A phonological and phonetic study of word-level stress in Chickasaw

Matthew Gordon
University of California, Santa Barbara

This paper presents results of a phonological and phonetic study of stress in Chickasaw, a Muskogean language spoken in south central Oklahoma. Three degrees of stress are differentiated acoustically, with primary stressed vowels having the highest f0 and greatest duration and intensity, unstressed vowels having the lowest f0 and shortest duration and intensity, and secondary stressed vowels displaying intermediate f0, duration, and intensity values. Vowel quality differences and segmental lenition processes also are diagnostic for stress. The location of stress is phonologically predictable, falling on word-final syllables, heavy (CVC and CVV) syllables and on the second in a sequence of light (CV) syllables. Short vowels in non-final open syllables are made heavy through a process of rhythmic vowel lengthening. Primary stress is sensitive to a further weight distinction, treating CVV as heavier than both CV and CVC. In words lacking a CVV syllable, stress falls on the final syllable.

1. Introduction

Languages differ in how they realize stress acoustically. Typically, stressed syllables are associated with some combination of the following properties: heightened fundamental frequency (f0), increased loudness, greater duration, and more peripheral vowel qualities, e.g. English (Fry 1955, Beckman 1986), Russian (Bondarko et al. 1973), Polish (Jassem et al. 1968), Mari (Baitschura 1976), Indonesian (Adisasmito-Smith and Cohn 1996), Tagalog (Gonzalez 1970), Dutch (Sluijter and van Heuven 1996), Pirahã (Everett 1998). While a relatively large body of literature has been devoted to acoustic investigation of stress, there is a paucity of quantitative phonetic data on stress in American Indian languages. Most studies of stress in American Indian languages, with some exceptions,[1] have focused on phonological descriptions (supported in some cases by native speaker intuitions) of the location of stress with, in many cases, impressionistic observations about how stress is manifested in the acoustic domain, cf. Sapir (1930) on Southern Paiute, papers on Yupik in Krauss (1985), Goddard (1979, 1982) on Delaware, Miner (1979, 1989), Hale (1985), Hale and White Eagle (1980) on Winnebago, Michelson (1988) on Northern Iroquoian languages, Everett and Everett (1984) and Everett (1988) on Pirahã, Buckley (1994) on Kashaya Pomo, Fitzgerald (1998, 1999) on Tohono O'odham. Phonological investigations of stress in American Indian languages have yielded important insights into the typology of stress, revealing interesting phenomena such as iambic lengthening in Yupik (Krauss 1985), post-tonic consonant lengthening in Delaware (Goddard 1979, 1982), extended extrametricality in Kashaya (Buckley 1994),

[1] Notable acoustic studies of prominence in American Indian languages include, among others, Seiler (1957) on Cahuilla, Michelson (1983) on Mohawk and Oneida, Doherty (1993) on Cayuga, Everett (1998) on Pirahã, Tuttle (1998) on Tanana, Hargus (2001) on Witsuwit'en, and Martin and Johnson (2002) on Creek.

positionally determined weight in certain Yupik varieties (Krauss 1985), and complex weight hierarchies in Asheninca (Payne et al. 1982, Payne 1990) and Nanti (Michael and Crowhurst 2002). Quantitative phonetic studies of American Indian languages, heretofore scarce, likewise promise to enhance our typological knowledge of stress and also offer a means for rigorously testing impressionistic phonological descriptions of stress in relatively understudied languages.

This paper presents results of a quantitative phonetic study of stress in Chickasaw, a Western Muskogean language spoken by no more than a few hundred speakers in south central Oklahoma (Gordon et al. 2000). Acoustic data from eight speakers of Chickasaw are analysed in order to examine the evidence for word-level stress in Chickasaw and to determine how primary and secondary stressed syllables are phonetically differentiated from each other and from unstressed syllables. A number of potential acoustic correlates of word-level stress, both primary and secondary stress, are investigated, including duration, fundamental frequency (the physical analog of the perceptual property of pitch), intensity, and vowel quality. In addition, segmental correlates of stress, including vowel devoicing and syncope, are discussed.

More generally, the present work belongs to the research program employing acoustic measurements in the development of phonological analyses. The phonological analysis of prominence in any language is complex and potentially influenced by a number of factors, including speaker, prosodic position in the utterance, syllable structure, morphology, and syntactic category. Acoustic analysis provides a means for objectively examining stress and teasing apart the numerous factors that potentially contribute to a syllable's prominence. Acoustic investigation is important in any language and particularly essential in languages where native speakers do not have strong or consistent intuitions about which syllables are stressed, as is the case for the Chickasaw speakers with whom I have worked.

2. Background on Chickasaw prosody

2.1. Rhythmic lengthening

Munro and Ulrich (1984) describe a process of rhythmic lengthening potentially related to stress in Chickasaw and closely related Choctaw (see also Nicklas 1974, 1975 on Choctaw rhythmic lengthening). Rhythmic lengthening targets the second in a sequence of vowels in open syllables, provided the potential target vowel is non-final.[2] For example, the second and fourth vowels in the Chickasaw word /tʃipisalitok/ 'I looked at you' are lengthened relative to their short counterparts in the first, third, and fifth syllables, i.e. [tʃipiːsaliːtok], where rhythmically lengthened vowels are indicated by an IPA length symbol ː.[3] Rhythmic lengthening does not target word-final syllables; thus, the final vowel in /tʃipisali/ 'I look at you' does not undergo rhythmic lengthening, i.e. [tʃipiːsali], even though it is in an open syllable following another CV syllable. All

[2] Rhythmically lengthened vowels may be equivalent in length to phonemic long vowels or slightly shorter depending on the speaker and the vowel quality (see Gordon et al. 2000 for phonetic data).

[3] In the orthography used by Munro and Willmond (1994), rhythmic lengthening is not marked, while phonemic vowel length is indicated by a double letter.

word-final vowels undergo some lengthening due to a general final lengthening effect observed in most languages of the world (Wightman et al. 1992).[4]

Munro and Ulrich (1984) assume that heavy syllables, including CVC, underlying long vowels and rhythmically lengthened vowels, are prominent, though Munro and Ulrich do not attribute rhythmic lengthening to stress. One of the goals of the present paper is to determine the precise relationship between rhythmic lengthening and stress in Chickasaw. One hypothesis is advanced by Ulrich (1986) in his discussion of rhythmic lengthening in Choctaw, Chickasaw's closest relative. Ulrich suggests that rhythmic lengthening imposes a layer of metrical structure that is distinct from stress prominence. Another position is advocated by Hayes (1995), who unites stress and rhythmic lengthening, analyzing rhythmic lengthening as the manifestation of prominence in light syllables falling in metrically strong, i.e. stressed, positions. This analysis parallels that of Martin and Johnson's (2002) account of related Creek and is reflected in the phonological representations assumed by Hayes for Choctaw and Chickasaw, according to which iambic feet are constructed from left to right over a word. In Hayes' analysis, iambs consist of either two light syllables, a heavy syllable grouped together with a single preceding light syllable, or a single heavy syllable, as in the metrical representations in (1).

(1)

```
(   x )(   x)( x )                          (     x)            ( x )(    x)
tʃi pi sa li tok ‘I looked at you’          no tak fa ‘jaw’     ʃaːɬ ko na ‘earthworm’
```

The rhythmic lengthening of underlying short vowels in metrically strong open syllables, e.g. /tʃipisalitok/ 'I looked at you' → [tʃipiːsaliːtok], reflects an attempt to create optimal iambic feet consisting of a light syllable followed by a heavy syllable, a process also found in several other languages with iambic stress feet (see Hayes 1995, Buckley 1998). An additional feature of Hayes' analysis is that word-final CV remains metrically unparsed (see sections 4.1 and 5.2 for counterevidence suggesting that final CV is always metrically parsed) when immediately following another strong syllable, as in [notakfa].

2.2. Primary stress

Neither Munro and Ulrich (1984) nor Hayes (1995) discusses which of the prominent syllables in a word with multiple prominent syllables is most prominent in Chickasaw. Munro and Ulrich and Ulrich (1986) do, however, claim that final syllables in Chickasaw and Choctaw carry a high tone accent distinct from the prominence associated with heavy syllables. Similarly, Munro (1996) suggests that the final syllable of a word is generally most prominent in Chickasaw. In a study of intonation, Gordon (1999, to appear) makes a distinction between word-level and phrase-level stress, and describes the location of phrase-level prominence, which is realized as a pitch accent on a syllable in the final word of a phrase. Stress coincides with this pitch accent. In questions, the pitch accent (and stress) falls on a final long vowel (i.e. underlying CVV since rhythmic lengthening does not target final vowels), otherwise on a heavy penult (both CVV and CVC) and

[4] An example of word-final lengthening can be observed in figure 1 in section 4.1.

otherwise on the antepenult. In statements, the final syllable carries the pitch accent in keeping with Munro and Ulrich's (1984) analysis of isolation words.

Gordon (1999, to appear) does not examine the acoustic correlates of stress. Nor does his work treat word-level stress, i.e. stress in non-phrase-final words, other than agreeing with Munro and Ulrich's claims about heavy syllables being prominent. This paper will examine evidence for a distinction between primary and secondary stress in Chickasaw. This issue is important since it is commonly assumed by theoretical phonologists (e.g. Liberman and Prince 1977, Prince 1983, Hayes 1995) that all words in non-tone languages have a single syllable that is more prominent than all others.

2.3. Chickasaw as a stress vs. pitch accent language

Chickasaw is an interesting case study in the role of various phonetic properties to signal prominence, since Chickasaw shares with other Muskogean languages a system of pitch accents, termed "grades" by scholars of Chickasaw and related Muskogean languages. Munro and Willmond (1994:lv-lxii) contain detailed discussion of Chickasaw grades, which are summarized briefly here. A subset of verbs is marked as carrying a pitch accent, phonetically a high tone, on a particular syllable. Verbs carrying one of these pitch accents are often (though not always) semantically and phonologically related to a base word from which they are derived, though the precise semantic relationship between the base and the morpholexically accented form is not transparent in many cases. Verb grades convey aspectual information, such as intensification, active and stative changes, and habitual action, among other properties. For example, the grade form /hȋkːiʔja/ 'be standing' is based on the verb /hika/ 'stand up' and the grade form /tʃofânta/ 'be cleaner' is related to the base /tʃofata/ 'be clean'. There are various classes of verb grades differing in their semantic and phonological relationship with the base from which they are derived (see Munro and Willmond 1994:lv-lxii). Crucially for present purposes, grade forms contain one syllable which carries a high tone, the penult in most unsuffixed grade forms, but the antepenult or preantepenult in certain grades.[5]

One of the interesting questions raised by the existence of pitch accents in Chickasaw is whether certain syllables stand out as acoustically prominent in words lacking a pitch accent and, if so, how this prominence is manifested acoustically. One possibility is that Chickasaw lacks stress prominence in words lacking pitch accents, much as many words lack a pitch accent in Japanese. Another possibility is that stress exists in addition to the pitch accent system. If so, the role of different acoustic parameters in the expression of stress must be determined. It is conceivable that Chickasaw parallels other functionally more "prototypical" pitch accent languages like Japanese in its acoustic reliance on fundamental frequency over duration and intensity to signal prominence (Beckman 1986). Alternatively, one might hypothesize that the high functional load of f0 in the pitch accent system makes it less available as a potential marker of stress than other properties such as duration and intensity. The present study attempts to answer these questions by examining the role of f0, duration, and intensity in the expression of word-level prominence in Chickasaw.

