A PHONETIC STUDY OF FINAL VOWEL LENGTHENING IN CHICKASAW[1]

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1. Introduction

Phonetic studies of many languages have shown that word-final sounds are usually longer than their word-medial counterparts. This lengthening effect has been shown to be cumulative such that segments in final position of larger prosodic domains are characteristically longer than those in final position of smaller domains. For examples, in their study of English, Wightman et al. (1992) observe a hierarchical lengthening effect such that Intonational Phrase-final vowels are longer than their counterparts in final position of smaller phrases, which in turn are longer than vowels in word-final phrase-medial position. Other languages in which final lengthening has been found at one or more prosodic levels are numerous, including Arabic (de Jong and Zawaydeh 1999), Dutch (Gussenhoven and Rietveld 1992), Finnish (Oller 1979), Greenlandic Eskimo (Nagano-Madsen 1992), Hebrew (Berkovits 1991), Hungarian (Hockey and Fagyal 1999), Italian (van Santen and D'Imperio 1999), and Spanish (Oller 1979).

This paper examines phonetic aspects of final lengthening in Chickasaw, a language that is genetically and prosodically different from languages in which final lengthening has been studied. Previous studies focused on final lengthening have been largely limited to languages spoken in Europe and Asia with few devoted to indigenous languages of the Americas. Furthermore, Chickasaw differs from other languages in which final lengthening has been studied in possessing an iambic stress system featuring the phenomenon of iambic vowel lengthening (described in the literature as "rhythmic lengthening"). For example, in Chickasaw (Munro and Ulrich 1984, Munro and Willmond 1994, 2005, Munro

1996, 2005), the phonemic short vowels in the second and the fourth syllables in the words /asabikatok/ 'I was sick' and /tʃipisalitok/ 'I looked at you' substantially lengthen (indicated by an IPA half-length mark) since they occur in metrically strong positions, i.e. as the head of iambic feet: /asabikatok/ → (asáˑ)(bikáˑ)(tók) and /t͡ʃipisalitok/ → (t͡ʃipíˑ)(sali ˑ)(tók). Vowels do not lengthen in closed syllables, as observed in the Chickasaw form (tók)(saláʔ)(páʔ) 'lizard', where lengthening is suppressed in the metrically strong first, third and fourth syllables, all of which are closed.

The examination of final lengthening in a prototypical iambic stress language like Chickasaw with iambic lengthening is important for several reasons. First, the study of final lengthening in an iambic stress language expands the set of prosodic systems in which final duration has been explored. Final lengthening has been identified in tone languages such as Taiwanese (Peng 1997), Mandarin (Ho 1977, Duanmu 1996) and Yoruba (Nagano-Madsen 1992), languages with a single prominent syllable per word, such as Greenlandic Eskimo (Nagano-Madsen 1992), French (Fletcher 1991, Smith 2002), and languages with trochaic stress patterns, such as English (Klatt 1975, Umeda 1975, Wightman et al. 1992), and Hungarian (Hockey and Fagyal 1999). Johnson and Martin (2001) also find a final lengthening effect in Creek, which has a prominence system that is sensitive to an iambic parse (Haas 1977, Martin and Johnson 2002), but which is pitch-accentual rather than stress-based and lacks iambic lengthening. It thus still remains to be determined whether final lengthening is also found in prototypical iambic stress systems like the one in Chickasaw.

A second point of interest in studying final duration patterns in Chickasaw is the potential for interaction between final lengthening and iambic lengthening. As Hayes (1995) and Buckley (1998) observe, lengthening is reported to be suppressed in word-final strong open syllables. Thus, in the Chickasaw forms (asá·)(biká) 'I am sick' and (pisá) 'He sees it', the final vowels fail to undergo lengthening despite their occurrence in metrically strong positions. The failure of iambic lengthening to apply word-finally is striking since final position is otherwise cross-linguistically prone to lengthening. If phonetic data confirms the impressionistic observations of researchers, the absence of iambic lengthening in final position would constitute an exception to a nearly universal pattern.

Investigation of final vowels also has implications for metrical stress theory. If final vowels do not lengthen, this means that final position would be the only context in which stressed syllables may be light (CV). Furthermore, the blocking of iambic lengthening in final position would mean that the inventory of feet must be expanded to include CVCV feet, an otherwise unattested type of foot in Chickasaw.

Finally, examination of final vowel duration is interesting in a language like Chickasaw, which contrasts phonemic short and long vowels in both final and non-final positions. If final lengthening asymmetrically affects shorts but not long vowels, it would have the potential to obscure a phonemic contrast in vowel length.

The present paper investigates the duration of vowels in final position of different prosodic constituents in Chickasaw. Word-medial vowels, both phonemic short and phonemic long ones, are examined in final position of three progressively larger domains: word-final position that is phrase- and utterance-medial, phrase-final position that is utterance-medial, and utterance-final position. Drawing on these results, we offer possible explanations for the phonetic length patterns in final position and examine their relationship to the Chickasaw prosodic system and the prosodic systems of other iambic stress languages.

2. Chickasaw prosody: an introduction

2.1. Stress and metrical structure

Basic to an understanding of the interaction between final lengthening and iambic lengthening is the issue of stress placement and metrical structure in Chickasaw[2] (see Munro and Ulrich 1984, Munro 1996, Munro and Willmond 2005, Gordon 2003, 2004, 2005). Stress in Chickasaw is associated with a combination of higher fundamental frequency and increased duration and intensity depending on the speaker (Gordon 2004). In addition, unstressed vowels are centralized relative to their secondary and primary stressed counterparts.

Chickasaw words display a basic binary stress pattern whereby alternating syllables are stressed counting from the left edge of the word. The alternating stress count is interrupted by heavy syllables, i.e. closed syllables (CVC) and those containing a long vowel (CVV[3]), all of which are stressed. All non-final stressed syllables in Chickasaw are heavy on the surface, either because they are intrinsically heavy (CVC or CVV) or because they are made heavy through a process of vowel lengthening targetting the second vowel in a sequence of non-final CV syllables (Munro and Ulrich 1984, Munro and Willmond 1994, 2005, Munro 1996, 2005). Chickasaw stress and length patterns fit the profile of an iambic stress system in which syllables are parsed into either light-heavy disyllabic feet or monosyllabic feet consisting of a single heavy syllable. The iambic parse is illustrated in the forms in (1) while the words in (2) demonstrate iambic lengthening (indicated by a half-length IPA symbol). Note that primary and secondary stress are not distinguished pending discussion of stress levels in the next section.

(1)

(ís)(sobá)	‘horse’
(abóː)(koʃíʔ)	‘river’
(báː)(tám)(bíʔ)	Chickasaw name
(tʃalák)(kíʔ)	‘Cherokee’
(ók)(fók)(kól)	‘type of snail’

(2)

(tʃitʃóˑ)(kóʃ)(komóˑ)(tʃi)	‘He makes you play’
cf. (tʃokóʃ)(komóˑ)(tók)	‘He played’
(saháˑ)(ʃáː)	‘I am angry’
cf. (haʃáː)	‘He is angry’
(tʃikíˑ)(silíˑ)(tók)	‘He bit you’
cf. (kisíˑ)(litók)	‘He bit it’

(asáˑ)(bikáˑ)(tók) 'I was sick'

cf. (abíˑ)(katók) 'He was sick'

Two phonological restrictions hold of iambic lengthening.[4] It fails to apply to vowels in closed syllables, e.g. (tʃokóʃ)(komo) 'He plays' *(tʃokóˑʃ)(komó), and it is reported not to affect word-final vowels, e.g. (asáˑ)(biká) 'I am sick' *(asáˑ)(bikáˑ). It may be noted that the blocking of iambic lengthening in final syllables does not reflect a general ban on word-final long vowels, as vowel length is contrastive in both final and non-final syllables. Thus, the absence of iambic lengthening word-finally cannot be attributed to an independent ban on word-final length unlike in certain other languages (see section 5.1). Examples of phonemic length contrasts for the three vowels of Chickasaw /a, i, o/ appear in (3).[5]

(3)

Short		Long	
fal**a**	'crow'	fal**aː**	'It is long'
s**a**ɬkona	'intestines'	s**aː**ɬkona	'earthworm'
olː**a**li	'He laughs'	tal**aː**li	'He sets it upright'
tanamp**o**	'gun'	iʃhop**oː**	'You are jealous of him'
k**o**la	'It is dug'	k**oː**li	'He breaks it'
hakl**o**li	'I listen'	tʃĩːl**oː**loʔ	'your doodlebug'
t**i**kahbi	'He is tired'	t**iː**kãːʔtiʔ	'dirt dauber (wasp)'
mint**i**	'He approaches'	int**iː**	'his tea'
pihl**i**li	'I sweep'	tʃĩːl**iː**li	'He hoes for you'

Spectrograms of a word pair (uttered in isolation) contrasting in the length of both vowels, *wakaː* 'fly (verb)' vs. *waːka* 'be spotted', appear in figure 1. Phonetically, the long vowels are roughly twice as long as their short counterparts in identical positions, while both short and long vowels are longer word-finally than non-finally. Both final short and final long vowels end with a breathy phase. Lengthening and breathiness are characteristic of utterance-final vowels, both short and long, and will be discussed further in section 4.

