Some Phonetic Structures of Chickasaw

MATTHEW GORDON
University of California, Santa Barbara

PAMELA MUNRO AND PETER LADEFOGED
University of California, Los Angeles

Abstract. This paper provides a quantitative phonetic study of Chickasaw, a Muskogean language spoken in Oklahoma. Basic properties such as vowel quality, voice onset time, and consonant closure duration are examined and compared with the corresponding properties in other languages of the world. We also examine quantitative properties of the typologically unusual three-way length distinction in Chickasaw vowels.

1. Introduction. Chickasaw is an American Indian language spoken mainly in the Chickasaw Nation of south-central Oklahoma (indicated in figure 1) by no more than a few hundred speakers. Originally residents of the southeastern United States, the Chickasaws were one of the "Five Civilized Tribes" (along with the Choctaws, Creeks, Seminoles, and Cherokees) moved during the 1830s into the present state of Oklahoma. Chickasaw belongs to the Western branch of the Muskogean language family, along with closely related Choctaw. Chickasaw and Choctaw share many features, but differ markedly at all levels of grammar (Munro 1987). Perhaps because they are familiar with the Choctaw Bible and Hymnal, most Chickasaw speakers have some knowledge of Choctaw (Munro 1996).

Figure 1. Map indicating location of current Chickasaw nation and location of original Chickasaw homeland (based on map in Gibson 1971:5) prior to their removal to Oklahoma.

Chickasaw has been the subject of less linguistic research than Choctaw. Munro (to appear) provides a grammatical overview of Chickasaw and includes an analyzed text of a traditional

Chickasaw story. Munro and Willmond (1994) is a dictionary that also contains a thorough description of Chickasaw grammar. This paper relies on Munro and Willmond (1994), Munro (1996), and Munro (to appear) for phonological descriptions as well as many qualitative phonetic observations.

The present paper represents the first quantitative phonetic study of Chickasaw, providing a detailed description of several phonetic properties of Chickasaw vowels and consonants. Basic acoustic properties such as voice onset time, closure duration, and vowel formants are discussed, along with typologically more unusual aspects of Chickasaw, such as the pervasive length contrast in consonants and acoustic correlates of the three-way distinction in vowel length.

2. The present study. The present study is based on a word list of approximately 150 words that was designed to illustrate the principal phonetic features of Chickasaw. This word list was checked and recorded by one female speaker, F2, in Los Angeles. The remainder of the fieldwork was conducted in Oklahoma, where the word list was elicited from a further thirteen speakers, seven women and six men. Recordings were made in the speakers' homes, using a headmounted noise-canceling microphone, which ensured an approximately 45 dB signal to noise ratio. Speakers repeated each word twice while recordings were made on a Sony Digital Audio Tape Recorder at a sampling rate of 48 kHz. Upon return to the UCLA Phonetics Laboratory, the data that were to be used for acoustic analyses were transferred to the Kay Computerized Speech Lab and down-sampled to eight kHz so as to provide greater accuracy for analysis in the frequency domain (cf. Ladefoged 1997). Data from one of the male speakers was not analyzed quantitatively, since several features of his phonology and morphology differed markedly from the other speakers; thus, this paper presents data from eight female and five male speakers.

3. Vowels. Chickasaw has three different vowel qualities, which occur short, long, and nasalized. The nasalized vowels behave as long vowels, both phonetically in terms of duration and phonologically with respect to rules that are sensitive to syllable weight (see Munro and Willmond 1994 for discussion). The Chickasaw vowels are represented in table 1 in a broad transcription. The phonetic realization of vowel quality is discussed in section 3.1.

Table 1. Chickasaw vowels

SHORT	LONG	NASALIZED
i	***iː***	***i)***
o	***oː***	***o)***
a	***aː***	***a)***

In addition to the vowels in table 1, there are two other sets of phonetic vowels which arise on the surface. First, in certain morphologically derived forms termed "grades" (see Munro and Willmond 1994 for discussion), one non-final vowel in a word may carry a pitch accent, phonetically realized as a high tone; e.g., ***hik:i/ya*** 'he's standing up' from ***hika*** 'to stand up (punctual)'. Another set of vowels which plays a pervasive role in the phonology arises from a process of phonetic lengthening in alternate open syllables. This process of "rhythmic lengthening" lengthens the second in a series of two consecutive phonemically short vowels in open syllables that are not word final (for further discussion, see Munro and Ulrich 1984, Munro and Willmond 1994, and Munro et al. in preparation). Rhythmic lengthening is plausibly linked to the location of stress in Chickasaw. Word-final syllables, closed syllables, syllables containing long vowels, and syllables containing rhythmically lengthened vowels are realized with increased prominence which could be termed stress (Munro 1996, Munro et al. in preparation, Gordon 1999), though "stressed" syllables at the word-level are less prominent than stressed syllables at the phrase-level. If one assumes that stress falls on the second of a sequence of two consecutive open syllables containing a phonemic short vowel, rhythmic lengthening could be viewed as lengthening of a short stressed vowel in an open non-final syllable. In this paper, rhythmically lengthened vowels will be denoted with a half-long symbol; e.g., *aˑ*, in order to differentiate them from the phonemic long vowels such as *aː*. We will refer to the surface short vowels that are not lengthened by the rhythmic lengthening rule as "short" in the remainder of this paper.