[5] In addition, there are other segmental changes accompanying grade formation, such as gemination, nasalization, or laryngeal insertion.

3. Methodology

The present study is based on data from eight Chickasaw speakers, five females and three males. All speakers were over the age of sixty; all speak English in addition to Chickasaw. Data from two of the female speakers and the male speakers were collected in Oklahoma in 1996, while data from the remaining three female speakers were gathered in Los Angeles in 2002. A list of words designed to determine the location of stress and its acoustic correlates was recorded in Oklahoma, with the three speakers in Los Angeles providing an expanded set of data. The target words were nouns, either subjects or objects, and appeared in a phrase immediately followed by another word, typically a transitive verb but occasionally a possessed noun, which provided a right edge buffer to prevent phrase-final interference with word-level stress patterns. In order to minimize segmental effects on measurements, vowels in contexts associated with non-modal phonation were excluded from analysis. Thus, vowels adjacent to glottal stop or /h/ were not analyzed. In order to minimize effects of word length on segment duration (Lehiste 1970), most words were three syllables, with a smaller number of two syllable words and words with greater than three syllables.

After being given the English equivalent by the author and being asked for the corresponding Chickasaw phrase, speakers repeated each phrase between three and five times. Some sample phrases included in the corpus appear in (2), with the target word in bold. The corpus appears in Appendix 1.

(2)

tʃiʃanko haliːli She touches the arbor.
arbor touch

ʃantiʔ haliːli She touches the rat.
rat touch

okfokkol haliːli She touches the snail.
snail touch

Speakers were recorded while wearing a high quality noise cancelling head-mounted microphone and data were collected on a DAT recorder. The recorded material was then transferred to computer using Scicon PcQuirer and downsampled to 22.05kHz in preparation for acoustic analysis. Acoustic analysis was completed using the Praat software designed by Paul Boersma and David Weenink (www.praat.org). The analysis entailed four measurements of vowels in primary stressed, secondary stressed, and unstressed syllables: duration, intensity (RMS amplitude), f0 (pitch), and frequencies of the first three formants. The duration of each vowel was measured from the waveform in conjunction with a wide band spectrogram. The onset and offset of the second formant served as the beginning and end points, respectively, of each duration measurement. Intensity and f0 were averaged over the entire duration of each vowel using the query function in Praat. Finally, formant values were calculated over a 25 millisecond window centered visually in the middle of the vowel. Duration, intensity, and f0 were chosen as measurement parameters since they are common correlates of stress in languages of the world, cf. English (Fry 1955; Beckman 1986), Russian (Bondarko et al. 1973), Polish (Jassem et al. 1968), Mari (Baitschura 1976), Indonesian (Adisasmito-Smith and Cohn 1996), Tagalog (Gonzalez 1970).

4. Phonetic correlates of stress

Results of the acoustic study are reported in sections 4.1 and 4.2 with different acoustic properties discussed in separate sections and with results reported for speakers as a group and also individually. Section 4.1 present results for words containing either no long vowels or a single long vowel. Discussion of stress in words with multiple long vowels is deferred until section 4.2 given the greater indeterminacy of primary stress in words of this shape.

4.1 Words with one or no long vowels

The present work confirms the impressions of Munro and Ulrich (1984) and Munro (1996), who report that all heavy syllables, including CVC and CVV (both phonemic long and rhythmically lengthened vowels), are prominent. In addition, in keeping with Munro's (1996) impressions, all final syllables are stressed, even final CV following another stress. The present data further suggest a weight distinction between CVC and CVV for primary stress at the word-level. Stress falls on a CVV syllable if one occurs in the word. In words lacking a long vowel, primary stress falls on the final syllable, even if the final syllable is CV and there is a non-final CVC. Stress patterns for words with a single CVV appear in (3). Words illustrating the location of word-level stress in words lacking a long vowel appear in (4).

(3)

aˈboːkoˌʃiʔ	river
tʃoˈkaːˌno	fly
naˈʃoːba	wolf
okˈtʃaːˌlinˌtʃiʔ	savior
taˈlaːˌnomˌpaʔ	telephone
ˈʃiːˌki	buzzard
ˌmaʃˈkoːˌkiʔ	Creek
taˌʔosˈsaːˌponˌtaʔ	finance company
ˈnaːɬtoˌkaʔ	policeman
ˈaːˌtʃomˌpaʔ	trading post
ˌʃimmaˈnoːˌliʔ	Seminole
faˈla-ːt	crow (-subject)
ˈsaːɬkoˌna	earthworm
ˌinˌtikˈba-ːt	sibling (-subject)
ˌokˈtaːk	prairie

(4)

tʃiˌkaʃˈʃaʔ	Chickasaw
noˌtakˈfa	jaw
tʃiˌʃanˈko	arbor
ˌʃanˈtiʔ	rat
ˌtʃonˈkaʃ	heart
kaˌnanˈnak	striped lizard
iˌbiɬˈkan	snot
ˌkanˈtak	green briar plant
ʃaˌlakˈlak	goose
ʃoˈtik	sky
ˌinˌtikˈba	sibling
ˌtoksiˈkaʔ	hearth
tʃoˌkoʃˈpa	story
ˌlokˈtʃok	mud
ˌokˌfokˈkol	type of snail

Figure 1 contains a waveform and spectrogram of a word uttered by speaker F1. The primary stressed syllable has greater intensity than secondary stressed syllables, which in turn have greater intensity than unstressed syllables. In addition, the primary stressed vowel is the longest vowel (trivially in the case of figure 1 since the primary stressed vowel is the only long vowel). Fundamental frequency also serves to differentiate the three levels of stress in figure 1: the primary stressed vowel has a higher f0 than the secondary stressed vowel, while the unstressed initial vowel has a lower f0 than other syllables. As is apparent in figure 1, f0 tends not to rise or fall steeply in either stressed or unstressed syllables, except in the vicinity of glottal stop and /h/, both of which trigger f0 lowering. Because of the characteristic stability of f0 within a syllable, the f0 was computed as an average over each target vowel. It will be shown in section 4.1.1-4.1.3 that heightened f0, increased intensity, and longer duration are all correlates of stress in Chickasaw, although the strength of these cues varies as a function of speaker and which stress levels are being differentiated.

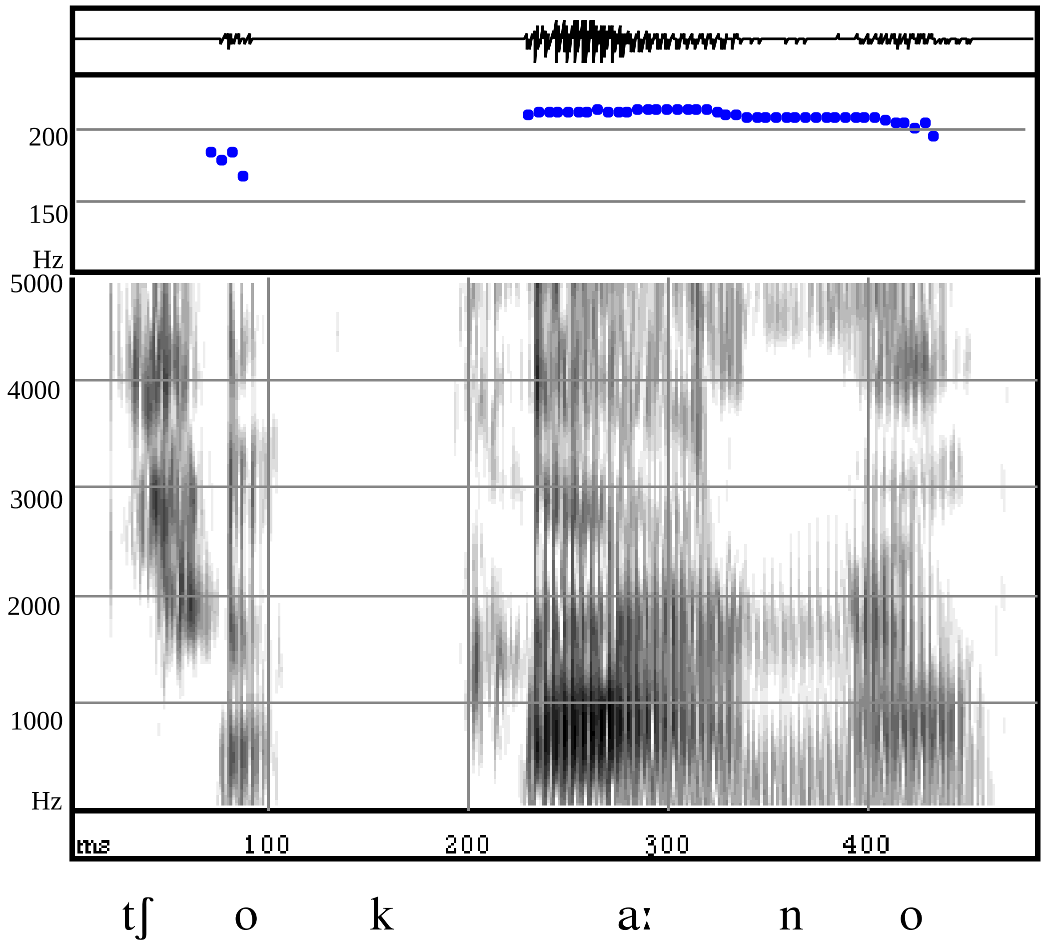

Figure 1. Waveform, pitch track, and spectrogram of the word /tʃoˈkaːˌno/ ‘housefly’ as produced by speaker F1

4.1.1. Fundamental frequency

Collapsing results for all speakers for words lacking long vowels failed to yield a significant effect of stress on fundamental frequency in a two factor analysis of variance (ANOVA) with speaker and stress level acting as independent variables: $F(2,461) = .254$, $p=.7758$. In order to test the robustness of pairwise comparisons of the three stress levels, Fisher’s PLSD posthoc tests were also conducted. They revealed a significant difference in f0 between all levels of stress, with f0 values highest for primary stressed vowels (183Hz), intermediate for secondary stressed vowels (179Hz), and lowest for unstressed vowels (162Hz): primary stressed vs. unstressed vowels and secondary stressed vs. unstressed vowels, $p<.0001$; primary stressed vs. secondary stressed, $p=.0059$. Speaker had a highly significant effect on f0: $F(7, 461) = 275.854$, $p<.0001$. There was also an interaction between speaker and stress level as factors, suggesting that speakers differed in their use of f0 to signal differences in stress level: $F(14, 461) = 1.946$, $p=.0204$.