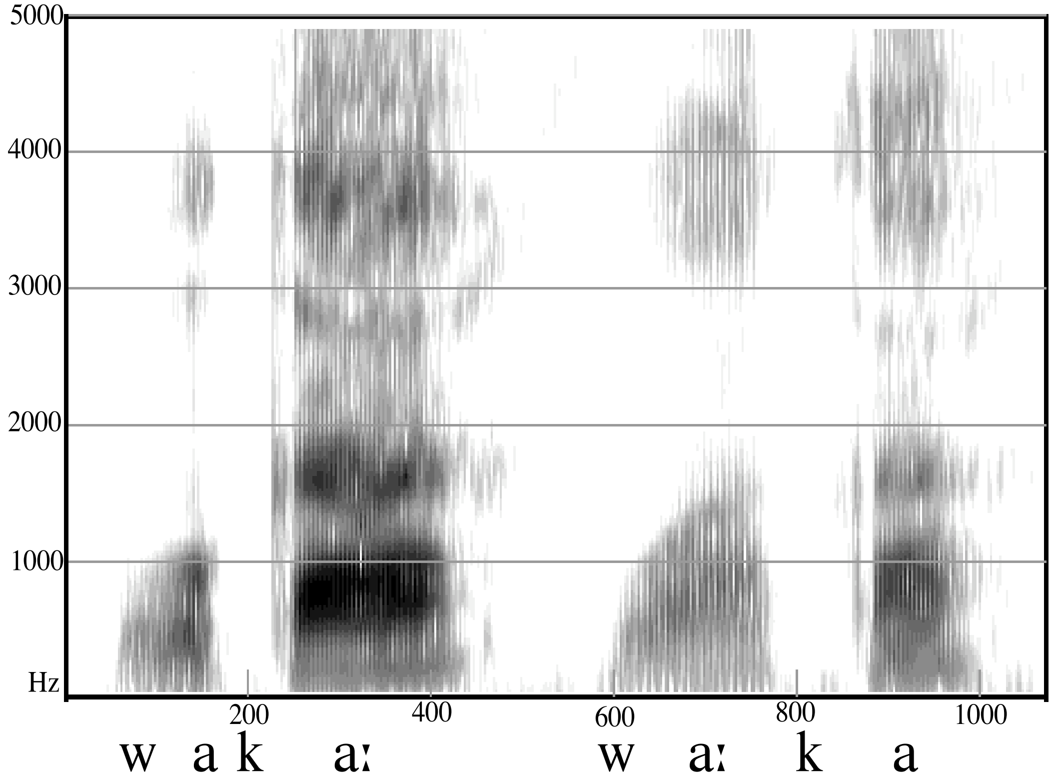

Fig. 1.--Chickasaw words illustrating the phonemic contrast in vowel length (female speaker)

2.2. Phrase-final vs. phrase-medial stress

It is important to draw a distinction between stress patterns found in phrase-final words and those found in phrase-medial words. Phrase-medially, a long vowel, whether phonemically long or long due to iambic lengthening, has primary stress. In phrase-medial words with multiple long vowels, there is interspeaker variation in whether the rightmost or the leftmost long vowel carries primary stress (see Gordon 2004). This variation will not be central to the present paper since words of this type will not be examined. In all phrase-final words and phrase-medial words lacking long vowels, primary stress falls on the final syllable. Like non-final stress, final stress is associated with not only higher fundamental frequency but also increased duration and intensity, indicating that final prominence is attributed to stress rather than a boundary tone. Furthermore, the actual fundamental frequency peak is often centered to the left of the right edge of the final vowel rather than at the right edge as one would expect if final prominence were merely attributed to a boundary tone (see Gordon 2003 for further discussion of this issue).

Given the attraction of primary stress by non-final long vowels in phrase-medial words, it is evident that Chickasaw treats syllables containing a long vowel (either a phonemic long vowel or an iambically lengthened one) as “heavier” than syllables containing a short vowel. This weight distinction exists in addition to the one seen earlier according to which both CVV and CVC attract at least secondary stress in the metrical parse of both phrase-medial and phrase-final words.

Despite the uniformity of foot structure between phrase-medial and phrase-final words, the distinction between these two contexts in the location of primary stress means that a word containing a non-final long vowel has primary stress on different syllables depending on the context in which the word appears. These shifts in stress are associated with measurable differences in fundamental frequency, duration, and intensity between the two contexts (see Gordon 2003 for phonetic results). In contrast, words either without long vowels or with a word-final long vowel have uniform stress patterns across contexts. Sample metrical parses of phrase-medial and phrase-final words of different shapes appear in (4) using grid-based representations of stress (Hayes 1995). In these representations, each grid mark dominating a syllable signifies a greater degree of stress. (Note that phonemic geminate consonants are represented as two consonants in order to clarify syllabification patterns in the metrical parse.)

(4)

	/saːɬkona/ ‘worm’	/notakfa/ ‘jaw’	/bakʃijaˑma/ ‘diaper’
Phrase-medial	(**x**)	(x)	(**x**)
	(x)(x)	(x)(x)	(x)(x)(x)
	ˈsaːɬ koˌna	noˌtak ˈfa	ˌbakʃiˈjaˑma
Phrase-final	(**x**)	(x)	(**x**)
	(x)(x)	(x)(x)	(x)(x)(x)
	ˌsaːɬ koˈna	no ˌtak ˈfa	ˌbak ʃiˈjaˑma

	/itti͡ʔt͡ʃanaː/ ‘wagon’	/hat͡ʃimihoː/ ‘your (pl) wives’
Phrase-medial	(x)	(x)
	(x)(x)(x)	(x)(x)
	ˌit tiʔ ˌt͡ʃaˈnaː	haˌt͡ʃimiˈhoː
Phrase-final	(x)	(x)
	(x)(x)(x)	(x)(x)
	ˌit tiʔ ˌt͡ʃaˈnaː	haˌt͡ʃimiˈhoː

	/t͡ʃoɬkan/ 'spider'
Phrase-medial	(x)
	(x)(x)
	ˌt͡ʃoɬ ˈkan
Phrase-final	(x)
	(x)(x)
	ˌt͡ʃoɬ ˈkan

The words /saːɬkona/ and /bakʃijaˑma/ show a shift in primary stress from a non-final long vowel in phrase-medial position to the final syllable in phrase-final contexts. The words /notakfa/, /ittiʔt͡ʃanaː/, /hat͡ʃimihoː/, and /t͡ʃoɬkan/ have the same stress patterns in both contexts.

In considering the words /notakfa/ 'jaw' and /bakʃijaˑma/ 'diaper' in (4), it is worth noting that the CV final syllable in these words, if truly unlengthened, would be considered a degenerate, or subminimal, monosyllabic foot (Hayes 1995). If final vowels did, however, lengthen, this would bring final monosyllabic feet into line with other monosyllabic feet, which are all heavy word-internally. There are several examples of monosyllabic feet consisting of a heavy syllable in (1): the first syllable in (saːɬ)(kona) 'worm', (bak)(ʃijaˑ)(ma) 'diaper', the first two syllables in (it)(tiʔ)(t͡ʃanaː) 'wagon', and both syllables in (t͡ʃoɬ)(kan) 'spider'.

In section 5.1, we return to the issue of degenerate feet in the context of the duration results for final vowels.

3. The present study

3.1. Methodology

A list of Chickasaw words was compiled for the purposes of examining length patterns for word-final vowels. Both nouns and verbs were included in the list; tests revealed no significant duration between nouns and verbs in their duration patterns for final vowels. Virtually all words, with a few exceptions, were trisyllabic in order to minimize possible effects of syllable count on segment duration. All of the target vowels, both word-final and word-medial, appeared in open syllables.

The words and the context in which the target words appeared differed along several dimensions. Representative examples from the corpus follow the discussion in table 1. First, words differed in whether the final vowel was a phonemic short or long vowel. Second, the final vowel was varied such that all three phonemic vowel qualities in Chickasaw /a, i, o/ were represented. Third, words ending in a short vowel differed in whether the final syllable was immediately preceded by an unstressed syllable, i.e. formed a disyllabic foot together with the preceding syllable, or whether the final syllable was immediately preceded by a stressed syllable, i.e. constituted a monosyllabic foot.

Finally, words appeared in three contexts. In one context, words appeared in medial (i.e. non-final) position of a phrase. This phrase-medial context consisted of the target word followed by a verb, which in most cases was *pisa·tok*

‘He saw/looked at it’. The target words in this case were nouns functioning as direct objects of the immediately following verb. Verbs were not used as phrase-medial targets due to the standard SOV sentential word order of Chickasaw. Prosodically, the target word and the following verb in the phrase-medial context were uttered under a single intonation contour characteristic of an Intonational Phrase (see Gordon 2005 for discussion of Chickasaw intonation). The target word in this case was thus not associated with any terminal f0 contours.

The second context in which target words appeared was immediately before a clause boundary followed by the word *tʃimaːʃli* ‘I say to you’. We term this position “phrase-final” since it is intermediate between the other two contexts in the level of disjuncture between the target word and the following frame word.

The last context in which the words appeared was utterance-final preceded by a frame word, which was either *himmakoʔsãː* [6] ‘now’ or *jammakoːt* ‘that’. Both nouns and verbs appeared in phrase-final and utterance-final position. Prosodically, the utterance-final target words were associated with the terminal f0 contours of a statement Intonational Phrase, an f0 peak occurring near the right edge of the Intonational Phrase. In addition, the degree of finality, as reflected in the durational characteristics and voice quality of the target vowel (see the results in sections 4.2 and 4.3), was greater for utterance-final vowels than for either phrase-final or phrase-medial ones.

In addition to the final vowels, word-medial phonemic short vowels (both lengthened and unlengthened) and phomemic long vowels, all in open syllables, were included in another set of target words (also three syllables long) functioning as controls for comparing word-medial and word-final vowel duration. The medial vowels were examined in phrase-internal words, where they received primary stress when lengthened and were unstressed when not lengthened.

TABLE 1

Examples of examined words in different contexts (target vowel in bold; stress marked for target word)

Word-medial	Disyllabic foot	Degenerate foot
Stressed	noˈn**a**ˑt͡ʃi ‘He bakes it’	----
Unstressed	holˈb**a**t͡ʃi ‘He takes a picture of it’	----
Word-final (all stressed)		
Phrase-medial	t͡ʃiˈpoˑˌt**a** pisatok ‘He looked at the child’	ˈjaːɬiˌp**a** pisatok ‘He looked at the hat’
Phrase-final	t͡ʃiˌpoˑˈt**a** t͡ʃimaːʃli ‘I say to you “child”’	ˌjaːɬiˈp**a** t͡ʃimaːʃli ‘I say to you “hat”’
Utterance-final	jammakoːt t͡ʃiˌpoˑˈt**a** ‘That’s a child’	jammakoːt ˌjaːɬiˈp**a** ‘That’s a hat’

Data were recorded from six speakers, four female speakers and two male speakers, all of whom were over 60 years old. Recordings were made with a unidirectional microphone connected to a Macintosh laptop computer using Sound Studio (GW Instruments; gwinst.com). Vowel duration measurements were made using Praat (www.praat.org) from a waveform used in conjunction with a wideband spectrogram. The onset and offset of the second format were used as the beginning and end points, respectively, of the duration measurements. Many phrase- and utterance-final vowels, and, sporadically, some word-final ones in phrase-medial position, were associated with a breathy offset. This breathy phase, as determined from visual inspection of the wideband spectrogram and waveform, was measured separately from the modally phonated portion of the vowel and is discussed in the results section of the paper.