3.1. Vowel quality. The frequencies of the first three formants for short, rhythmically lengthened, and long vowels were measured using an LPC display calculated over a thirty millisecond window in the center of the vowel superimposed over an FFT spectrum calculated over a 25.6 millisecond window. Measurements from the LPC display were checked against the FFT spectrum and visually against a spectrogram to enhance the accuracy of the formant measures. In most cases, the LPC window was calculated using fourteen coefficients, though more coefficients were sometimes used where resolution of the formants was particularly difficult. The targeted vowels all appeared in the third syllable of words with four syllables. In all cases, the target vowel was surrounded on both sides by ***l***. Two tokens were targeted for measurement for each speaker. Occasionally, however, only one measurement could be made, either because the intended word was uttered only once or because the acoustic signal did not allow for reliable measurement. The words examined appear in table 2.

Table 2. Words used to examine the quality of Chickasaw vowels

VOWEL	SHORT	RHYTHMICALLY LENGTHENED	LONG
a	***iSolːali*** 'you laugh'	***iStalaˑli*** 'I bring it here'	***iStalaːli*** 'you set it upright'
i	***impihlili*** 'I sweep for him'	***toksaliˑli*** 'I work'	***hatʃiːJiːli*** 'he hoes for you all'
o	***tʃihakloli*** 'I listen to you'	***iːJholoˑli*** 'I put on (shoes) for him'	***hatʃiːJoːlo/*** 'your (pl) doodlebug'

Average formant values for the vowels were taken for the thirteen speakers. Values appear in table 3. Each box delimited by thick lines contains data from a single speaker. Speakers are coded numerically and according to their gender (FS for female speakers and MS for male speakers); FS1 indicates female speaker 1, FS2 indicates female speaker 2, and so on. Formant values are for the first three formants (listed in columns) averaged over the two tokens recorded for each speaker.

Mean formant values for the first two formants are plotted in figure 2 for the female speakers. Axes are scaled non-linearly on a Bark scale (Zwicker and Feldtkeller 1967) to correspond more closely to the frequency domain in the auditory dimension. Ellipses indicate two standard deviations from the mean, which is plotted as a larger version of the vowel that it represents. Because paired t-tests showed no significant differences between the lengthened and long vowels for F1 or F2 for the female speakers, they are collapsed as long vowels in figure 2.

Table 3. Formant values for Chickasaw short, lengthened, and long vowels from thirteen speakers (two tokens averaged together for each speaker)

SPEAKER &VOWEL	LENGTH	F1	F2	F3	SPEAKER &VOWEL	LENGTH	F1	F2	F3
FS1					**FS8**				
	Short	448	1993	2606		Short	476	2296	3138
i	Lengthened	427	2406	2937	***i***	Lengthened	413	2662	3069
	Long	399	2517	3000		Long	400	2358	3027
	Short	696	1545	2703		Short	676	1848	2813
a	Lengthened	883	1427	2683	***a***	Lengthened	869	1579	2641
	Long	820	1345	2676		Long	889	1441	2697
	Short	469	1531	2062		Short	496	1193	2351
o	Lengthened	600	1344	2062	***o***	Lengthened	607	1269	2813
	Long	627	1276	1938		Long	679	1289	2827
FS2					**MS1**				
	Short	462	2241	3152		Short	427	1745	2475
i	Lengthened	448	2613	3179	***i***	Lengthened	420	1848	2331
	Long	413	2738	3131		Long	324	1882	2186
	Short	537	1855	2807		Short	620	1448	2579
a	Lengthened	882	1814	3614	***a***	Lengthened	655	1344	2455
	Long	889	1931	3606		Long	669	1275	2386
	Short	386	1425	2938		Short	489	1200	2220
o	Lengthened	448	1041	3007	***o***	Lengthened	427	938	2344
	Long	545	1195	3290		Long	427	1055	2331
FS3					**MS2**				
	Short	351	1848	2379		Short	413	1883	2331
i	Lengthened	379	2048	2200	***i***	Lengthened	434	1965	2345
	Long	379	2241	3152		Long	386	2006	2407
	Short	434	1317	2241		Short	710	1524	2317
a	Lengthened	662	1268	2206	***a***	Lengthened	620	1420	2537
	Long	572	1227	2103		Long	641	1317	2517
	Short	427	1379	2193		Short	482	1289	2110
o	Lengthened	393	1069	2220	***o***	Lengthened	496	1048	2848
	Long	400	1021	2262		Long	413	1062	2124
FS4					**MS3**				
	Short	427	1999	2275		Short	338	1834	2179
i	Lengthened	372	2455	2827	***i***	Lengthened	331	1820	2276
	Long	317	2469	2821		Long	331	1896	2110
	Short	565	1572	2414		Short	565	1503	2207
a	Lengthened	648	1289	2883	***a***	Lengthened	655	1365	2489
	Long	751	1200	2924		Long	662	1296	2351
	Short	434	1131	2241		Short	413	1324	1903
o	Lengthened	407	1014	2483	***o***	Lengthened	365	875	2200
	Long	400	1028	2200		Long	427	875	2241