Similar results were found in words with a single long vowel (which carries primary stress). A two-factor ANOVA (stress level and speaker as factors) revealed a significant effect of both stress ($F(2,780) = 3.538$, $p=.0295$) and speaker ($F(7, 780) = 253.751$, $p<.0001$) on f0. In addition, there was an interaction between speaker and stress: $F(14, 780) = 3.514$, $p<.0001$. Pairwise posthoc tests indicated a tripartite distinction in f0 values between the three stress levels, with the same rank ordering of f0 values as in words lacking long vowels: highest f0 for primary stressed vowels and lowest for unstressed vowels. The difference between all three degrees of stress was significant at $p<.0001$.

As the results from the ANOVAs suggest, there was some interspeaker variation in results. Average f0 values for individual speakers for primary stressed long vowels and short vowels carrying different degrees of stress appear in Table 1. Table 2 shows the pairwise comparisons in f0 that reached statistical significance for individual speakers.

Table 1. Fundamental frequency values for vowels in words containing one or no long vowels

Speak	Prim Str Vː	Prim Str V	Sec Str V	Unstr V
F1	196	174	163	155
F2	205	206	194	192
F3	213	238	231	219
F4	178	167	170	166
F5	219	200	195	194
M1	127	117	122	116
M2	176	168	164	158
M3	107	101	101	99

Table 2. Statistically significant differences in f0 for individual speakers

Word type	Overall effect	Prim vs. Sec	Prim vs. Unstr	Sec vs. Unstr
excluding Vː	F1, F2, F3	F2, F4	F1, F2, F3	
including Vː	F1, F2, F3, F5, M1	F1, F2, F5, F3	F1, F5, M1, M2	F1

For words lacking a long vowel, three speakers display an overall effect of stress level on f0 according to ANOVAs calculated for individual speakers. Two speakers reliably differentiated primary and secondary stressed vowels according to Fisher's PLSD posthoc tests, while three speakers distinguished primary stressed vowels from unstressed vowels. Female speaker F4 showed a somewhat unexpected pattern: her secondary stressed vowels had marginally higher f0 values than primary stressed vowels, $p=.0008$. None of the individual speakers used f0 to separate secondary stressed and unstressed vowels in words lacking a long vowel.

F0 emerges as a more reliable signal of stress if words containing a long vowel are included in the analysis. A significant overall effect of stress level on f0 was found for five of the eight speakers, all except F4, M2, and M3. Furthermore, all speakers except F4 and M3 used f0 to distinguish at least two levels of stress. Four speakers distinguish primary and secondary stress and four use f0 to differentiate primary stressed vowels from unstressed ones. Speaker F1 uses f0 to reliably differentiate all three degrees of stress. Speaker F3 displayed an unusual pattern relative to the other speakers: her f0 values were greater for secondary stressed vowels than either primary stressed or unstressed vowels, suggesting that primary stressed long vowels are not associated with heightened f0. Only the difference between primary and secondary stressed vowels, however, proved to be statistically reliable.

In summary, in words either lacking long vowels or containing a single long vowel, f0 is generally used to differentiate stress level, though not all speakers distinguish all degrees of stress through f0 differences, and one speaker, M3, does not use f0 to signal stress at all. Raised f0 is a particularly robust cue to stress for long vowels carrying primary stress, though one speaker, F3, displays the opposite trend and realizes long vowels with lowered f0. Most robustly differentiated across speakers were primary stressed syllables from both secondary stressed and unstressed syllables.

4.1.2 Duration

A two-factor ANOVA (stress level and speaker) was performed to determine whether short vowels differed significantly in duration according to stress level. Long vowels were excluded from the duration analysis, as they would of course be expected to be longer than short vowels. The ANOVA indicated a highly significant effect of both stress level and speaker on duration: for stress, $F(2, 461)=75.289$, $p<.0001$; for speaker, $F(7,461)=20.519$, $p<.0001$. There was also an interaction between stress and speaker, suggesting interspeaker differences in their reliance on durational cues to stress: $F(14,461)=4.526$, $p<.0001$. All ANOVA results for individual speakers showed a significant overall effect of stress on duration and the same general pattern: primary stressed vowels were longest (87 milliseconds averaged over all speakers), and unstressed vowels were shortest (58 milliseconds), with secondary stressed vowels having intermediate duration values overall (76 milliseconds) and showing greater interspeaker variability relative to primary stressed and unstressed vowels. Pairwise posthoc tests tied to the overall ANOVA indicated significant differences at the $p<.0001$ level between all three stress levels. Average duration values for individual speakers for short vowels carrying different degrees of stress appear in Table 3. Table 4 shows the individual speaker pairwise comparisons that reach statistical significance.

Table 3. Duration values for vowels in words containing one or no long vowels (in milliseconds)

Speak	Prim Str V	Sec Str V	Unstr V
F1	100	75	54
F2	72	70	31
F3	92	85	73
F4	100	77	57
F5	92	75	67
M1	87	83	74
M2	104	94	67
M3	124	90	74

Table 4. Statistically significant differences in duration for individual speakers

Overall effect	Prim vs. Sec	Prim vs. Unstr	Sec vs. Unstr
All speakers	F1, F4, M2, M3	All speakers	F1, F2, F3, F4, F5, M2

Three speakers, F1, F4, and M2, made a three way length distinction according to posthoc tests. Speakers F2, F3, and F5, had a significant length difference between primary stressed and unstressed vowels and between secondary stressed and unstressed vowels. These three speakers did not reliably distinguish primary stressed and secondary stressed vowels in duration. Speaker M3 distinguished primary stressed vowels from both secondary stressed and unstressed vowels. Finally speaker M1 only reliably distinguished primary stressed and unstressed vowels; the duration of secondary stressed vowels fell between durations for the other two categories, not sufficiently distinct from either for the differences to reach statistical significance.

In summary, duration served to reliably differentiate primary stressed vowels from unstressed vowels for all eight speakers and secondary stressed vowels from unstressed vowels for six of eight speakers. Primary and secondary stress were durationally distinguished by four speakers. Increased duration may thus be regarded as a reliable property associated with stress in Chickasaw.

4.1.3. Intensity

An ANOVA pooled over all speakers and conducted on short vowels indicated a significant effect of both stress and speaker on intensity: for stress, $F(2,461)=24.477$, $p<.0001$, for speaker, $F(7,461)=156.646$, $p<.0001$. There was also an interaction between stress and speaker: $F(14,461)=5.011$, $p<.0001$. All three stress levels were differentiated in intensity according to Fisher's posthoc tests, with intensity greatest for primary stressed vowels (78dB averaged over all speakers), least for unstressed vowels (75dB) and intermediate for secondary stressed vowels (76dB): primary stressed vs. secondary stressed vowels, $p<.0001$; primary stressed vs. unstressed vowels, $p<.0001$; secondary stressed vs. unstressed vowels, $p=.0015$.

If words containing long vowels are included in the analysis, both stress ($F(2,780)=16.294$, $p<.0001$) and speaker ($F(7,780)=130.191$, $p<.0001$) exert a significant effect on intensity with the two factors interacting as well, $F(14,780)=6.469$, $p<.0001$. All three stress levels were distinguished in posthoc tests pooled over all speakers: primary stressed vs. secondary stressed vowels, $p=.0217$; both primary stressed and secondary stressed vowels vs. unstressed vowels, $p<.0001$.

Intensity values for individual speakers in words lacking long vowels and words containing a single long vowel appear in Table 5. Table 6 contains statistical summary results for individual speakers.

Table 5. Intensity values for vowels in words containing one or no long vowels (in decibels)

Speak	Long V	Prim Str V	Sec Str V	Unstr V
F1	76.9	72.5	70.3	66.7
F2	78.8	76.2	73.8	72.7
F3	79.7	84.1	83.8	83.1
F4	80.0	80.0	80.4	77.6
F5	78.9	78.6	79.4	74.6
M1	78.1	76.6	76.0	76.8
M2	72.6	71.8	68.6	69.5
M3	82.9	82.7	79.2	80.1

Table 6. Statistically significant differences in intensity for individual speakers

Word type	Overall effect	Prim vs. Sec	Prim vs. Unstr	Sec vs. Unstr
excluding Vː	F1, F2, F4, F5, M2, M3	F1, F2, M1, M2, M3	F1, F2, F4, F5	F1, F4, F5
including Vː	F1, F2, F3, F4, F5, M1, M3	F2, F3	F1, F2, F3, F4, F5, M1, M3	F4, F5, M1, M3

In words without a long vowel, all but two individual speakers, F3 and M1, showed a significant effect of stress level on intensity in separate ANOVAs. One speaker, F1, distinguished all three stress levels. Two speakers, F4 and F5, distinguished both primary and secondary stressed vowels from unstressed vowels. Speaker F2 distinguished primary stressed vowels from both secondary stressed and unstressed vowels. Speaker M1 did not display an overall effect of stress on intensity and only reliably distinguished primary from secondary stress. Speakers M2 and M3 had a significant difference between primary and secondary stressed vowels. Finally, speaker F3 did not show any effect of stress on intensity and did not use intensity to distinguish any of the levels of stress.

If words containing a long vowel are included in the analysis, intensity was significantly affected by stress level for all speakers except M2. Furthermore, all speakers except M2 distinguished at least two levels of stress in posthoc tests. Six speakers had greater intensity in primary stressed vowels than in unstressed vowels. Four of these six speakers, all except F1 and F2, also distinguished secondary stressed and unstressed vowels in intensity. One speaker, F2, also used intensity to distinguish primary and secondary stressed vowels. Finally, F3 displayed a different pattern: primary stressed vowels had slightly less intensity than both secondary stressed and unstressed vowels.