4. Results

4.1. Word-final vs. word-medial durations

As a first step, duration results were pooled for word-final vowels across the three examined contexts and compared with their word-medial counterparts.[7] Duration results as a function of position and stress averaged across the six speakers are shown graphically in figure 2 followed by numerical results for individual speakers in table 2. Data is presented for both stressed and unstressed short vowels in word-medial syllables and for long vowels in medial syllables on the left side of the figure. On the right side, results for final vowels are shown collapsing the three word-final contexts. Results for these three environments are separated later in section 4.2. Results are presented for final long vowels, as well as for two types of short vowels: short vowels belonging to the second syllable of a canonical disyllabic foot and those forming a (potentially) monosyllabic light foot. Recall from section 2.1 that all final vowels are stressed in Chickasaw, whether short or long.

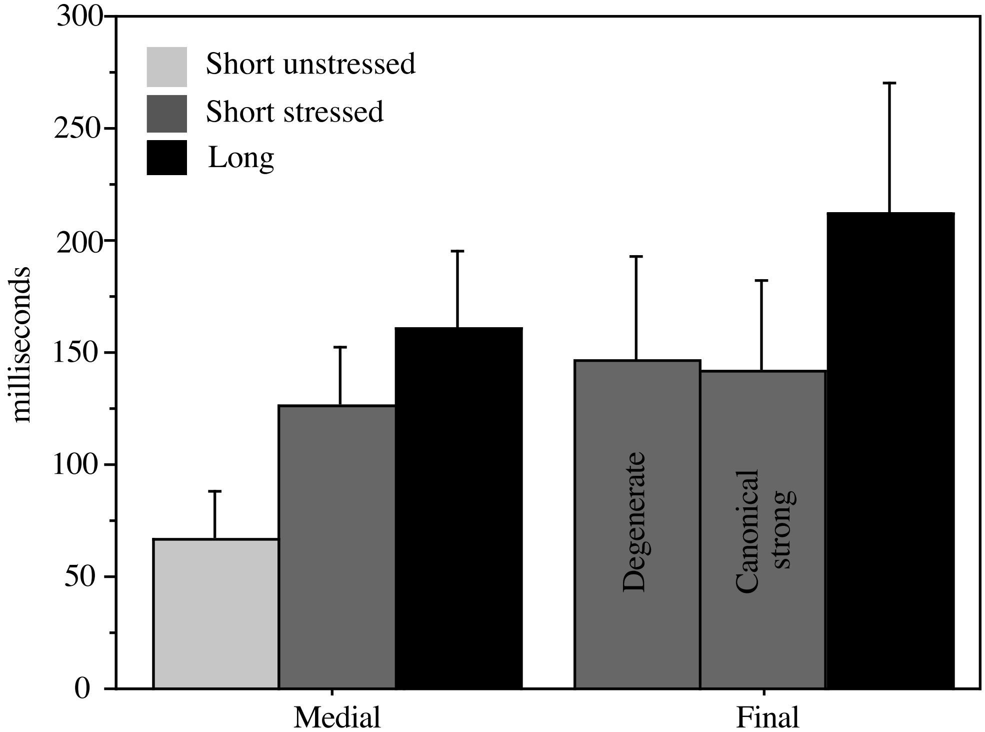

Fig. 2.--Duration (in milliseconds) of word-medial and word-final vowels in different metrical positions (averaged over 6 speakers). Whiskers represent standard deviations

TABLE 2

Duration (in milliseconds) of word-medial and word-final vowels in different metrical positions (averaged across prosodic contexts) for individual speakers

	Medial			Final		
	Short		Long	Short		Long
	Stressed	Unstressed	Stressed	Canonical	Degenerate	Stressed
F1	115	53	175	127	130	219
F2	110	68	127	101	109	157
F3	157	74	183	176	172	267
F4	129	68	193	169	180	226
M1	115	70	149	141	138	210
M2	135	60	142	139	144	198
Mean	**126**	**67**	**161**	**141**	**145**	**212**

A number of differences in vowel duration are evident in figure 2. First, in word-medial syllables, there is a tripartite phonetic duration distinction between phonemic short unstressed, phonemic short stressed (and accordingly lengthened), and phonemic long vowels. Phonemic long vowels are longest (161 milliseconds averaged across speakers), phonemic short unstressed vowels are shortest (67 milliseconds), and phonemic short stressed vowels are intermediate in duration (126 milliseconds). Pairwise t-tests indicated that all three categories of vowels were distinct from each other in word-medial position: short unstressed vs. short stressed ($t(df = 354) = 23.846$, $p<.0001$); short unstressed vs. long ($t(df = 395) = 32.083$, $p<.0001$); short stressed vs. long ($t(df = 405) = 11.379$, $p<.0001$). All speakers, with the exception of speaker M2, differentiate the three types of vowels phonetically. This finding of three phonetic lengths subject to interspeaker variation in the robustness of the distinction is consistent with the results reported for word-medial vowels in Gordon et al. (2000).[8]

In word-final position, long vowels (212 milliseconds averaged across speakers) are still substantially longer than short vowels, both short vowels in disyllabic feet (141 milliseconds) and those in monosyllabic feet (145 milliseconds): long vowels vs. short vowels in disyllabic feet, $t(df = 1044) = 22.241$, $p<.0001$); long vowels vs. short vowels in monosyllabic feet, $t(df=1107) = 19.364$, $p<.0001$). This pattern is observed for all speakers. For all speakers, the two types of short vowels in final position have virtually identical duration values:

averaged across speakers, 141 milliseconds for those in disyllabic feet versus 145 milliseconds for those in monosyllabic feet. This result argues against the view that differences in foot structure are durationally manifested in stressed vowels. We discuss this finding further in section 5.1.

Turning to the comparison of medial and final vowels, there was a significant final lengthening effect averaged across short and long vowels: 155 milliseconds averaged across speakers for final vowels vs. 122 milliseconds for non-final vowels ($t(df = 2435) = 13.055$, $p<.0001$. Trivially, the difference between unstressed short vowels (all of which are medial) and stressed final vowels was highly significant for all speakers: $t(df=1730)=22.297$, $p<.0001$. The difference between medial and final long vowels was also statistically robust across speakers: $t(df=520) = 11.646$, $p<.0001$.

Comparison of the medial and final stressed short vowels (averaging those in disyllabic and those in monosyllabic feet) indicated that final short vowels are longer (143 milliseconds averaged across speakers) than their medial counterparts (126 milliseconds): $t\ (df=1740)=5.075$, $p<.0001$. This result was not consistent across all speakers, though it held for the majority. It robustly obtained for speakers F1 (129 milliseconds for final vowels vs. 115 milliseconds for non-final vowels), F3 (174 milliseconds vs. 157 milliseconds), F4 (175 milliseconds vs. 129 milliseconds), and speaker M1 (140 milliseconds vs. 115 milliseconds), but not for speakers F2 (105 milliseconds vs. 110 milliseconds) or M2 (142 milliseconds vs. 135 milliseconds). Nevertheless, the overall result would appear to suggest that final position combined with stress exerts a stronger lengthening effect than stress alone at least for many speakers. As it turns out, however, this result is misleading since final vowels differed significantly in length as a function of the domain in which they appeared in final position. This finding is discussed further in the next section.

4.2. Duration by prosodic domain

There were substantial differences in the duration of final vowels as a function of the level of the prosodic domain they ended. First we consider phonemic short vowels. Results for final vowels belonging to disyllabic feet and those in monosyllabic feet will be henceforth collapsed since they did not differ from each other (see discussion in section 4.1). Figure 3 compares word-final, phrase-final, and utterance-final short vowels averaged across speakers. Word-medial stressed vowels are also shown for the sake of comparison. Results for individual speakers are given in table 3.

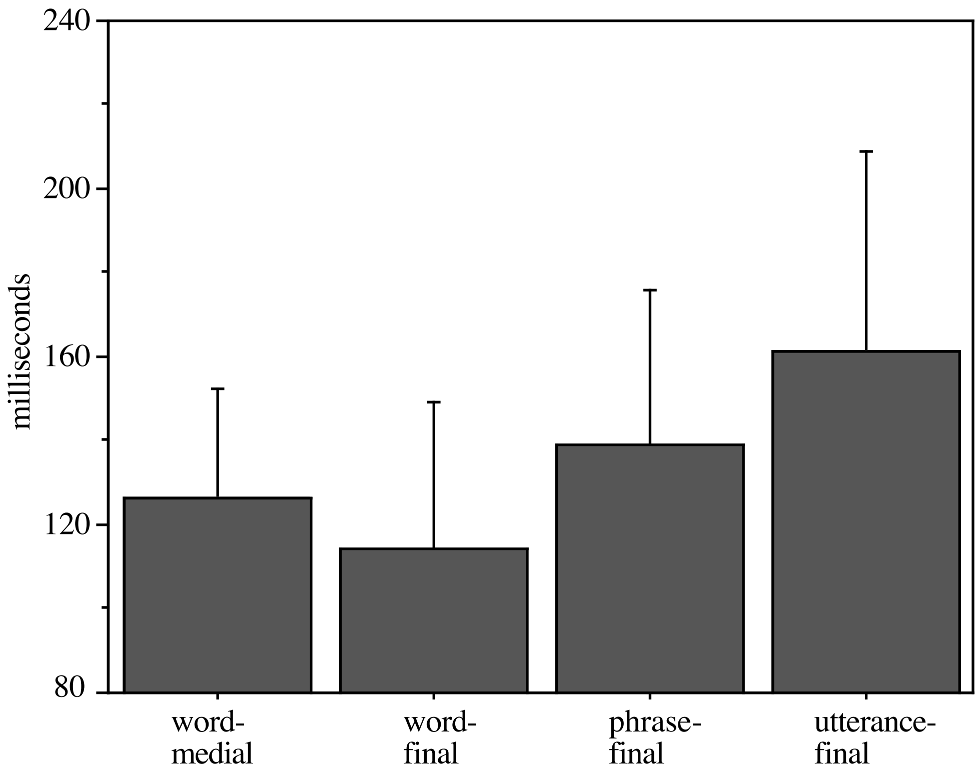

Fig. 3.--Duration (in milliseconds) of word-medial vs. final short vowels at different prosodic levels (averaged over 6 speakers)

TABLE 3

Stressed short vowels in word-medial position compared to final position at three different prosodic levels

	Word-medial	Word-final	Phrase-final	Utterance-final
F1	115	100	132	138
F2	110	91	106	112
F3	157	142	186	177
F4	129	143	158	206
M1	115	115	124	166
M2	135	90	135	170
Mean	**126**	**114**	**139**	**161**

As figure 3 shows, final vowel duration follows a continuum with word-final vowels that are phrase-medial being slightly shorter than phrase-final vowels, which in turn, are slightly shorter than utterance-final vowels. All pairwise differences involving final vowels were statistically significant in t-tests: word-final vs. phrase-final, $t(df{=}925) = 9.812$, $p<.0001$; word-final vs. utterance-final, $t(df{=}917) = 14.981$, $p<.0001$; phrase-final vs. utterance-final, $t(df{=}1270)=9.215$, $p<.0001$.

