, *mason* and *masonry*: the stressed syllable nucleus /eɪ/ is shorter in words of more syllables even when unaccented; the unstressed syllable /ən/ is similarly shorter in trisyllables than in disyllables, although the subsyllabic distribution of the effect is not reported for unstressed syllables. One explanation for these observations is that there is a domain-span process at the word-rhyme-level: thus, as the length of the word-rhyme increases, the duration of subconstituent duration decreases. The locus of word-rhyme compression appears to be the syllable nucleus in stressed syllables; it may be that the locus is likewise the nucleus in unstressed syllables. There is little evidence that other subsyllabic constituents are affected in stressed syllables.

It is considered in Section 4.1.2 that the locus of a domain-span process might either be the domain itself, with all constituents subject to compression, or the head of the domain. The head of the word-rhyme, if correctly identified as a prosodic constituent, would logically be the stressed syllable or the stressed syllable nucleus. The latter certainly appears to be the locus of word-rhyme compression within the stressed syllable; however, unstressed syllables within the word-rhyme also seems to be subject to word-rhyme compression. If the locus of the effect is the nuclei of all constituent syllables, then the picture somewhat resembles that found for utterance-final lengthening: in both cases, subsets of constituents within the word-rhyme are affected. Utterance-finally, all the codas within the word-rhyme, plus the final nucleus, are lengthened. Word-rhyme compression could likewise be seen as a domain-final effect: according to this interpretation, the stressed syllable nucleus is shorter in a word-rhyme of more syllables because it is further from the final edge of the word. Likewise, unstressed syllables are shorter word-medially than word-finally because of their adjacency in the latter position to the word boundary, rather than because of a direct effect of word-rhyme length. This has some support from Oller (1973) and Wightman *et al.* (1992), who find most lengthening at lower-level boundaries on the stressed syllable nucleus rather than the coda. The word-final lengthening interpretation of word-rhyme compression is discussed further in Chapter 5 and suggestions for resolving the issue are presented in Chapter 6.

There is one other source of evidence for domain-span processes in Experiment 2: the finding of compensatory shortening in syllables in which the onset has been lengthened word-initially or phrase-initially, or the coda has been lengthened utterance-finally. The adjustments in the syllable are in the direction of maintaining constant syllable duration despite the lengthening of the onset or coda, thus one interpretation of the observations could be that there is a domain-span effect at the syllable level. This is discussed in Chapter 5, where alternative explanations is also considered.

4.11 Summary

Word-level processes

The results of Experiment 2 suggest evidence for three durational processes relating to word structure:

Accentual lengthening: all constituents are lengthened in an accented word.

Word-initial lengthening: the primary stressed syllable onset is longer word-initially than word-medially.

Word-rhyme compression: the duration of the primary stressed syllable nucleus is inversely related to the number of syllables in the word-rhyme.

The finding that the word is the locus of accentual lengthening agrees with research such as Sluijter (1995) and Turk & White (1999), although the magnitude of lengthening is distributed slightly differently in Experiment 2: unstressed syllables preceding the primary stress show greater lengthening than previously observed. The magnitude of lengthening on the primary stressed syllable is greatest in monosyllables, less in disyllables and less still in trisyllables. Because there is a trend towards greater accentual lengthening at the initial and final edges of words, the attenuation of accentual lengthening is particularly marked on stressed syllable constituents adjoining the added syllables: the stressed syllable onset in right-headed keywords such as *mend*, *commend* and *recommend*; the stressed syllable coda in left-headed keywords such as *mace*, *mason* and *masonry*.

The polysyllabic accent effect emerges because of this link between word length and the magnitude of accentual lengthening: in accented words only, stressed syllable duration is inversely related to word length. Previous evidence for polysyllabic shortening is presented in research such as Lehiste (1972) and Port (1981), where the presence of a pitch accent on the measured syllable seems highly probable, although Turk & Shattuck-Hufnagel (2000) do find some evidence of polysyllabic shortening in unaccented words.