In summary, intensity is also a reliable cue to stress in Chickasaw, with all speakers using intensity differences to signal at least two levels of stress and multiple speakers distinguishing all three levels of stress. For all but one speaker, greater stress was associated with higher intensity. Speaker F3 was anomalous in not using intensity at all to mark stress in words lacking long vowels and having less intense long vowels than short vowels at all stress levels.

4.1.4 Vowel quality

Frequency values for the first two formants were also calculated for a subset of the speakers, F1, F2, and F3, to determine whether vowel quality differs as a function of stress level in Chickasaw. Cross-linguistically, many languages tend to centralize unstressed vowels, e.g. English (Bolinger 1958, Fry 1965), Maithili (Jha 1940-4, 1958), Tauya (MacDonald 1990), Delaware (Goddard 1979, 1982). For this phase of the experiment, surrounding consonant environment was controlled for by measuring vowel triplets with the same adjacent consonants but different levels of stress. The measured vowels were phonemically short. For example, one measured triplet consisted of the boldfaced vowels in the set: haʃː**a**n 'edible weed' (primary stress), tʃiʃ**a**nko 'arbor' (secondary stress), ʃ**a**nakhaʔ 'area between shoulder blades' (unstressed). The corpus appears in Appendix 2. Formants were calculated using an LPC analysis (10 poles) calculated over a 25 millisecond window centered in the middle of the vowel.

Collapsing speakers and the three different phonemic vowel qualities of Chickasaw (a, i, o) yielded a significant effect of stress on first formant values in a two factor ANOVA (stress and speaker as factors): $F(2, 274)=18.128$, $p<.0001$. Speaker did not exert a significant effect on first formant values, nor was there any interaction between stress and speaker as factors. Fisher's posthoc tests indicated that first formant values for both primary stressed and secondary stressed vowels were significantly ($p<.0001$) higher than those for unstressed vowels. Second formant values also differed as a function of stress level in a two-factor ANOVA: $F(2,274)=5.662$, $p=.0039$. Pairwise comparison showed that both primary and secondary stressed vowels had higher second formant values than unstressed vowels: primary stressed vs. unstressed, $p=.0012$; secondary stressed vs. unstressed, $p=.0165$.

Looking at individual vowels, the first two formants for the three vowels under different stress conditions are plotted in figure 2. Values for individual speakers appear in Table 7.

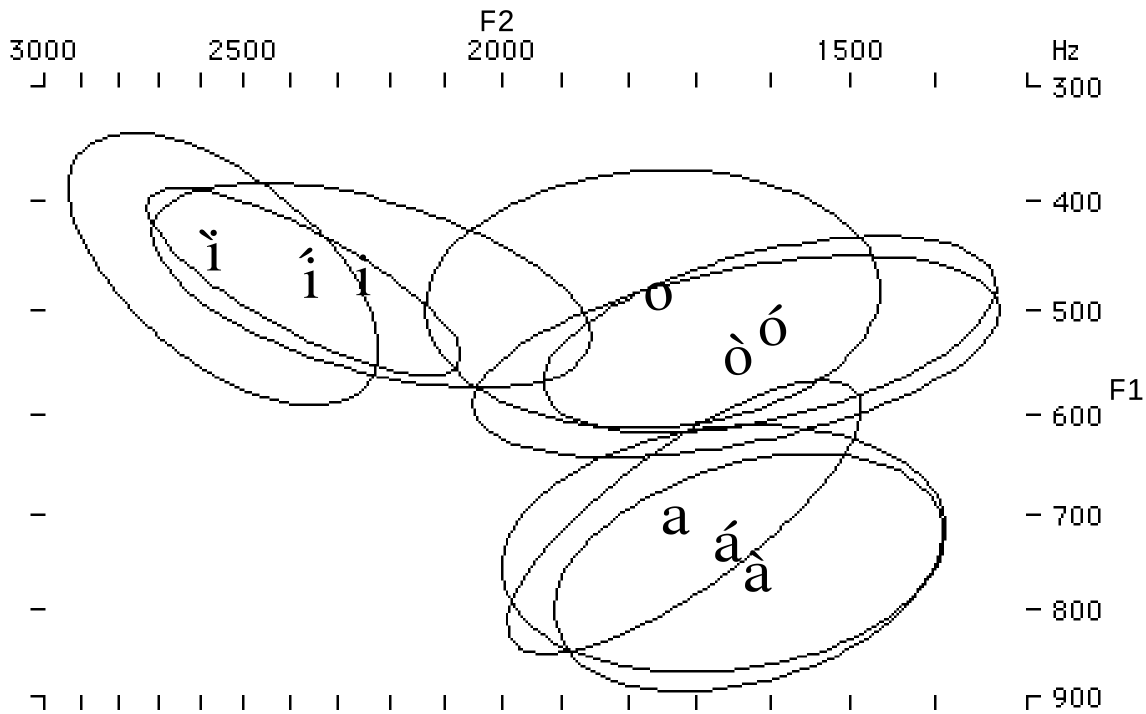

Figure 2. First and second formant values for vowels under different stress conditions (averaged over three speakers). Ellipses mark two standard deviations from mean.

Table 7. Fundamental frequency values for phonemic short vowels under different stress conditions.

		Speaker					
Vowel	Stress Level	F1		F2		F3	
		1st F	2nd F	1st F	2nd F	1st F	2nd F
	Primary	442	2429	477	2429	487	2308
i	2ndary	444	2678	472	2483	473	2501
	unstressed	497	2360	476	2169	465	2254
	Primary	705	1643	736	1681	773	1690
a	2ndary	744	1611	746	1676	798	1621
	unstressed	643	1643	736	1768	742	1776
	Primary	518	1477	471	1564	569	1777
o	2ndary	508	1651	525	1472	597	1846
	unstressed	503	1982	459	1612	510	1765

Looking at figure 2, the back vowel /o/ has slightly lower first and higher second formant values when unstressed than when either primary stressed or secondary stressed, suggesting a raising and fronting effect in unstressed /o/. Analyses of variance conducted for each formant for /o/ indicated a significant effect of stress level on frequency values for both formants: for the first formant, $F(2,34)=5.354$, $p=.0095$; for the second formant, $F(2,34)=13.936$, $p<.0001$. Pairwise posthoc tests for the first formant indicated a significant difference between secondary stressed and unstressed vowels, p=.0021, and a nearly significant difference between primary stressed and unstressed vowels, p=.0514. Second formant values differed significantly between primary stressed and unstressed vowels, p<.0001, and between secondary stressed and unstressed vowels, p=.0019. There was some variation between speakers in their formant values. Speaker F1 did not show any reliable differences in first formant as a function of stress, speaker F2 had higher first formant values under secondary stress than either primary stress (p=.0270) or no stress (p=.0071), and speaker F3 had higher first formant values for both primary (p=.0480) and secondary (p=.0070) stressed /o/ than unstressed /o/. Both of the ANOVAs to which the posthocs for these two speakers were pinned showed a significant effect of stress on first formant frequency: for speaker F2, F(2,11)=6.069, p=.0167; for speaker F3, F(2,12)=5.492, p=.0203. Speaker F1 shows a three way hierarchy in second formant values and an overall effect of stress on values according to an ANOVA: F(2,11)=17.214, p=.0004: highest for unstressed /o/ and lowest for primary stressed /o/. Pairwise posthoc comparisons between unstressed /o/ and both primary stressed (p=.0001) and secondary stressed /o/ (p=.0028) reached significance with the difference between primary and secondary stressed /o/ narrowly missing significance, p=.0570. Differences in the second formant did not reach significance for speaker F3. Speaker F2 had similar values for primary stressed and unstressed vowels, both of which had higher second formant values than secondary stressed vowels. Only the comparison between unstressed and secondary stressed reached significance, though, at p=.0151. The main ANOVA for this speaker indicated a significant effect of stress on formant values: F(2,11)=4.250, p=.0429.

Turning to /a/, first formant values were highest for secondary stressed vowels, slightly lower for primary stressed vowels, and lowest for unstressed vowels, though these differences were all fairly small. Second formant vowels were conversely highest for unstressed vowels, slightly lower for primary stressed vowels, and lowest for secondary stressed vowels. Overall these results suggest that unstressed /a/ is centralized relative to stressed /a/ and that secondary stressed /a/ is lower and backer than primary stressed /a/. ANOVAs conducted for both formants indicated a significant effect of stress level on first and second formant values: for the first formant, F(2,133)=.0027, p=.0027; for the second formant, F(2,133)=.0420, p=.0420. Pairwise posthoc tests showed a significant difference in first formant values between primary and secondary stressed /a/, p=.0190, as well as a difference between secondary stressed and unstressed /a/, p=.0007. The difference between primary stressed and unstressed vowels just missed significance at p=.0503. The only significant difference in second formant values was between secondary stressed and unstressed vowels, p=.0211. Speaker F1 followed the overall trend for secondary stressed vowels to have the higher first formant values and for unstressed vowels to have the lowest first formant levels. In an ANOVA, significance was high: F(2,48)=11.289, p<.0001. All pairwise posthoc tests reached significance: primary stressed vs. secondary stress, p=.0086; primary stressed vs. unstressed, p=.0072; secondary stressed vs. unstressed, p<.0001. The other two speakers did not reliably distinguish first formant values by stress level. The only speaker to distinguish second formant values was speaker F3, who was primarily responsible for the pattern seen in the overall result: highest second formant for unstressed vowels, lowest for secondary stressed vowels, and intermediate for primary stressed vowels. In an individual ANOVA, the effect of stress on the second formant was significant: $F(2,42)=7.483$, $p=.0017$. The pairwise posthoc comparison between primary stressed and secondary stressed vowels was significant at $p=.0159$, as was the comparison between secondary stressed and unstressed vowels at $p=.0009$. The difference between primary stressed and secondary stressed vowels narrowly missed significance at $p=.0525$.