Interestingly, only phrase-final and utterance-final vowels but not word-final vowels were longer than word-medial stressed vowels: phrase-final vs. word-medial, $t(df{=}821) = 4.444$, $p<.0001$; utterance-final vs. word-medial, $t(df{=}813)=9.465$, $p<.0001$. Word-medial stressed vowels were in fact slightly longer (by 12 milliseconds averaged over the six speakers) than word-final stressed vowels, a difference that nevertheless reached significance: $t(df{=}468) = 4.083$, $p<.0001$.

Results for individual speakers largely follow the same pattern. Virtually all speakers display the same length continuum whereby utterance-final vowels are longer than phrase-final vowels, which in turn, are longer than word-final vowels. The only exception to this pattern is speaker F3 for whom phrase-final vowels are slightly longer than utterance-final vowels. It may also be noted that the difference between phrase-final and utterance-final vowels is relatively small for speakers F1 and F2. Speaker F2 is also noteworthy for not distinguishing word-medial vowels from either phrase-final or utterance-final vowels durationally, though her word-medial vowels were longer than her word-final ones in keeping with the dominant pattern. Four of the six speakers had longer word-medial than word-final vowels, F4 and M1 being exceptional in this regard. F4 actually reverses the dominant pattern and has longer word-final vowels than word-medial vowels.

Long vowels display the same three-way continuum in length in final position: word-final vowels are shortest, followed by phrase-final ones, and then utterance-final ones (see figure 4). All of these differences reached statistically significance according to t-tests, though it may be noted that the difference between phrase-final and utterance-final long vowels is numerically smaller and statistically less robust than the other pairwise comparisons: word-final vs. phrase-final, t(*df*=169) = 4.076, p<.0001; word-final vs. utterance-final, t(*df*=165) = 7.240, p<.0001; phrase-final vs. utterance-final, t(*df*=256)=2.823, p=.0051.

In contrast with the short vowels, word-medial and word-final long vowels are not reliably different from each other as the small difference in average values between the two positions across speakers indicates: 166 milliseconds vs. 161 milliseconds. Word-medial long vowels were shorter than both phrase-final and utterance-final long vowels: word-medial vs. phrase-final, t(*df*=353) = 9.433, p<.0001; word-medial vs. utterance-final, t(*df*=349) = 15.298, p<.0001.

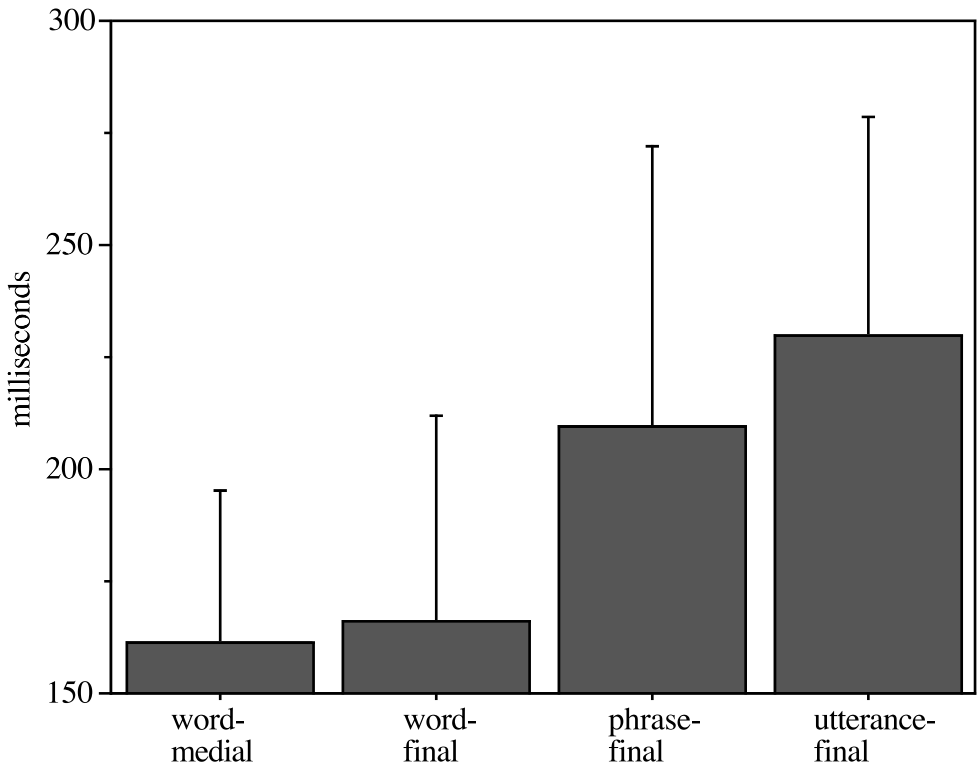

Fig. 4.--Duration of word-medial vs. final long vowels at different prosodic levels (averaged over 6 speakers)

Table 4 shows results for individual speakers for the long vowels.

TABLE 4

The duration of stressed long vowels in word-medial position compared to final position in different prosodic contexts

	Word-medial	Word-final	Phrase-final	Utterance-final
F1	175	151	250	205
F2	127	133	148	175
F3	183	247	277	262
F4	193	188	191	271
M1	149	165	191	243
M2	142	151	170	248
Mean	**161**	**166**	**210**	**229**

Results are fairly consistent across speakers though some differences are apparent. The biggest source of interspeaker difference concerns the relative length of word-medial and word-final long vowels. Speaker F1 has longer word-medial than word-final long vowels, while speakers F3 and F4 (and to a lesser extent M2) have longer word-final than word-medial long vowels. Speakers F2 and F4 have virtually identical values for word-medial and word-final long vowels. The continuum of vowel length as a function of prosodic level is more consistent. Three speakers (F2, M1, M2) make a clear tripartite distinction, while speaker F4 makes a two-way difference, word- and phrase-final vowels being shorter than utterance-final ones. Speakers F1 and F3, interestingly, show a reversal between phrase-final and utterance-final long vowels such that phrase-final vowels are longer than utterance-final ones with word-final vowels being shorter than both. Figure 5 compares the duration of the stressed short and long vowels in the four measured contexts.

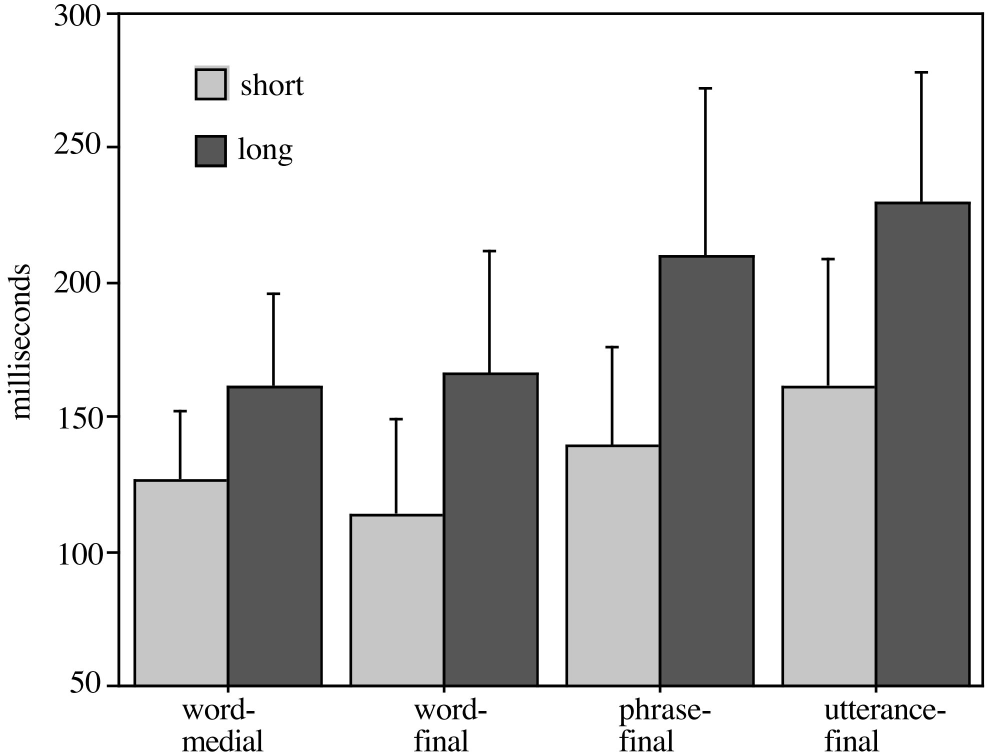

Fig. 5.--Duration of short and long vowels at different prosodic levels (averaged over 6 speakers)

It is clear from the figure that short and long vowels are distinguished in all positions. Results for individual speakers in table 5 show that all speakers distinguish short and long vowels in all four contexts.

TABLE 5

The duration of stressed short and long vowels in different prosodic contexts

	Word-medial		Word-final		Phrase-final		Utterance-final	
F1	115	175	100	151	132	250	138	205
F2	110	127	91	133	106	148	112	175
F3	157	183	142	247	186	277	177	262
F4	129	193	143	188	158	191	206	271
M1	115	149	115	165	124	191	166	243

M2	135	142	90	151	135	170	170	248
Mean	**126**	**161**	**114**	**166**	**139**	**210**	**161**	**229**

Nevertheless, it is interesting to note that phonemic short vowels in utterance-final position are as long as word-medial and word-final long vowels for most speakers. This means that phonemic length contrasts are phonetically relativized to the position in which they are realized.