Word-initial lengthening, which is noted by Oller (1973) and Cooper (1991) among others, does not appear to be dependent upon the presence of pitch accent. There are two other observations made in Experiment 2 effects relating to word-initial lengthening. Firstly, there is evidence that the magnitude of lengthening of the word-initial syllable onset may be greater in monosyllables than in disyllables and trisyllables. Secondly, there may be some compensatory shortening within the rest of the word-initial syllable, although the magnitude of this is not as large as the word-initial lengthening itself. There is also some evidence in Experiment 2 that word-initial onset consonants are further lengthened phonological-phrase-initially, and the remainder of the initial syllable may manifest further compensatory shortening.

Word-rhyme compression has not previously been proposed, although its effect in left-headed disyllables is similar to syllable ratio equalisation, for which Turk & Shattuck-Hufnagel (2000) put forward evidence. It seems likely the combination of the polysyllabic accent effect and word-rhyme compression is sub-additive, because shortening of syllable nucleus duration in left-headed sequences such as *mace*, *mason* and *masonry* is not markedly greater in accented words than in unaccented words. It may be that word-rhyme compression, the only domain-span effect for which evidence is found in Experiment 2, is better understood as word-final lengthening affecting syllable nuclei within a word-rhyme locus.

Experiment 1 in Chapter 3 examines the effect of word length and accent on the duration of initial and final stressed syllables in phrases such as *thank fulfil* and *thankful Phil*. Initial syllables, such as /θaŋk/, are significantly longer in monosyllables than in disyllables, when accented and unaccented; final syllables, such as /fɪl/, as significantly longer in monosyllables than in disyllables only when accented, there being a slight but non-significant difference in unaccented words. These results are broadly compatible with the three word-level processes proposed here. The phrase-initial syllables are subject to both the polysyllabic accent effect and word-rhyme compression, the latter operating both in accented and unaccented words. Phrase-final syllables are subject to the polysyllabic accent effect and word-initial lengthening. Although word-initial lengthening ought to affect the stressed syllable onset in accented and unaccented words—thus causing the /f/ of /fɪl/ to be shorter in *fulfil* than in *Phil*—only full syllable durations are reported and the magnitude of the effect may be masked by variation in the rest of the syllable, particularly if there is a compensatory shortening effect in the nucleus.

Utterance-level processes

Experiment 2 finds evidence for two effects relating to utterance structure:

Utterance-initial shortening: the onset of word-initial primary stressed syllables is shorter utterance-initially than utterance-medially.

Utterance-final lengthening: all codas within the word-rhyme are lengthened utterance-finally; the nucleus is also lengthened in absolute-utterance-final position.

Fourakis & Monahan (1988) and Fougeron & Keating (1997) report utterance-initial shortening in unstressed syllable onsets; here it is observed in stressed syllable onsets, and explained as an absence of any hierarchical initial lengthening effect, because, being preceded by silence, the utterance-initial boundary requires no such cue. According to this interpretation, it would not be correct to describe utterance-initial shortening as a process, but rather as the absence of a process observed at other hierarchical levels.

Many studies, as discussed in Chapter 2, have reported that the greatest final lengthening in intonational phrases or utterances is found on the final syllable rhyme. Cambier-Langeveld (2000) finds that stressed syllables in utterance-penultimate position are lengthened, an effect also suggested by Nakatani *et al.* (1981) and Turk (1999) for intonational phrases. Experiment 2 shows that the coda of a stressed syllable in utterance-penultimate or utterance-antepenultimate position is lengthened, although the trend is for greater lengthening nearer the boundary; both the nucleus and coda of the utterance-final stressed syllable show large amounts of lengthening.

Unstressed syllables in utterance-final position also show a large amount of lengthening relative to utterance-medial position; utterance-penultimate syllables show a small lengthening effect, which indirect evidence suggests may be localised on the syllable coda.

The hypothesis that stressed syllable duration is inversely related to the number of syllables in the utterance, proposed by Jones (1942–43) and Lehiste (1974), is not supported. There is some evidence of utterance-medial phrase-initial lengthening of stressed syllable onsets, but little evidence of utterance-medial phrase-final lengthening below the intonational phrase level.

The results of Experiment 2, and the durational processes they suggest, are discussed further in Chapter 5, particularly where results differ from those of previous studies. An model of English suprasyllabic speech timing incorporating these processes is presented in Chapter 6, and ideas are put forward for research which could resolve some of the outstanding theoretical issues.