Stress level had virtually no effect on the first formant of the front vowel /i/ and yielded insignificant results in both an ANOVA and posthoc tests pooled over all speakers. Separate ANOVAs for individual speakers also yielded insignificant results, though speaker F1 showed a tendency to raise first formant values for unstressed vowels relative to both primary and secondary stressed ones. The pairwise posthoc comparison between secondary stressed and unstressed vowels reached significance at $p=.0320$, while the comparison between primary stressed and unstressed vowels narrowly missed significance at $p=.0524$. All three levels of stress were differentiated in second formant values: the second formant was lowest for unstressed vowels, higher for primary stressed vowels, and highest for secondary stressed vowels. These differences suggest a centralization of unstressed /i/ relative to stressed /i/ and a fronting of secondary stressed /i/ relative to primary stressed /i/. An ANOVA indicated a significant overall effect of stress on the second formant, $F(2,89)=21.277$, $p<.0001$. Furthermore, pairwise comparisons between /i/ under different stress conditions were all significant: primary vs. secondary stress, $p=.0006$; primary vs. unstressed, $p=.0054$; secondary stressed vs. unstressed, $p<.0001$. ANOVAs conducted for individual speakers indicated a significant effect of stress level on second formant frequency for all three speakers: speaker F1, $F(2,23)=5.925$, $p=.0084$; speaker F2, $F(2,32)=12.780$, $p<.0001$; speaker F3, $F(2,34)=5.997$, $p=.0059$. Speaker F1 had higher second formant values for secondary stressed vowels than for either primary stressed ($p=.0343$ in posthoc tests) or unstressed vowels ($p=.0030$). Speaker F3 followed the same rank ordering of second formant values: secondary stressed vs. primary stressed vowels, $p=.0194$; secondary stressed vs. unstressed vowels, $p=.0017$. Speaker F2 had higher second formant values for both primary stressed and secondary stressed vowels than unstressed vowels: primary stressed vs. unstressed, $p=.0006$; secondary stressed vs. unstressed, $p<.0001$.

4.1.5. Lenition

The data also indicated the existence of a number of lenition processes affecting unstressed vowels. Unstressed high vowels optionally delete between voiceless consonants in word-medial syllables. Vowels (most commonly high vowels but also other vowels) also optionally undergo devoicing, which targets vowels in the first syllable of a word, including word-initial vowels before voiceless consonants. Figure 3 illustrates high vowel devoicing in an initial syllable.

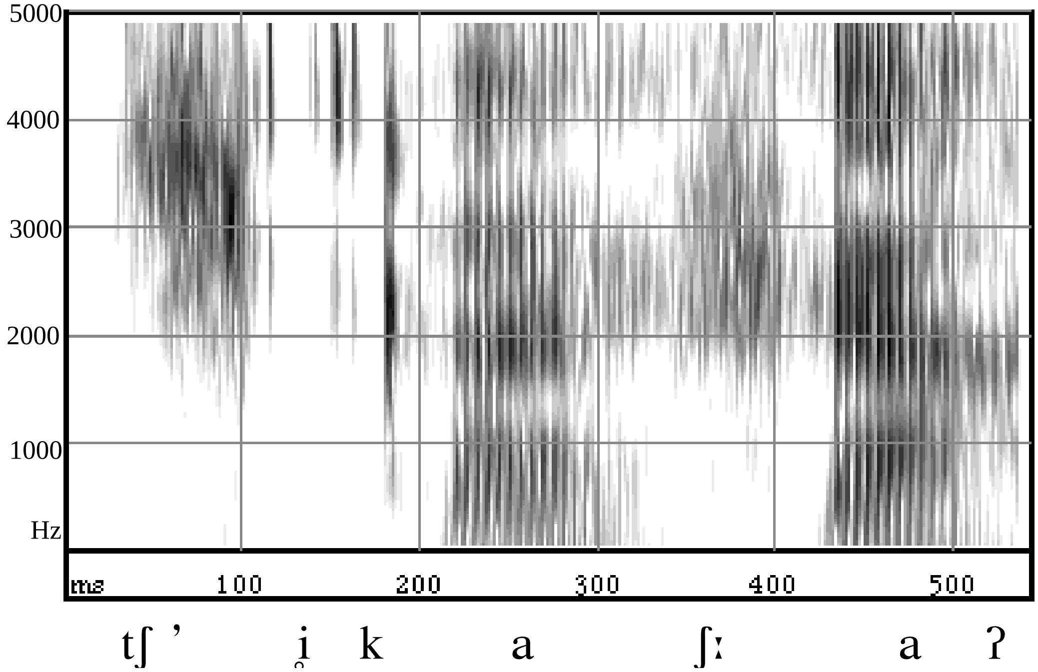

Figure 3. Spectrogram of the word /tʃiˌkaʃˈʃaʔˌ/ ‘Chickasaw’ containing a voiceless high vowel as produced by speaker F1.

In addition, unstressed vowels of all qualities are subject to a number of deletion processes in certain morphophonological environments described in detail by Munro and Ulrich (1984), Munro and Willmond (1994), and Munro (1996). These deletion processes feed certain segmental rules and may be viewed as an extreme form of vowel reduction.

4.1 Words with multiple long vowels

Although it is clear that all long vowels carry at least secondary stress in words with more than one CVV syllable, the determination of which CVV carries primary stress is less straightforward. In a series of recorded words containing two long vowels, there appears to be considerable variation in the location of primary stress between both speakers and individual tokens of the same word for a single speaker. In some cases, both long vowels carry equal prominence. There are also tokens displaying split prominence, whereby different long vowels in the same word are realized with different types of prominence. For example, one long vowel may be longer than the other long vowel, while the second long vowel has greater intensity and higher f0.

Alternate stress patterns (primary stress on the first long vowel, primary stress on the second long vowel, and primary stress on both long vowels) for a series of words containing multiple long vowels are illustrated in (5) which includes words with long vowels in different positions and words with different morphological compositions, i.e. monomorphemic nouns and nouns carrying the nominative suffix –at (realized as length on a preceding /a/).

(5)

ˈaːkiˌlaːʔ	ˌaːkiˈlaːʔ	ˈaːkiˈlaːʔ	wick
tʃoˈkːaːˌlaːʔ	tʃoˌkːaːˈlaːʔ	tʃoˈkːaːˈlaːʔ	guest
ˈjaːɬiˌpa-ːt	ˌjaːɬiˈpa-ːt	ˈjaːɬiˈpa-ːt	hat (subj)
tʃoˈkaːˌna-ːt	tʃoˌkaːˈna-ːt	tʃoˈkaːˈna-ːt	fly (subj)
ˌiʃtiˈlaːˌmaːˌtʃi	ˌiʃtiˌlaːˈmaːˌtʃi	ˌiʃtiˈlaːˈmaːˌtʃi	fan
ˈnaːfˌkaːɬˌtoʔ	ˌnaːfˈkaːɬˌtoʔ	ˈnaːfˈkaːɬˌtoʔ	suitcase
taˌʔosˈsaːˌʃaːˌtʃi	taˌʔosˌsaːˈʃaːˌtʃi	taˌʔosˈsaːˈʃaːˌtʃi	bank
ˈnaːˌholˌla-ːt	ˌnaːˌholˈla-ːt	ˈnaːˌholˈla-ːt	white man (subj)
ˌokˈtʃaːlinˌtʃa-ːt	ˌokˌtʃaːlinˈtʃa-ːt	ˌokˈtʃaːlinˈtʃaːt	savior (subj)
oˈsaːˌpa-ːt	oˌsaːˈpa-ːt	oˈsaːˈpa-ːt	field (subj)

Figures 4 and 5 show a spectrogram and waveform of the word /naːfkaːɬtoʔ/ ‘suitcase’ excerpted from two different tokens of the sentence /naːfkaːɬtoʔ laknatok/ ‘The suitcase was brown’ recorded by speaker F1. In figure 4, the first long vowel is associated with greater intensity and higher f0 than the second vowel, although the second long vowel is longer than the first one. In figure 5, the second long vowel has higher f0 and greater duration than the first long vowel, yet the first long vowel has greater intensity than the second long vowel.

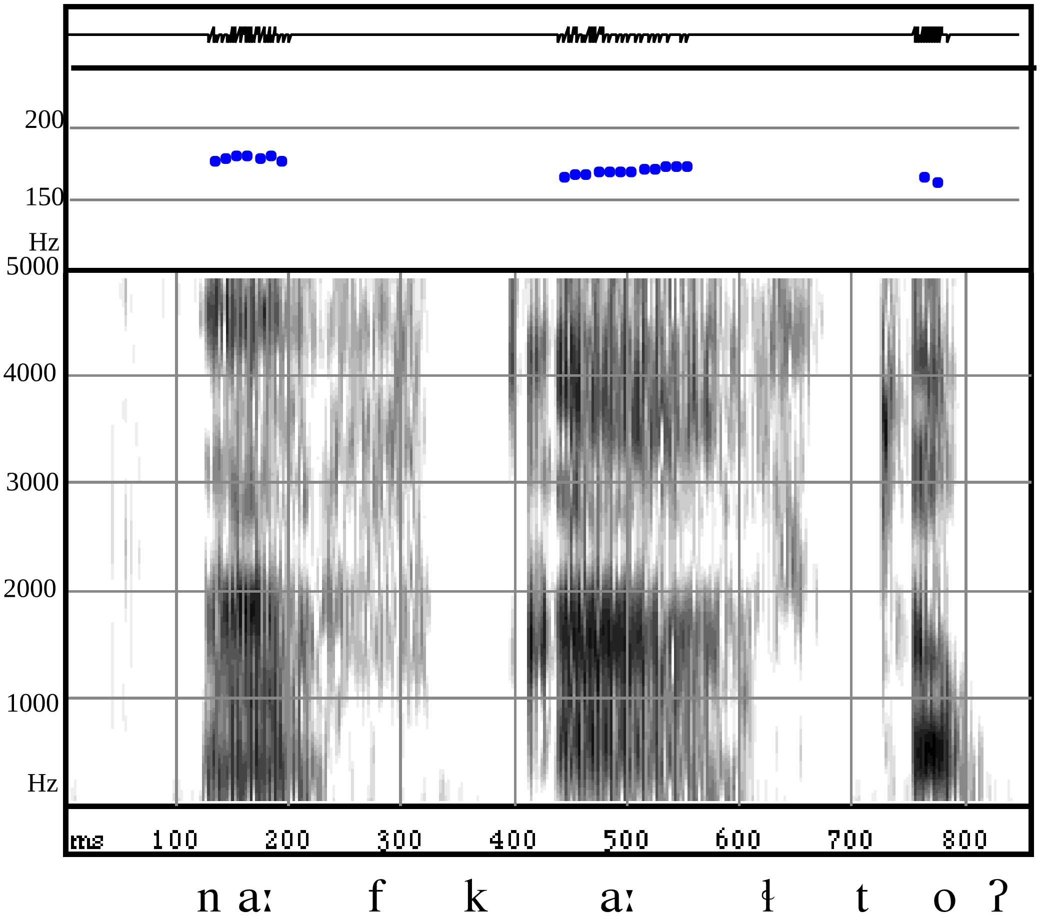

Figure 4. Spectrogram of the word /naːfkaːɬtoʔ/ ‘suitcase’ produced by speaker F1 with higher f0 and greater intensity on the first long vowel but longer duration associated with the second long vowel.