4.3 Final breathiness

Not only do final vowels differ in their durational characteristics, they also differ in their voice quality. Unlike medial vowels, vowels in final position often ended in a breathy voiced phase, characterized by decreased amplitude and noise. The breathy voicing often culminated in complete devoicing. The duration of the breathy phrase relative to the modal phase differed substantially as a function of domain size, with more breathiness found in final position of larger domains. The presence of breathiness at the end of domain final vowels in Chickasaw is consistent with results from other languages, e.g. Lehiste 1979 and Kreiman 1982 on English, Smith 2002 on French, Myers in press on Kinyarwanda, Myers and Hansen to appear on Finnish.

In the examined data, each vowel was separated into a modal voiced phase and a breathy/devoiced phase. The point at which noise was evident in the waveform and the spectrogram was taken as the demarcation point between these phases. Figure 6 shows the percentage of phonemic short vowels associated with breathiness and devoicing in final position. Since word-medial vowels were never breathy, they are excluded from the figure. Furthermore, results for final vowels in monosyllabic feet and those in disyllabic feet are collapsed since they did not differ from each other in degree of breathiness.

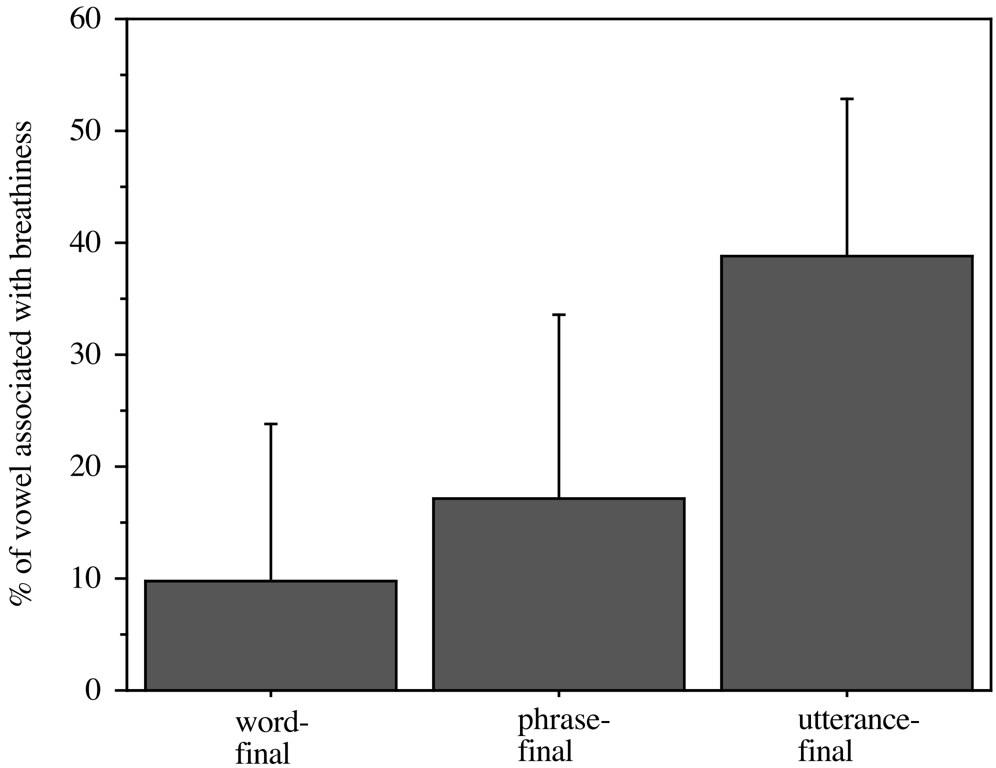

Fig. 6.--Percentage of breathiness/devoicing as a function of the total duration of final short vowels at different prosodic levels (averaged over 6 speakers)

As figure 6 shows, the amount of breathiness relative to the total vowel duration varies along a continuum with the proportionally longest breathiness found in utterance-final vowels, followed by progressively less breathiness in phrase-final and then word-final vowels. All three positions were distinct from each other in their degree of breathiness according to t-tests: word-final vs. phrase-final, t(*df*=925) = 6.674, p<.0001; word-final vs. utterance-final, t(*df*=917) = 28.639, p<.0001; phrase-final vs. utterance-final, t(*df*=1270)=24.917, p<.0001.

Results for individual speakers largely follow the overall pattern, as table 6 shows, though not all speakers distinguish all three levels. Speakers F1, F2, and M2 show a three-way continuum, while speakers F3 and F4 distinguish two of the three levels in the expected direction. For speaker F4, word-final and phrase-final vowels have similar amounts of breathiness, while speaker F3 has similar values for phrase-final and utterance-final vowels. Curiously, for speaker M1, breathiness spans proportionally more of word-final vowels than phrase-final ones, though vowels at both levels have less breathiness than utterance-final vowels.

TABLE 6

The percentage of breathiness/devoicing relative to the entire vowel duration for final short vowels at three different prosodic levels

	Word		Phrase		Utterance	
	Total	% Breathy	Total	% Breathy	Total	% Breathy
F1	100	22.27	132	26.71	138	35.71
F2	91	2.17	106	10.49	112	33.74
F3	142	9.06	186	26.09	177	24.66
F4	143	5.23	158	3.56	206	48.05
M1	115	15.42	124	6.70	166	40.52
M2	90	3.02	135	33.60	170	50.98
Mean	**114**	**9.71**	**139**	**17.20**	**161**	**38.71**

Turning to breathiness in final long vowels, there is only a two way distinction averaged over all six speakers. Both word-final and phrase-final long vowels have proportionally less of their total durations associated with breathiness than utterance-final long vowels: word-final vs. utterance-final, t(*df*=165) = 9.876, p<.0001; phrase-final vs. utterance-final, t(*df*=256)=18.158, p<.0001. Comparing figures 6 and 7, short and long vowels display similar amounts of devoicing relative to total vowel duration, although the duration of devoicing relative to the total vowel duration for long vowels is somewhat less than for their short counterparts.

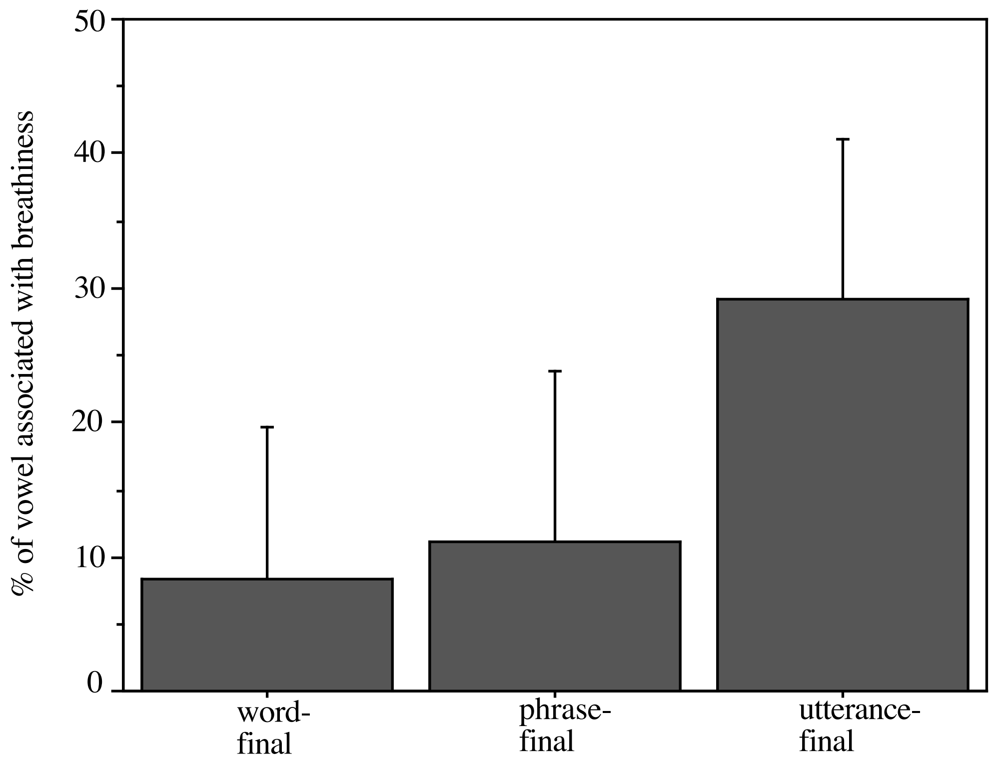

Fig. 7.--Percentage of breathiness/devoicing as a function of the total duration of final long vowels at different prosodic levels (averaged over 6 speakers)

Results for long vowels for individual speakers appear in table 7.

TABLE 7

The percentage of breathiness/devoicing relative to the entire vowel duration for final long vowels at three different prosodic levels

	Word		Phrase		Utterance	
	Total	% Breathy	Total	% Breathy	Total	% Breathy
F1	151	15.48	250	24.20	205	28.07
F2	133	0.0	148	1.96	175	27.51
F3	247	16.21	277	14.14	262	20.14
F4	188	0.0	191	0.0	271	47.64
M1	165	10.20	191	2.29	243	22.02
M2	151	7.73	170	14.81	248	36.21
Mean	**166**	**9.6**	**210**	**13.3**	**229**	**29.3**

For all speakers, breathiness is proportionally longer in utterance-final position than for other positions for the long vowels. Two speakers (F2, F4) show virtually no devoicing in either word- or phrase-final long vowels. All speakers show relatively small differences between word-final and phrase-final vowels, though it is worth pointing out that speaker F1 has more of a difference between word-final and phrase-final vowels than between phrase-final and utterance-final vowels. For this speaker, phrase-final and utterance-final vowels both have proportionally greater devoicing than word-final vowels.

Figures 8 and 9 show graphically the relative contribution of the modal voiced phase (the dark shaded bars) and the breathy voiced phase (the light shaded bars) to the total duration of short and long vowels in both medial and final positions. Short vowels are shown in figure 8 and long vowels in figure 9. For both short and long vowels, phrase-final vowels have the longest modal phases. For the long vowels, the only pairwise comparisons of modal vowel duration that were statistically reliable according to t-tests are those involving phrase-final vowels: phrase-final vs. word-medial, t(*df*=353) = 4.807, p<.0001; phrase-final vs. word-final, t(*df*=169) = 3.904, p<.0001; phrase-final vs. utterance-final, t(*df*=256)=3.729, p=.0002. For short vowels, however, all four positions were durationally distinguished from each other with respect to modal voicing duration. Word-medial vowels were longest followed in turn by phrase-final, word-final and utterance-final vowels. All pairwise differences reached statistical significance according to t-tests: word-medial vs. phrase-final, t(*df*=821) = 5.181, p<.0001; word-medial vs. word-final, t(*df*=468) = 8.780, p<.0001; word-medial vs. utterance-final, t(*df*=813) = 13.028, p<.0001; phrase-final vs. word-final, t(*df*=925) = 5.145, p<.0001; phrase-final vs. utterance-final, t(*df*=1270) = 10.291, p<.0001; word-final vs. utterance-final, t(*df*=917)=2.729, p=.0065.