Table 3. Formant values for Chickasaw short, lengthened, and long vowels from thirteen speakers (two tokens averaged together for each speaker) (continued)

FS5					**MS4**				
	Short	393	2448	2807		Short	399	1931	2531
i	Lengthened	413	2579	2986	***i***	Lengthened	455	1917	2496
	Long	441	2600	2848		Long	393	2000	2379
	Short	696	1903	2717		Short	538	1489	2551
a	Lengthened	855	1496	2745	***a***	Lengthened	648	1386	2586
	Long	875	1476	2772		Long	648	1386	2634
	Short	469	1696	2503		Short	455	1413	2386
o	Lengthened	434	993	2717	***o***	Lengthened	469	1062	2475
	Long	427	951	2648		Long	448	1028	2441
FS6					**MS5**				
	Short	503	2207	2758		Short	427	2007	2572
i	Lengthened	510	2234	2869	***i***	Lengthened	413	2248	2724
	Long	489	2151	2903		Long	406	2262	2565
	Short	765	1710	2917		Short	503	1538	2606
a	Lengthened	896	1627	2765	***a***	Lengthened	800	1462	2800
	Long	738	1634	2131		Long	759	1400	2710
	Short	572	1365	2496		Short	462	1345	2400
o	Lengthened	565	1510	2675	***o***	Lengthened	434	1034	2469
	Long	545	1255	2806		Long	393	1069	2317
FS7									
	Short	365	1972	2827					
i	Lengthened	393	1744	2676					
	Long	310	2200	2896					
	Short	628	1538	2669					
a	Lengthened	875	1420	2724					
	Long	931	1393	2249					
	Short	448	1234	2483					
o	Lengthened	545	1097	2289					
	Long	621	1131	2207					

Looking at figure 2, it is apparent that short vowels are generally centralized for female speakers relative to their lengthened and long counterparts. This centralization is most apparent for the non-low vowels in the F2 (front-back) dimension. An analysis of variance of the front vowel with duration category (short, lengthened, long) and repetition number (first or second) as independent variables demonstrated a significant effect of duration category on F2 values ($F(2, 41)=4.770$, $p=.0137$), but no significant effect on F1 ($F(2, 41)=1.610$, $p=.2123$) or F3 values ($F(2, 41)=2.292$, $p=.1138$). Fisher's PLSD tests indicate that the source of this difference in F2 values is primarily between the short and rhythmically lengthened vowels ($p=.0282$) and between the short and phonemically long vowels ($p=.0046$). F2 values for the rhythmically lengthened and phonemically long vowels differed insignificantly from each other according to Fisher's PLSD tests ($p=.4661$). Repetition number did not significantly affect formant values (for F1, $F(2, 41) = .810$, $p=.3734$; for F2, $F(2, 41)=.094$, $p=.7607$; for F3, $F(2, 41)=.596$, $p=.4444$).