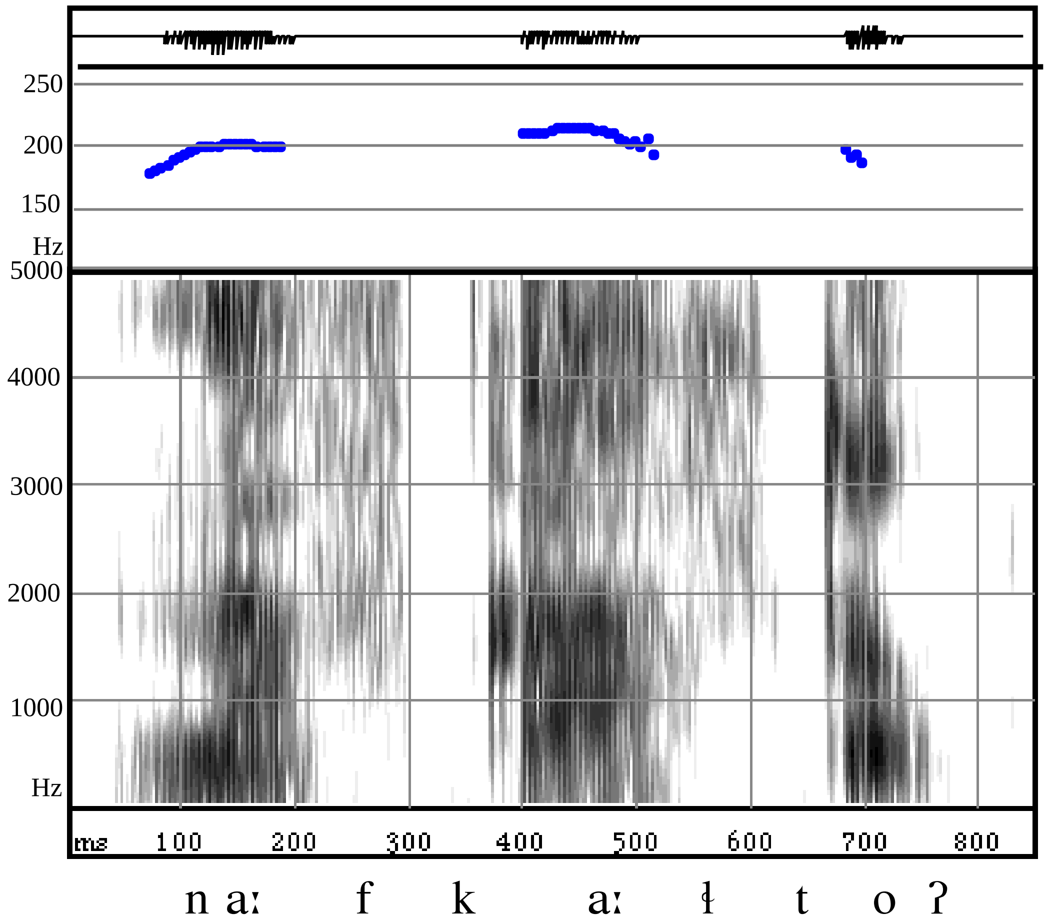

Figure 5. Spectrogram of another token of the word /naːfkaːɬtoʔ/ 'suitcase' also produced by speaker F1 with higher f0 and greater duration associated with the second long vowel but greater intensity on the first long vowel.

Given the intertoken and interspeaker inconsistency in primary stress placement, it is not surprising that results comparing long vowels pooled over multiple tokens seldom were seldom robust for fundamental frequency, duration, or intensity for any of the speakers. These properties are considered in turn in section 4.2.1-4.2.3.

4.1.1 Fundamental frequency

In a two-factor ANOVA (location of long vowel, i.e. first or second, and speaker) pooling results from all speakers, the first and the second long vowel were not robustly differentiated from each other in fundamental frequency: $F(1,256)=.071$, $p=.7902$. Speaker, however, did exert a significant effect on fundamental frequency: $F(7,356)=60.435$, $p<.0001$. There was no interaction between speaker and location of long vowel: $F(7,356)=1.534$, $p=.1545$. None of the individual speakers reliably used fundamental frequency to differentiate the first and second long vowel according to ANOVAs conducted for individual speakers, as table 8 shows.

Table 8. Fundamental frequency values for long vowels in words with two long vowels (in Hertz)

Speak	1st Long V	2nd Long V
F1	181	175
F2	215	212
F3	166	158
F4	182	158
F5	198	213
M1	129	145
M2	188	197
M3	112	116

4.1.2 Duration

Overall for all speakers, duration did not reliably differentiate the two long vowels in words with multiple long vowels: F(1,356)=.727, p=.3945 in an ANOVA. Duration did differ, however, as a function of speaker, F(7,356)=9.724, p<.0001, and there was an interaction between speaker and location of the long vowel, F(7,356)=2.788, p=.0078. Two speakers used duration to distinguish the two long vowels in a statistically robust manner. For speaker F1, the first long vowel was somewhat shorter than the second long vowel (125 ms vs. 112 ms; p=.01 in an unpaired t-test); if results are pooled across all words with two long vowels for this speaker. Speaker F2 showed the opposite trend: the second long vowel was significantly longer than the first one: p<.0001 according to an unpaired t-test. Other speakers did not consistently lengthen either the first or second long vowel. Results appear in table 9.

Table 9. Duration values for long vowels in words with two long vowels (in milliseconds)

Speak	1st Long V	2nd Long V
F1	125	112
F2	124	146
F3	132	94
F4	88	105
F5	94	93
M1	85	90
M2	109	129
M3	124	121

4.2.3 Intensity

Intensity was not useful in separating long vowels: F(1,356)=.022, p=.8818 in a two factor ANOVA conducted over all speakers. There was significant interspeaker variation in intensity: F(7,356)=165.781, p<.0001, but no interaction between the two factors. Six of the eight speakers did not have consistently greater intensity on one of the long vowels. Speaker F4 had greater intensity on the first long vowel in words with two long vowels, p=.0022, whereas speaker M3 had greater intensity on the second long vowel, p=.0141. Results are in table 10.

Table 10. Intensity values for long vowels in words with two long vowels (in decibels)

Speak	1st Long V	2nd Long V
F1	69.8	69.6
F2	82.5	83.1
F3	71.8	69.2
F4	83.8	80.4
F5	82.7	82.5
M1	78.3	82.2
M2	81.4	81.2
M3	85.3	87.7

5. Discussion

5.1. Acoustic correlates of stress

The present study has shown that Chickasaw displays clear acoustic correlates of prominence that point to three levels of stress : primary stress, secondary stress, and lack of stress. Differences in degree of stress are generally associated with differences along several acoustic dimensions similar to those reported for other languages: typically, the greater the level of stress, the greater the duration and intensity of vowels, and the higher their fundamental frequency. In general, duration is the most reliable property distinguishing different level of stress, being used more consistently than intensity in Chickasaw. The greater robustness of duration relative to intensity as a marker of stress is compatible with results from other languages, including English (Fry 1955). Fundamental frequency is primarily used to differentiate primary stressed vowels from other vowels and not to cue the difference between secondary stress and lack of stress. This result is perhaps not surprising given the important role of fundamental frequency in the verb grade system (see section 2.3).   F0 plays a further role in the phrase-level prominence system, where the final word in each Intonational Phrase carries a phonologically predictable pitch accent if does not already carry an inherent grade pitch accent on the penult, the rightmost docking site for a pitch accent (Gordon 1999, to appear). Using duration and intensity rather that f0 to differentiate secondary stressed vowels from unstressed vowels frees f0 to signal grade morphology as well as higher level prominence distinctions such as primary word-level stress and phrasal prominence. At the word level, Chickasaw's use of duration and intensity to signal prominence thus classifies it as a stress accent language in the sense of Beckman (1986).

Vowels also differ in quality, as reflected in their formant structure, depending on their level of stress in keeping with Chickasaw's classification as a stress accent language. Greater stress is characteristically associated with an expansion of the vowel space, though, curiously, the secondary stressed /i/ is associated with fronting relative to its primary stressed counterpart. Finally, unstressed vowels are subject to lenition processes such as devoicing and deletion that do not affect either secondary or primary stressed vowels. These cues to stress are most robust in words containing only short vowels and words containing a single long vowel. In words with multiple long vowels, there is considerable variation in the location of primary stress and also sharing of prominence between different long vowels in the same word.

Setting aside these indeterminate cases, the realization of stress is quite similar across speakers in Chickasaw, though not all speakers use the same cues to distinguish all levels of stress. Table 11 summarizes how individual speakers use intensity, fundamental frequency, and duration to signal differences in stress.

Table 11. Cues used by individual speakers to mark stress (F=f0, D=duration, I=intensity)

Speak	Primary vs. secondary	Primary vs. unstressed	Secondary vs. unstressed
F1	F, D	F, D, I	F, D, I
F2	F, I	D, I	D
F3	F, I	D, I	D
F4	D	D, I	D, I
F5	F	F, D, I	D, I
M1		F, D, I	I
M2	D	F, D	D
M3	D	D, I	I

All speakers use at least one of the three measured properties to distinguish all three levels of stress with one exception: the distinction between primary and secondary stress for speaker M1 did not emerge from the measured parameters. The greatest source of interspeaker variation was attributed to one female speaker, F3, who realized primary stressed long vowels but not short vowels with *lower* fundamental frequency and slightly *less* intensity than either unstressed or secondary stressed vowels contrary to other speakers. This result is atypical from a cross-linguistic standpoint, though there is circumstantial evidence that it perhaps has an analog in another language of North America, Kashaya (Buckley 1994), in which long vowels but not short vowels show a tendency to resist the high tone accent at the left edge of a word. It is conceivable that long vowels are inherently associated with lowered fundamental frequency in Kashaya, thus accounting for their rejection of the pitch accent. It is also interesting to note that certain tone languages, e.g. Lamba (Bickmore 1995), have low tone on all long vowels. The lowering of fundamental frequency and plausibly the lowering of intensity (which is often correlated with f0) by the one Chickasaw speaker may thus not be without precedent in languages of the world.[6] Such a strategy for marking stress is clearly rare cross-linguistically, however, and appears, on the basis of the eight speakers analysed in this paper, also not to be typical for Chickasaw. Rather, Chickasaw provides evidence

---

[6] It may also be worth noting that this speaker is the youngest of the recorded speakers and uses Chickasaw less frequently than the others. It is difficult to see, however, how this fact might explain her lowered f0 in long vowels. This speaker's prosody is otherwise similar to that of other speakers with respect to other phonetic properties, including intonation, durational patterns, and vowel quality.

that the acoustic cues to stress found in most languages of the world are also exploited in North American Indian languages.