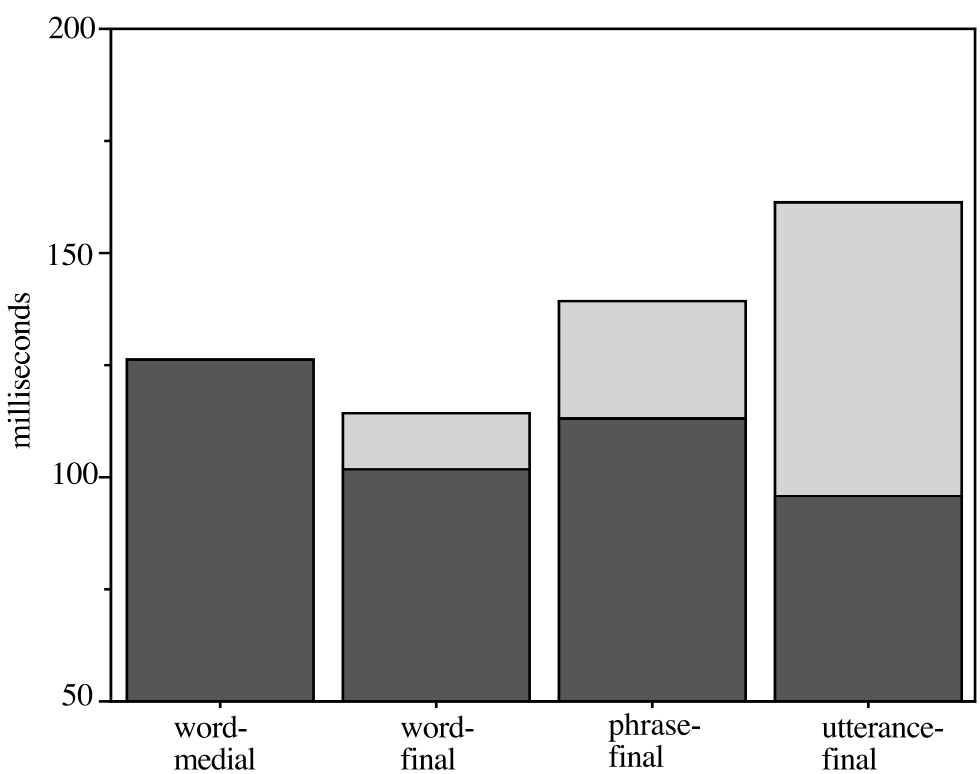

Fig. 8.--Modal and breathy phases of stressed short vowels in four different prosodic positions (averaged over 6 speakers)

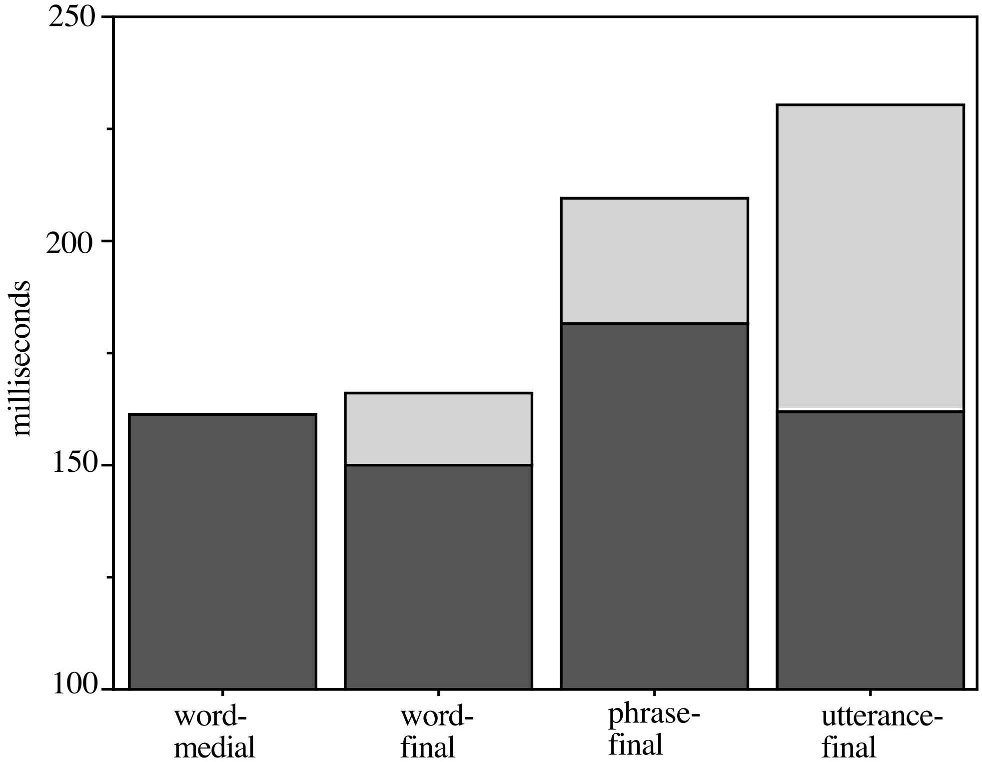

Fig. 9.--Modal and breathy phases of stressed long vowels in four different prosodic positions (averaged over 6 speakers)

The duration of the modal phases of vowels for individual speakers are given in tables 8 (short vowels) and 9 (long vowels).

TABLE 8

The duration (in milliseconds) of the modal voiced portion of short stressed vowels in word-medial position compared to final position at three different prosodic levels

	Word-medial	Word-final	Phrase-final	Utterance-final
F1	115	75	95	87
F2	110	89	93	74
F3	157	128	136	133
F4	129	132	152	106
M1	115	97	115	96
M2	135	87	86	77
Mean	**126**	**102**	**113**	**96**

TABLE 9

The duration (in milliseconds) of the modal voiced portion of long stressed vowels in word-medial position compared to final position at three different prosodic levels

	Word-medial	Word-final	Phrase-final	Utterance-final
F1	175	124	185	148
F2	127	133	145	127
F3	183	209	236	209
F4	193	188	191	149
M1	149	149	186	189
M2	142	138	142	154
Mean	**161**	**150**	**182**	**162**

For the short vowels, results for individual speakers generally fall into line with the overall results though not all speakers distinguish all positions durationally. Four of the six speakers (F1, F2, F3, M2) have longer modal voiced phases for vowels in word-medial positions than all other positions. Speaker M1 has longer modal voiced phases for both word-medial and phrase-final vowels relative to word-final and utterance-final ones. Contra the dominant pattern, speaker F4 has the longest modal voiced phases in phrase-final vowels, while word-medial and word-final vowels rank second in duration of modal voicing. Phrase-final modal phases are longer than word-final and utterance-final ones for four of six speakers. Both of the speakers lacking this pattern (F2 and M2) have longer modal voicing phrase-finally than utterance-finally but not word-finally. Word-final vowels are distinguished from utterance-final ones for three speakers (F2, F4, M2) with the other speakers either not distinguishing the two levels (F3, M1) or running contrary to the dominant pattern in having shorter vowels word-finally (F1).

For the long vowels, in keeping with overall pattern, three speakers (F1, F2, F3) have the longest modal phases phrase-finally. The other speakers distinguish phrase-final vowels from either one or two, but not three, levels: phrase-final vs. utterance-final for speaker F4, phrase-final vs. word-medial and word-final for speaker M1, and phrase-final vs. utterance-final for speaker M2. Speaker M2, however, has *longer* modal phases utterance-finally. Certain speakers show duration differences between levels other than the phrase, e.g word-medial vs. word-final for speaker F3 and utterance-final vs. word-final for speakers F1, F4, M1, and M2, but these results were not consistent enough to produce a reliable overall effect across speakers.

4.4. Summary of the results

Several findings have emerged in the data. First, differences in foot structure over the final syllable were shown not to correlate with differences in duration. Vowels were the same duration whether they occurred in a monosyllabic foot or in the strong syllable of a disyllabic foot. Second, vowel duration adhered to a continuum with vowels being longest in final position of the largest domain, the utterance, and progressively shorter in final position of smaller domains, the phrase and the word. Word-final and word-medial stressed vowels were both substantially lengthened relative to their word-medial unstressed counterparts, with the degree of lengthening being slightly greater for word-medial stressed vowels for certain speakers. A similar durational continuum was observed for the amount of breathiness associated with the end of final vowels, both short and long. Breathiness was longest in final position of the utterance and progressively shorter in phrase-final position and word-final position. Word-medial vowels were not characterized by any breathiness. When breathiness is subtracted from the overall duration values, short vowels are longest phrase-finally, followed in turn by vowels word-medially, word-finally, and utterance-finally. In the case of modal voicing in long vowels, the only consistent pattern was for the modal voiced phase of phrase-final vowels to be longer than the modal voiced phase in all other positions, i.e. word-medially, phrase-finally, and utterance-finally. Finally, phonemic short and phonemic long vowels were shown to be durationally distinct in all positions.

5. Discussion

In sections 5.1 and 5.2, we explore the relevance of the present results for the two main issues addressed earlier in the paper: the relationship between metrical structure and final vowel duration and the cumulative nature of final lengthening as a function of prosodic domain size. Metrical structure and final vowel duration is discussed in sections 5.1, while section 5.2 examines final lengthening.

5.1. Metrical structure and vowel duration

Buckley's (1998) typological survey of the relationship between metrical structure and final vowel duration explores potential explanations for the apparent blocking of iambic lengthening in final position. He suggests that there is no single unifying account of the failure of final vowels to lengthen in iambic stress systems. Rather, different factors conspire to block final iambic lengthening in different languages.