5.2. Metrical analysis

The stress patterns diagnosed through acoustic analysis are compatible with a metrical analysis similar to the one presented in Hayes (1995) and discussed in section 2.1, although certain modifications are necessary in light of the present findings. First, final CV syllables immediately following another stress are metrically parsed into degenerate feet rather than left unparsed. Second, another tier of prominence is necessary in order to account for the distinction between primary and secondary stress. If present, CVV carries prominence on the primary stress tier; otherwise, the final syllable carries an additional grid mark in words lacking a CVV syllable. Revised metrical representations reflecting the primary stress and degenerate feet in final position appear in (6).

(6)

(x)	(x)	(x)
(x)(x)	(x)(x)	(x)(x)
tʃo ˈkaː ˌno ‘fly’	no ˌtak ˈfa ‘jaw’	ˈsaːɬ ko ˌna ‘earthworm’

It is interesting to note that the stress on final CV (as opposed to a pitch accent) and the evidence for a second tier of grid marks reflecting primary stress make Chickasaw different from its Western Muskogean neighbor Choctaw. The stressing of final CV after a heavy syllable in Chickasaw also differs from Creek, a Muskogean language whose prominence system has been the subject of recent phonetic investigation by Martin and Johnson (2002). Martin and Johnson (2002) find phonetic support for Haas’ (1977) analysis of Creek as having a weight-sensitive iambic system (CVV and CVC heavy) parallel to Chickasaw. Unlike Chickasaw, however, Creek assigns a pitch accent to the rightmost strong syllable in a word. Furthermore, Creek differs from Chickasaw in leaving final CV following another stress metrically unparsed. Creek also does not retract stress leftward onto CVV if there is a metrically strong syllable to its right and does not show pronounced lengthening of strong CV syllables. The forms in (7) (from Martin and Johnson 2002) illustrate the metrical parse of representative Creek words for point of comparison with the Chickasaw forms in (6).

(7)

(x)	(x)
(x)(x)	(x)(x)
al pa to tʃi ‘baby alligator’ (p.31)	tʃiː kol ko ‘purple martin’ (p.32)

In Chickasaw, the variation in the location of primary stress in words with multiple long vowels is indicative of variation in the configuration of level two grid marks. Three possible configurations exist. The rightmost CVV may be assigned a grid mark on the primary stress tier, the leftmost CVV may carry a level two gridmark, or both CVV in a word with two CVV may be associated with a primary stress grid mark (8).

(8)

```
(      x    )            ( x           )         ( x     x    )
( x )(  x )(x)           ( x )(  x )(x)          ( x )(  x )(x)
ˌnaːfˈkaːɬˌtoʔ           ˈnaːfˌkaːɬˌtoʔ          ˈnaːfˈkaːɬˌtoʔ    ‘suitcase’
```

It is worth noting that the rightmost configuration with two primary stresses constitutes a violation of the principle requiring that each prosodic word have a single primary stress. Further research is needed to investigate this issue in Chickasaw, including examination of words with greater than two long vowels and assessment of other potential correlates of stress.

5.3. Syllable weight

Chickasaw is typologically unusual in treating both CVC and CVV as heavy for secondary stress but not for primary stress, which asymmetrically falls on non-final CVV but not CVC. Languages with weight-sensitive stress characteristically do not make different weight distinctions depending on level of stress. Many languages assign stress to heavy syllables, either to both CVV and CVC or only to CVV depending on the language, and then promote one of the stressed syllables to primary stress on the basis of direction, either the rightmost or leftmost stressed syllable. Languages with systems combining weight-sensitive secondary stress with directionally-determined primary stress include Delaware (Goddard 1979, 1982), Fijian (Schütz 1985), and Cahuilla (Seiler 1957, 1965, 1977). Other languages, e.g. Kwakw’ala (Boas 1947, Bach 1975), Lushootseed (Hess 1976), are not reported as having secondary stress and simply assign primary stress on the basis of directionality and weight, stressing the rightmost or leftmost heavy syllable depending on the language. Finally, still others, e.g. Klamath (Barker 1964), Mam (England 1983), are sensitive to weight hierarchies involving three or more degrees of weight for primary stress, the only level of stress described.

Chickasaw is unusual for its three-way weight hierarchy operating over multiple levels of stress. CVV is heaviest since it attracts both primary and secondary stress, CVC is intermediate in weight since it is heavy only for secondary stress, while CV is lightest since it does not possess any stress-attracting abilities, except in final position where all syllables are stressed. I am aware of only two languages with a similar weight split between primary and secondary stress. One, Asheninca, assigns secondary stress to heavy syllables, CVV in the Pichis (Payne 1990) dialect and both CVV and CVC in the Apurucayalí (Payne et al. 1982) dialect, and places primary stress on the basis of a complex combination of vowel length and vowel quality. The other language, Nanti (Michael and Crowhurst 2002), is sensitive to a complex weight hierarchy involving vowel length, coda weight and vowel sonority, where the ordering of certain elements along the hierarchy differs between secondary and primary stress.

6. Summary

This paper has shown that at least three levels of stress can be acoustically distinguished in Chickasaw. Greater stress is characteristically associated with higher f0 and increased duration and intensity. In addition, vowels are qualitatively different as a function of their level of stress. The measured data provide support for a typologically unusual system of weight-sensitive stress. Stress falls on heavy syllables, i.e. long vowels and closed syllables, as well as on final syllables. Primary stress falls on the final syllable unless there is a long vowel, which carries primary stress even in non-final position. Primary stress in words with two long vowels is subject to free variation falling on either one or both of the long vowels.

References

Adisasmito-Smith, Niken and Abigail C. Cohn. 1996. Phonetic correlates of primary and secondary stress in Indonesian: A preliminary study. *Working Papers of the Cornell Phonetics Laboratory* 11: 1-16.

Bach, Emmon. 1975. Long vowels and stress in Kwakiutl. *Texas Linguistic Forum* 2: 9-19.

Baitschura, Uzbek. 1976. Instrumental phonetische Beiträge zur Untersuchung der Sprachmelodie und des Wortakzentes im Tscheremissischen. *Études Finno-Ougriennes XIII*: 109-22.

Barker, Muhammad Abd-al-Rahman. 1964. *Klamath Grammar*. University of California Publications in Linguistics 32. Berkeley: University of California Press.

Beckman, Mary. 1986. *Stress and Non-stress Accent*. Dordrecht: Foris.

Bickmore, L. 1995. Tone and stress in Lamba. *Phonology* 12: 307-41.

Boas, Franz. 1947. *Kwakiutl Grammar with a Glossary of the Suffixes*. Helene Boas Yampolsky and Zelig Harris (ed.). *Transactions of the American Philosophical Society* 37: 201-377.

Bolinger, D. L. 1958. A theory of pitch accent in English. *Word* 14: 109-49.

Bondarko, L. V., L. P. Verbitskaya, and L.P. Tscherbakova. 1973. Ob opredelenii mesta udareniya v slove. *Izvestiya AN SSSR, Seriya OLYA* 2.

Buckley, Eugene. 1994. Persistent and cumulative extrametricality in Kashaya. *Natural Language and Linguistic Theory* 12: 423-464.

Buckley, Eugene. 1998. Iambic lengthening and final vowels. *International Journal of American Linguistics* 64: 179-223.

Doherty, Brian. 1993. *The Acoustic-Phonetic Correlates of Cayuga Word-Stress*. Ph.D. dissertation. Harvard University.

England, Nora. 1983. *A Grammar of Mam, a Mayan Language*. Austin: University of Texas Press.

Everett, Daniel and Keren Everett. 1984. Syllable onsets and stress placement in Pirahã. *Proceedings of the West Coast Conference on Formal Linguistics* 3: 105-16.

Everett, Daniel. 1988. On metrical constituent structure in Pirahã. *Natural Language and Linguistic Theory* 6: 207-246.

Fitzgerald, Colleen. 1998. The meter of Tohono O'odham songs. *International Journal of American Linguistics* 64: 1-36.

Fitzgerald, Colleen. 1999. Loanwords and stress in Tohono O'odham. *Anthropological Linguistics* 41: 1-33.

Fry, D. B. 1955. Duration and intensity as physical correlates of linguistic stress. *Journal of the Acoustical Society of America* 27: 765-8.

Fry, D. B. 1965. The dependence of stress judgments on vowel formant structure. *Proceedings of the 5th International Congress of Phonetic Sciences*: 306-311.
Goddard, Ives. 1979. *Delaware Verbal Morphology*. New York: Garland.
Goddard, Ives. 1982. The historical phonology of Munsee. *International Journal of American Linguistics* 48: 16-48.
Gonzales, A. 1970. Acoustic correlates of accent, rhythm, and intonation in Tagalog. *Phonetica* 22: 11-44.
Gordon, Matthew. 1999. The intonational structure of Chickasaw. *Proceedings of the 14th International Congress of Phonetic Sciences*, pp. 1993-1996.
Gordon, Matthew. To appear. Intonational phonology of Chickasaw. In *Prosodic Models and Transcription: Towards Prosodic Typology*, edited by Sun-Ah Jun. Oxford: Oxford University Press.
Gordon, Matthew, Pamela Munro and Peter Ladefoged. 2000. Some phonetic structures of Chickasaw. *Anthropological Linguistics* 42: 366-400.
Haas, Mary. 1977. Tonal accent in Creek. In *Studies in Stress and Accent* [*Southern California Occasional Papers in Linguistics* 4], edited by Larry Hyman, pp. 195-208. Los Angeles: University of Southern California.
Hale, Kenneth. 1985. A note on Winnebago metrical structure. *International Journal of American Linguistics* 51: 427-9.
Hale, Kenneth and Josie White Eagle. 1980. A preliminary metrical account of Winnebago accent. *International Journal of American Linguistics* 46: 117-32.
Hargus, Sharon. 2001. Quality sensitive stress reconsidered. *University of Washington Working Papers in Linguistics* 20: 25-56.
Hayes, Bruce. 1995. *Metrical Stress Theory: Principles and Case Studies*. Chicago: University of Chicago Press.
Jassem, W., J. Morton, and M. Steffen-Batóg. 1968. The perception of stress in synthetic speech-like stimuli by Polish listeners. *Speech Analysis and Synthesis I*, edited by W. Jassem, pp. 289-308. Warsaw: Panstwowe Wydawnictwo Naukowe.
Jha, Subhadra. 1940-4. Maithili phonetics. *Indian Linguistics* 8: 435-459.
Jha, Subhadra. 1958. *The Formation of the Maithili Language*. London: Luzac.
Krauss, Michael (ed.). 1985. *Yupik Eskimo Prosodic Systems: Descriptive and Comparative Studies*. Fairbanks, Alaska: Alaska Native Language Center.
Lehiste, Ilse. 1970. *Suprasegmentals*. Cambridge, Mass.: MIT Press.
Liberman, Mark and Alan Prince. 1977. On stress and linguistic rhythm. *Linguistic Inquiry* 8: 249-336.
MacDonald, Lorna. 1990. *A Grammar of Tauya*. New York: Mouton de Gruyter.
Martin, Jack and Keith Johnson. 2002. An acoustic study of "tonal accent" in Creek. *International Journal of American Linguistics* 68: 28-50.
Michael, Lev and Megan Crowhurst. 2002. *Iterative footing and prominence driven stress in Nanti (Kampa)*. Ms. University of Texas at Austin.
Michelson, Karin. 1983. *A Comparative Study of Accent in the Five Nations Iroquoian Languages*. PhD dissertation. Harvard University.
Michelson, Karin. 1988. *A Comparative Study of Lake-Iroquoian Accent*. Dordrecht: Kluwer.
Miner, Kenneth. 1979. Dorsey's Law in Winnebago-Chiwere and Winnebago accent. *International Journal of American Linguistics* 45: 25-33.

Miner, Kenneth. 1989. Winnebago accent: the rest of the data. *Anthropological Linguistics* 31: 48-72.

Munro, Pamela. 1996. *The Chickasaw sound system*. Ms. UCLA.

Munro, Pamela and Charles Ulrich. 1984. Structure-preservation and Western Muskogean rhythmic lengthening. *West Coast Conference on Formal Linguistics* 3: 191-202.

Munro, Pamela and Catherine Willmond. 1994. *Chickasaw: An Analytical Dictionary*. Norman: University of Oklahoma Press.

Nicklas, Thurston Dale. 1974. *The Elements of Choctaw*. PhD dissertation. University of Michigan.

Nicklas, Thurston Dale. 1975. Choctaw morphophonemics. In *Studies in Southeastern Indian Languages*, edited by James Crawford, pp. 237-250. Athens, Georgia: University of Georgia Press.

Payne, Judith. 1990. Asheninca stress patterns. In *Amazonian Linguistics*, edited by Doris Payne, pp. 185-212. Austin: University of Texas Press.

Payne, David, Judith Payne, and Jorge Sanchez Santos. 1982. *Morphologia, Fonologia y Fonetica del Asheninca del Apurucayali*. Serie Lingüística Peruana 18. Pucallpa, Peru: Instituto Lingüístico de Verano.

Rigault, André. 1962. Rôle de la fréquence, de l'intensité et de la durée vocaliques dans la perception de l'accent en francais. *Proceedings of the Fourth International Congress of Phonetic Sciences*: 735-48.

Sapir, Edward. 1930. *Southern Paiute: A Shoshonean Language*. Cambridge, Mass.: American Academy of Arts and Sciences.

Schütz, Albert. 1985. *The Fijian Language*. Honolulu: University of Hawaii Press.

Seiler, Hansjakob. 1957. Die phonetischen Grundlagen der Vokalphoneme des Cahuilla. *Zeitschrift für Phonetik und allgemeine Sprachwissenschaft* 10: 204-23.

Seiler, Hansjakob. 1965. Accent and morphophonemics in Cahuilla and Uto-Aztecan. *International Journal of American Linguistics* 31: 50-59.

Seiler, Hansjakob. 1977. *Cahuilla Grammar*. Banning, CA: Malki Museum Press.

Sluijter, A. M. C. and V. J. van Heuven. 1996. Spectral balance as an acoustic correlate of linguistic stress. *Journal of the Acoustical Society of America* 100: 2471-2485.

Tuttle, Siri. 1998. *Metrical and Tonal Structures in Tanana Athabaskan*. PhD dissertation. University of Washington.

Ulrich, Charles. 1986. *Choctaw Morphophonology*. PhD dissertation. UCLA.

Wightman, C.W., S. Shattuck-Hufnagel, M. Ostendorf, and P.J. Price. 1992. Segmental durations in the vicinity of prosodic phrase boundaries. *Journal of the Acoustical Society of America* 92: 1707-17.

Acknowledgments

The author owes a great debt of gratitude to the Chickasaw speakers (Onita Carnes, Mary James, William Pettigrew, Eloise Pickens, Lee Fannie Roberts, Thomas Underwood, Jimmie Walker, and Catherine Willmond) who so kindly provided the data for this paper. Thanks to Keren Rice, Karin Michelson, Jack Martin, and John Alderete for their many extremely helpful comments and suggestions on an earlier draft of this paper. Thanks

also to Pam Munro for her encouragement and insightful feedback on my work on Chickasaw prosody.

Appendix 1. Words used for duration, intensity, and fundamental frequency measurements. Note that words containing multiple long vowels have both primary and secondary stressed marked for long vowels indicating the variability in primary stress location.

Object in carrier phrase

ˌamˌbakˈbak	woodpecker
paˈkãːʔˌliʔ	proper name
tʃaˌlanˈtak	buckeye
noˌtakˈfa	jaw
ˌtakˈha	catfish
ˌhaʃˈʃan	edible weed
ˌʃanˈtiʔ	rat
tʃiˌʃanˈko	arbor
ʃaˌnakˈhaʔ	area between shoulders
ˌtʃaʃʃaˈnak	nape, base of neck
ˈãːˌhaʃˌʃan	my edible weed (my=/ãː/)
haˌkaʃˈtap	trash
tʃiˌkaʃˈʃaʔ	Chickasaw
saˌtʃonˈkaʃ	my heart (my=/sa/)[7]
ˈãːhaˌkaʃˌtap	my trash (my=/ãː/)
ˌkaʃˈti	flea
kaˌnanˈnak	green striped lizard
iˌbiɬˈkan	snot
ˌaŋˌkanˈtak	my green briar plant (my=/aŋ/)
ˌkanˈtak	green briar plant
taˈnap	war
ˌtanˈnap	other side
ʃaˌlakˈlak	goose
ʃaˌlakˈhaʔ	liver
hoˌʃolˈlak	bran, hulls of chorn
ˈãːʃaˌlakˌlak	my goose (my=/ãː/)
ˌsaɬkoˈna	intestines
ˈsaːɬkoˌna	earthworm

ˌʃinˈka	nightbird
haˌʃinˈtak	comb
ʃiˈnok	sand, dirt
ˌiʃˈkin	eye
tʃoˌkoʃˈpa	story
ˌlokˈtʃok	mud
ˌtʃokˈfiʔ	rabbit
ˌokˌfokˈkol	snail
aˈboːkoˌʃiʔ	river
tʃoˈkaːˌno	fly
ˌokˈtʃaːˌlinˌtʃiʔ	savior
taˈlaːˌnomˌpaʔ	telephone
ˌoʃˈpaːˌniʔ	Mexican
ˌmaʃˈkoːˌkiʔ	Creek
ˌʃimmaˈnoːˌliʔ	Seminole
ˈʃiːˌki	buzzard
ˌˈaːbiˌˈtʃiːˌliʔ	spout
ˌˈaːfoˌˈjoːˌpaʔ	vent
ˌˈaːkiˌˈlaːʔ	wick
ˌtʃokˌˈkaːˌˈlaːʔ	guest
ˌiʃˌˈtaːtakaːˌliʔ	hinge
ˌiʃtilaːmaːˌtʃiʔ	fan
ˌnanˌˈnaːˌˈtʃiːˌfaʔ	sink
ˌˈnaːfˌˈkaːˌkanˌtʃiʔ	dry-goods store
ˌˈnaːfˌˈkaːɬˌtoʔ	suitcase
ˌˈnaːfˌˈkaːtakaʔˌliʔ	nail
ˌˈnaːfˌˈkaːtaˌkohˌliʔ	clothesline
ˌtʃokfaɬˌˈpoːbaˌˈpiːsaˌtʃiʔ	shepherd
ˌˈoːˌˈtaːɬɬiˌkaʔ	edge
taˌʔosˌˈsaːˌˈʃaːˌtʃiʔ	bank

[7] The first person inalienable suffix is /sa/, while the alienable prefix has four allomorphs: /an/ before /t/, /am/ before /p/, /aŋ/ before /k/, and /ãː/ before fricatives (see Munro and Willmond 1994).

fa'la	crow	ˌpasˌ'kaːnoˌ'naːˌtʃiʔ	oven
'ãːfaˌla	my crow (my=/an/)		
ʃo'tik	sky	Subject (-at) in carrier phrase	
ˌinˌtik'ba	sibling		
ˌtoksi'kaʔ	hearth	ˌhatta'kat	man
'ãːʃoˌtik	my sky (my=/ãː/)	ˌ'baːˌtamˌ'baːt	proper name
ˌiɬpi'tʃik	nest	tʃoˌ'kaːˌ'naːt	fly
tʃiˌkaʃ'ʃaʔ	Chickasaw	'ˌkaːˌ'laːt	collar
'tʃiːˌkoʔˌsiʔ	fast	ˌokˌ'tʃaːˌlinˌ'tʃaːt	savior
ˌtʃiski'lik	blackjack oak	oˌ'saːˌ'paːt	field
'jaːɬiˌpa	hat	ˌoʃˌ'paːˌ'naːt	Mexican
ˌamˌpas'ka	my bread (my=/am/)	ˌ'jaːɬiˌ'paːt	hat
'waːˌkaʔ	cow	naˌ'ʃoːˌ'baːt	wolf
na'ʃoːˌba	wolf	ˌ'naːˌholˌ'laːt	white man

Appendix 2. Words used for formant measurements. Measured vowel appears in boldface.

ʃaˌl**a**k'l**a**k	goose	ˌinˌt**i**k'baʔ	sibling
hoˌʃol'l**a**k	hulls of corn	ʃo't**i**k	sky
saˌl**a**k'haʔ	liver	ˌtoks**i**'kaʔ	hearth
ˌkan't**a**k	green briar plant	ˌlok'tʃ**o**k	mud
noˌt**a**k'fa	jaw	ˌtʃ**o**k'fiʔ	rabbit
t**a**'kõːˌlo	peach	tʃ**o**ˌkoʃ'pa	story
ˌamˌb**a**k'b**a**k	my woodpecker (my=/am/)		