Buckley suggests that in some languages lengthening is blocked because the final syllable is metrically unparsed. For example, in Hixkaryana (Derbyshire 1979, 1985), iambs are formed over CVCV sequences word-internally and the stressed syllable in the foot lengthens: (toróː)no 'small bird', (nemóː)(kotóː)no 'it fell', (atʃóː)wowo 'wind'. However, final syllables are not parsed into feet whether they follow a stressed syllable or not, as the example (atʃóː)wowo 'wind' indicates. Evidence for the non-parse of final syllables comes from disyllabic CVCV words, which have stress on the first syllable rather than the second syllable and lengthen the first vowel, e.g. (káː)na 'fish', (túː)na 'water', which one would expect in an iambic stress system.

Another reason for iambic lengthening to be blocked word-finally according to Buckley is an independent ban on final long vowels. Buckley cites Choctaw (Nicklas 1975, Munro and Ulrich 1984, Ulrich 1986) as a language in which this is the relevant factor. Choctaw has an iambic lengthening pattern similar to Chickasaw's but, unlike Chickasaw, does not contrast vowel length in final position. The lack of iambic lengthening word-finally is thus attributed in Buckley's account to an independent restriction against final long vowels.

Finally, a third explanation for the blocking of final lengthening relates to morphological factors. Buckley notes that Kashaya Pomo (Oswalt 1961, Buckley 1994) has certain suffixes that fail to undergo iambic lengthening even word-medially. Because all verbs must end in a member of this set of suffixes, appearances initially suggest a positionally governed ban on final lengthening. However, this restriction turns out upon closer inspection to be morphologically conditioned.

As Buckley points out, because the ban on lengthening in final position is linked to a number of disparate factors cross-linguistically, we would also expect to find languages in which these factors are absent and iambic lengthening does apply word-finally. Buckley cites Maidu (Shipley 1964) and Macushi (Abbott 1991) as languages in which stressed vowels are reported to lengthen even in final syllables. Interestingly, though, neither language displays the prototypical iambic lengthening pattern either word-medially or word-finally. Although both languages have iambic stress systems, lengthening targets closed as well as open syllables and also applies to final vowels even in monosyllabic feet.

Since Buckley's work does not present phonetic data comparing final and non-final vowels, it is unclear whether there is any lengthening of final vowels in languages reported to asymmetrically lengthen stressed vowels in word-medial feet but not word-final ones. In the absence of quantitative phonetic data, it is also uncertain how much lengthening occurs in languages like Maidu and Macushi in which final stressed vowels are reported to lengthen.

The present results shed light on this matter, at least for Chickasaw. As we have seen, final vowels, all of which are stressed, do lengthen relative to medial unstressed vowels in Chickasaw, such that they are nearly as long as word-medial stressed vowels. This finding is significant since Chickasaw is a language typically described as asymmetrically lengthening medial but not final vowels in metrically strong positions. Crucially, as in Maidu and Macushi, lengthening is not sensitive to foot structure in Chickasaw; rather it applies to vowels in both monosyllabic and disyllabic feet. Unlike Maidu and Macushi, however, lengthening is not a salient feature of closed syllables in Chickasaw. The lengthening of final vowels in monosyllabic feet may be viewed as a strategy to ensure that there are no degenerate feet in Chickasaw; all monosyllabic feet consist of a syllable that is heavy either because it has a coda consonant or because it undergoes vowel lengthening. More generally, final lengthening guarantees that all stressed syllables, both those in monosyllabic and disyllabic feet, are heavy in Chickasaw.

Lengthening of stressed vowels in final position, however, is not the same phonetically as lengthening of stressed medial vowels. Rather than being modal voiced throughout their duration like medial vowels, final vowels end in a breathy phase often culminating in complete devoicing, particularly in final position of larger prosodic domains. Thus, although the total duration of final vowels is nearly equivalent to that of their medial counterparts, the modal voiced phase of final vowels is characteristically shorter (for 5 of 6 speakers) than that of medial vowels. The sixth speaker has equivalently long modal voiced phases in medial and final short vowels. The phonation difference characteristic of the majority of speakers may offer an explanation for why lengthening is often not reported for final stressed vowels cross-linguistically. Breathiness and devoicing are less salient than modal voicing from a perceptual standpoint and are thus often ignored by listeners in assessing vowel duration. For example, Myers and Hansen (to appear) find that the devoiced phase of final vowels in Finnish is factored out by Finnish listeners making judgments about phonemic length. It would be natural for lengthening associated with breathiness and/or devoicing to be factored out by both speakers of languages with lengthening of medial stressed vowels and perhaps linguists describing these languages. This is particularly likely if length judgments are based largely on words uttered in utterance-final position or isolation, contexts in which the modal voiced phase of final vowels is likely, based on the Chickasaw data, to be substantially shorter than the modal voiced phase of equivalently stressed vowels in non-final syllables. While this account must be regarded as somewhat speculative, especially since it is based on data from a single language, it has the virtue of reconciling two apparently contradictory patterns: the pervasiveness of final phonetic lengthening and the reported lack of lengthening of final stressed vowels.

There is one more issue regarding length to be addressed: the role of final lengthening in the phonology of Chickasaw. In fact, it is difficult to garner evidence either for or against the phonological status of final lengthening in Chickasaw. One could argue that the lengthening is closely linked to foot structure, since the additional length in final syllables may be viewed as a strategy for ensuring that feet end in a heavy syllable, in keeping with the general word-internal requirement that stressed syllables be heavy. What is less clear is the directionality of the relationship between the weight of final syllables and metrical structure. It is possible that the additional length associated with final position is responsible for the attraction of stress by final syllables, since all heavy syllables are stressed in Chickasaw. Alternatively, it could be that final vowels are lengthened because they are stressed, in response to the general requirement that stressed syllables be heavy in Chickasaw. The latter position is unlikely to be the entire story, since long vowels also lengthen despite presumably already being heavy enough to attract stress. The application of final lengthening to both short and long vowels suggests that it is a basic and independent phonetic characteristic of Chickasaw just as in most languages in the world. Regardless of the directionality of the relationship between weight and stress, stress and lengthening in final CV syllables crucially act synergistically to create a phonetically natural match between stress and syllable weight.

5.2. Final lengthening

As we have seen, Chickasaw displays a continuum of lengthening in final position such that final vowels are longer at the end of larger prosodic domains than at the end of smaller domains. Final lengthening is likely due to a slowing down of articulators as they return to their rest position after they reach the target position for a given sound (Edwards et al. 1991, Beckman et al. 1992). If the deceleration of oral gestures is accompanied by a laryngeal opening gesture in preparation for vegetative breathing, breathiness and devoicing result (Ohala 1983), as in Chickasaw.

In Chickasaw, three final contexts were differentiated through lengthening and final breathiness: the word, the phrase, and the utterance. The cumulative nature of final lengthening in Chickasaw parallels effects observed in other languages[9], though the prosodic constituents triggering lengthening vary from language to language. For example, English distinguishes several levels in terms of final lengthening (Oller 1973, Klatt 1975, Umeda 1975, Wightman et al. 1992). Wightman et al. (1992) observe a hierarchical lengthening effect such that word-final phrase-medial vowels are shorter than accentual phrase-final vowels, which in turn are shorter than intermediate phrase-final vowels, which in turn are shorter than Intonational Phrase-final vowels. De Jong and Zawaydeh (1999) find a similar hierarchy of final lengthening in their study of Jordanian Arabic vowels, as do Gussenhoven and Rietveld (1992) in their examination of Dutch. Other languages for which final lengthening has been found for at least one prosodic level are numerous, including Creek (Johnson and Martin 2001), Finnish (Oller

1979), French (Fletcher 1991, Jun and Fougeron 1995, Smith 1999, 2002), Greenlandic Eskimo (Nagano-Madsen 1992), Hebrew (Berkovits 1991), Hungarian (Hockey and Fagyal 1992), Italian (van Santen and D'Imperio 1999), Korean (Jun 1993), and Spanish (Oller 1979). The degree of final lengthening varies substantially from language to language. For example, Delattre finds a ratio of final-to-non-final vowel duration of 1.17:1 in Spanish but a ratio of 1.78:1 for French. In Creek, a Muskogean language like Chickasaw, Johnson and Martin (2001) find a ratio of approximately 1.35:1, where their final vowels were utterance-final. In the present study, the ratio of utterance-final to word-medial vowels is also 1.35:1 averaged over short and long vowels, 1.28:1 for short vowels and 1.42:1 for long vowels.

Final lengthening affects both short and long vowels in Chickasaw, thereby ensuring that the phonemic vowel length contrast is preserved in all prosodic contexts. This fits a pattern seen in other languages with phonemic length distinctions in final position. For example, the contrast between phonemic short and phonemic long vowels in Creek (Johnson and Martin 2001), Finnish (Oller 1979) and Hungarian (Hockey and Fagyal 1999) is preserved in final position since both vowel categories undergo final lengthening. This should not imply, however, that length contrasts in final position are stable in all languages in the face of final lengthening. In fact, there are many languages, e.g. Chimwi:ni (Kisseberth and Abasheikh 1974), Macushi (Abbott 1991), Tiberian Hebrew (Prince 1975, McCarthy 1979), in which phonemic length contrasts are neutralized in final position. We may speculate that length contrasts are unstable in final position precisely because final lengthening potentially reduces the duration ratio between short and long vowels. Chickasaw is likely exceptional in this regard since it displays an unusually substantial lengthening effect for stressed medial vowels, such that the long-to-short duration ratio is smaller word-medially than word-finally. The long-to-short ratio in the Chickasaw data examined here was 1.28:1 word-medially (averaged over six speakers) vs. 1.46:1 word-finally, 1.51:1 phrase-finally, and 1.42:1 utterance-finally.

Interestingly, the large lengthening effect observed in word-medial stressed vowels in Chickasaw means that these vowels are as long as their word-final counterparts in phrase-medial position. Thus, the final lengthening effect only is observed independent of stress-induced lengthening at levels above the word in Chickasaw. This might seem counterintuitive, since one might expect stress and final position to act synergistically and cause extra lengthening in word-final position. One possible explanation for the lack of additional word-final lengthening relates to the pressure to distinguish multiple levels in the prosodic hierarchy. The strong word-medial lengthening effect in Chickasaw leaves less room for lengthening in word-final position while simultaneously differentiating word-final position from higher domains such as the phrase and the utterance. Under this view, the primary function of final lengthening is to aid the listener in the prosodic parsing of an utterance. An association of word-final position with additional length beyond that due to stress would potentially interfere with the cueing of prosodic constituency at higher levels. This hypothesis adopts the plausible assumption there is an upper range of lengthening permissible in final position at any level, even the utterance.

Even though the total duration of word-final vowels is not longer than that of word-medial stressed vowels in Chickasaw, vowels in the two positions do differ phonetically. Word-final vowels for many speakers are associated with breathiness and devoicing near their right edge. Breathiness and/or devoicing in final position has been observed for other languages, including English (Lehiste 1979, Kreiman 1982), French (Smith 2002), Finnish (Lehtonen 1970, Myers and Hansen to appear), and Kinyarwanda (Myers in press), and may be regarded as another cue, along with lengthening, to prosodic constituency. In Chickasaw, the length of breathiness increases with the size of the immediately following prosodic boundary, and often culminates in complete devoicing at the end of the utterance. The sensitivity of breathiness and devoicing to domain size is in keeping with an increased propensity for devoicing at the end of relatively large constituents cross-linguistically (Gordon 1998).

Breathiness is caused by spreading the vocal folds along part of their duration, thereby creating turbulence mixed with periodic vocal fold vibration. If the laryngeal opening is sufficiently large, the vocal folds will cease to vibrate and the result will be a devoiced vowel. The increase in the length of breathiness and the increased likelihood of devoicing in final position of higher domains suggests the presence of both a longer and a larger laryngeal opening gesture at higher prosodic levels.

As a final note, the presence of final breathiness in much of the examined data raises a question the question of whether the Chickasaw words that we have assumed to end in a final vowel might actually end in /h/, a possibility discussed by Munro and Willmond 1994:xxxviii). Such an analysis finds support from the closely related language Choctaw, in which words that are cognate with vowel-final words in Chickasaw end in an /h/ (Munro and Ulrich 1984, Ulrich 1986, Munro and Willmond 2005). Although this analysis cannot be definitively ruled out for Chickasaw since breathiness and /h/ are phonetically equivalent, there are reasons, we believe, why this analysis does not readily extend to Chickasaw. First, breathiness is highly variable in Chickasaw in ways that argue that breathiness is a purely phonetic phenomenon rather than a separate phoneme. The presence and the duration of final breathiness vary gradiently as a function of speaker and the size of the domain it borders. If breathiness reflected a phonemic /h/, we would not expect it to be present for some speakers and not for others at the word-level and to display so much interspeaker variation in duration at higher prosodic levels. The cumulative nature of breathiness strongly suggests that it is a cue to prosodic boundaries, parallel to final lengthening, rather than a phoneme, which would not be expected to be gradiently sensitive to domain size. Finally, the duration of the modal voiced phase and breathiness stand in a compensatory relationship at the phrase- and utterance-level, such that breathiness is short and modal voicing is long phrase-finally while breathiness is long and modal voicing is short utterance-finally. We would not expect this kind of compensatory relationship in final position if breathiness were a phonemic /h/, since there is no other consonant for which additional length as a function of domain size triggers shortening in the preceding vowel. In summary, although one cannot definitively rule out on phonological grounds the possibility of final /h/ in Chickasaw, the phonetic data are more compatible with an analysis in which final breathiness, like final lengthening, is a phonetic effect.

7. Summary

This paper has sought to determine whether iambic vowel lengthening affects word-final vowels in Chickasaw and whether the cross-linguistically pervasive phenomenon of final lengthening is also observable in a prototypical iambic stress language. Results of a phonetic study of duration suggest that final vowels in Chickasaw display similar patterns to segments in final position in other languages: final vowels undergo phonetic lengthening where the degree of lengthening is commensurate with the size of the domain at whose right edge the vowel occurs. Lengthening affects both phonemic short and phonemic long vowels, thereby preserving the phonemic length contrast in all positions. Furthermore, final lengthening affects all short vowels uniformly regardless of metrical structure thus ensuring that there are no subminimal feet in Chickasaw and that all stressed syllables are heavy. Finally, breathiness and devoicing are also associated with vowels at the right edge of large prosodic constituents.

Appendix. Corpus of words examined in duration study[10]

	i	a	o
<u>Final vowels</u>			
Disyllabic foot	mallitʃ**i** 'He bounces it (a baby)'	honkop**a** 'He steals it'	noktʃit**o** 'He behaves'
	kallotʃ**i** 'He makes it hard'	hottop**a** / ittop**a** 'It hurts'	aɬtip**o** 'It is tented, covered'
	sotkotʃ**i** 'He thickens it'	oktap**a** 'It is blocked'	oppol**o**/okpol**o** 'It is broken, ruined'
	inkon**i** 'his skunk'	aɬtok**a** 'He is elected'	tã:lob**o** 'hominy'
	inkof**i** 'his quail'	aɬtob**a** 'It is paid for'	hoɬt͡ʃif**o** 'name'
	ĩ:hap**i** 'his salt'	intop**a** 'his bed'	intiʃ**o** 'his doctor's assistant'
		ya:ɬip**a** 'hat'	
		haʃo:mal**a** 'cottonwood'	
Degenerate foot	hoʃont**i** 'It is cloudy'	ayopp**a**/ayokp**a** 'He is happy'	okomm**o** 'He mixes it'
	hotamp**i** 'He strings them (beads)'	okʃitt**a** 'He closes it'	habiʃk**o** 'He sneezes'
	tilikp**i** 'It (the	sahoɬp**a** 'I get	iliss**o** 'He hits

	moon) is round, full’	burned’	himself’
	iʃkottʃ**i** ‘You put it out’	holiss**o** ‘book’	falakt**o** ‘It is forked’
	kilimp**i** ‘He is strong'	tanamp**o** ‘gun’	imanomp**a** ‘his language’
	int͡ʃokf**i** ‘his rabbit’	halamb**o** ‘lizard sp.’	impask**a** ‘his bread’
	hoʃont**i** ‘cloud’		t͡ʃipot**a** ‘child’
	ʃokmall**i** ‘lightning’		
Long vowels	tiːb**i**ː ‘tuberculosis’	hatʃimih**o**ː ‘your (pl) wives’	hat͡ʃink**a**ː ‘your(pl) car’
	hat͡ʃint**i**ː ‘your(pl) tea’	hat͡ʃiːʃ**o**ː ‘your(pl) show’	ittiʔt͡ʃan**a**ː ‘wagon’
		iʃhop**o**ː ‘You’re jealous’	ittan**a**ː ‘church’
			iʃwak**a**ː ‘You fly’
			tʃikam**a**ː ‘You’re striped’
			tʃikil**a**ː ‘You’re burning’

Medial

Vowels

Stressed short	yop**i**ˑtʃi ‘He bathes him’	pil**a**ˑtʃi ‘He sends it’	hol**o**ˑtʃi ‘He puts shoes on him’
	nos**i**ˑtʃi ‘He puts him to sleep’	non**a**ˑtʃi ‘He bakes it’	fol**o**ˑta ‘He turns around’
	hom**i**ˑtʃi ‘He makes it spicy’	mał**a**ˑta ‘He is surprised’	yok**o**ˑta ‘It shrinks’
		los**a**ˑtʃi ‘He makes it black’	
Unstressed short	haks**it**ʃi ‘He gets him drunk’	ʃomb**at**ʃi ‘They eat holes in them’	pokp**o**ki ‘It is foamy’
	biʃ**lit**ʃi ‘He strains/milks it’	ʃãːhb**at**ʃi /ʃamb**at**ʃi ‘He puts out her/his eyes’	inn**ot**ʃi ‘She puts it (a necklace) on’
		hoɬt**a**pi ‘They (beads) are strung’	
		holb**at**ʃi ‘He takes a picture of it’	
		waʃk**a**bi ‘It is itchy’	
		okt**a**pa ‘It is blocked’	

Long vowels	iʃ**li:**li 'You hoe it'	haʃ**a:**tok 'He was angry'	hop**o:**tok 'He was jealous'
	iʃ**ti:**ma 'You spread your tail tail' (e.g. of a turkey)'	kam**a:**tok 'It was striped'	iʃʃ**o:**li 'You hug him/her'
	ho:tʃ**i:**li 'They lay eggs'	kil**a:**tok 'It was burning	t͡ʃi:l**o:**loʔ 'your doodlebug'
		iʃʃ**a:**li 'You haul it'	

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[2] Chickasaw can be regarded as a stress accent language in the sense of Beckman (1986) since stress is realized through a combination of durational, intensity, and fundamental frequency cues (see Gordon 2004 for discussion). As the text indicates, stress is largely predictable based on syllable structure, although certain roots possess semantically related forms, termed "grades" in the Muskogeanist literature, that carry a lexical accent on a single syllable. Such forms are not relevant to the present paper (but see Munro and Willmond 1994 for discussion).

[3] Nasalized vowels, which contrast with oral vowels, are treated as phonologically long in keeping with their phonetic realization as long vowels.

[4] In addition, certain affixes fall outside of the iambic lengthening domain; these morphological factors will not be discussed further here (see the sources in the text for discussion of the role of morphology in iambic lengthening).

[5] Some speakers have a sequence VhV instead of a long vowel word-finally in verbs (Munro 1996:3). Furthermore, words with final long /iː/ are rare and may be produced with a final glottal stop, e.g. intiːʔ rather than intiː 'his tea'.

[6] Certain speakers used other words instead of *himmakoʔsãː*, including *himmakoʔsaːkayni* and *anõːwaʔ*. One speaker substituted *tʃimaːtʃili* for *tʃimaːʃli* in the phrase-final context.

[7] There were slight differences in length based on vowel quality with the non-high vowels /a, o/ being slightly but significantly longer ($p<.0001$ for both pairwise comparisons according to t-tests) than the high vowel /i/ following a common cross-linguistic pattern (Lehiste 1970): /a/ = 154 milliseconds, /o/ = 149 milliseconds, /i/ = 134 milliseconds. Since all vowel qualities were represented roughly equally in the examined data, they are all included in the analyses that follow.

[8] The presence of a three-way length contrast raises questions about the phonological representation of length. If iambically lengthened and phonemic long vowels are both represented as bimoraic (Hyman 1985, Hayes 1989) in keeping with their parallel phonological patterning as long vowels, this would incorrectly suggest that they are phonetically identical in length. This issue goes beyond the scope of this paper; the interested reader is referred to Hayes (1995) for discussion of complex weight hierarchies within moraic theory.

[9] It should be noted that final lengthening is not a universal phenomenon (see Myers and Hansen to appear) for cases of final shortening.

[10] Words that were unfamiliar to a particular speaker were not recorded from that speaker.