Like the front vowel, an analysis of variance of the back vowel with duration category and repetition number as independent variables demonstrated a significant effect of duration category on F2 values ($F(2, 42)=7.664$, $p=.0015$), but no effect on F1 ($F(2, 42)=1.755$, $p=.1854$) and F3 values ($F(2, 42)=.548$, $p=.5821$). Once again, Fisher's PLSD posthoc tests demonstrated that the main source of this effect lay in the difference between short and rhythmically lengthened (p=.0027) and between short and phonemically long vowels (p=.0009). Repetition number did not have any effect on values for any of the formants (for F1, F(2, 42)=.126, p=.7249; for F2, F(2, 42)=.061, p=.8056); for F3, F(2, 42)=.048, p=.8270).

In the case of the low vowel, the centralization is principally a matter of vowel height, reflected in F1 values, but also involves small fronting differences, as reflected in F2 values. An analysis of variance of the low vowels with duration category and repetition number as independent variables indicates a significant effect of duration category on F1 (F(2, 41)=15.946, p<.0001) and F2 (F(2, 41)=4.008, p=.0257), but not F3 (F(2, 41)=.998, p=.3773) for the low vowels. Fisher's PLSD tests indicated that the primary source for the F1 and F2 differences lay in differences between short and rhythmically lengthened vowels (for F1, p<.0001; for F2, p=.0479) and between short and phonemically long vowels (for F1, p<.0001; for F2, p=.0094). Rhythmically lengthened and long vowels did not differ from each other in either the F1 or F2 dimensions according to a Fisher's PLSD posthoc test (for F1, p=.5628; for F2, p=.5265). Speaker F6 was atypical in that none of her short vowels were substantially centralized relative to their lengthened or long counterparts. Repetition number did not exert a significant effect on formant values (for F1, F1(2, 41)=.226, p=.6371; for F2, F1(2, 41)=.075, p=.7853; for F3, F1(2, 41)=.042, p=.8389).

Values for the first two formants for the short and long vowels for male speakers are plotted in figure 3. For the male speakers (unlike the female speakers), only the phonemically long back vowel is neutralized with its lengthened counterpart; phonemically long ***aː*** and ***iː*** are not qualitatively neutralized with their lengthened counterparts. Consequently, phonetically lengthened ***aˑ*** and ***iˑ*** are omitted from figure 3 and are shown in comparison with their phonemically long counterparts in figure 4.

As figure 3 shows, the male speakers show a tendency for the short vowels to be centralized relative to their long and lengthened counterparts. However, statistically this effect is significant only for the back and low vowels. An analysis of variance conducted for the back vowels using duration category and repetition number as independent variables indicated an effect of duration category on F1 (F(2, 22)=4.058, p=.0316) and F2 values (F(2, 22)=40.076, p<.0001), but not F3 (F(2, 22)=2.228, p=.1314) values. Fisher’s PLSD posthoc tests indicate that the effect of duration category on F1 and F2 was primarily attributed to significant differences between short and rhythmically lengthened vowels along both the F1 (p=.0318) and F2 (p<.0001) dimensions, and between short and phonemically long vowels also on the F1 (p=.0174) and F2 (p<.0001) dimensions. Repetition number had no statistical effect on F1 (F(2, 22)=.082, p=.7774), F2 (F(2, 22)=.153, p=.6997), or F3 (F(2, 22)=.427, p=.5201).

For the low vowels, an analysis of variance with duration category and repetition number as independent variables indicated an effect of duration category on F1 (F(2, 23)=5.572), p=.0106) and F2 (F(2, 23)=21.848, p<.0001), but not F3 (F(2, 23)=1.324, p=.2857). Fisher's PLSD posthoc tests indicated that short vowels were differentiated from rhythmically lengthened vowels along both the F1 (p=.0090) and F2 (p=.0002) dimensions. Short vowels were also differentiated from phonemically long vowels along both the F1 (p=.0085) and F2 (p<.0001) dimensions. Additionally, rhythmically lengthened vowels differed from phonemically long vowels in the F2 dimension (p=.0415), but not in the F1 (p=.9193) dimension. Repetition number affected neither F1 (F(2,23) = ..052, p=.8216), F2 (F(2,23) = .615, p=.4410), nor F3 significantly (F(2,23) = .444, p=.5120) values.

Turning to the front vowel, duration category did not have a significant effect on F1 (F(2,24) = 2.645, p=.0916), F2 (F(2,24) = 2.004, p=.1568), or F3 (F(2,24) = .893, p=.4226) values. However, the F1 difference between long and lengthened front vowels barely reached statistical significance in a Fisher's PLSD posthoc test (p=.0382) and the F2 difference between short and long vowels almost reached statistical significance (p=.0588). Repetition number did not exert an influence on any of the formant values (for F1, F(2,24) = .053, p=.8191; for F2, F(2,24) = .215, p=.6474); for F3, F(2,24) = .902, p=.3518).

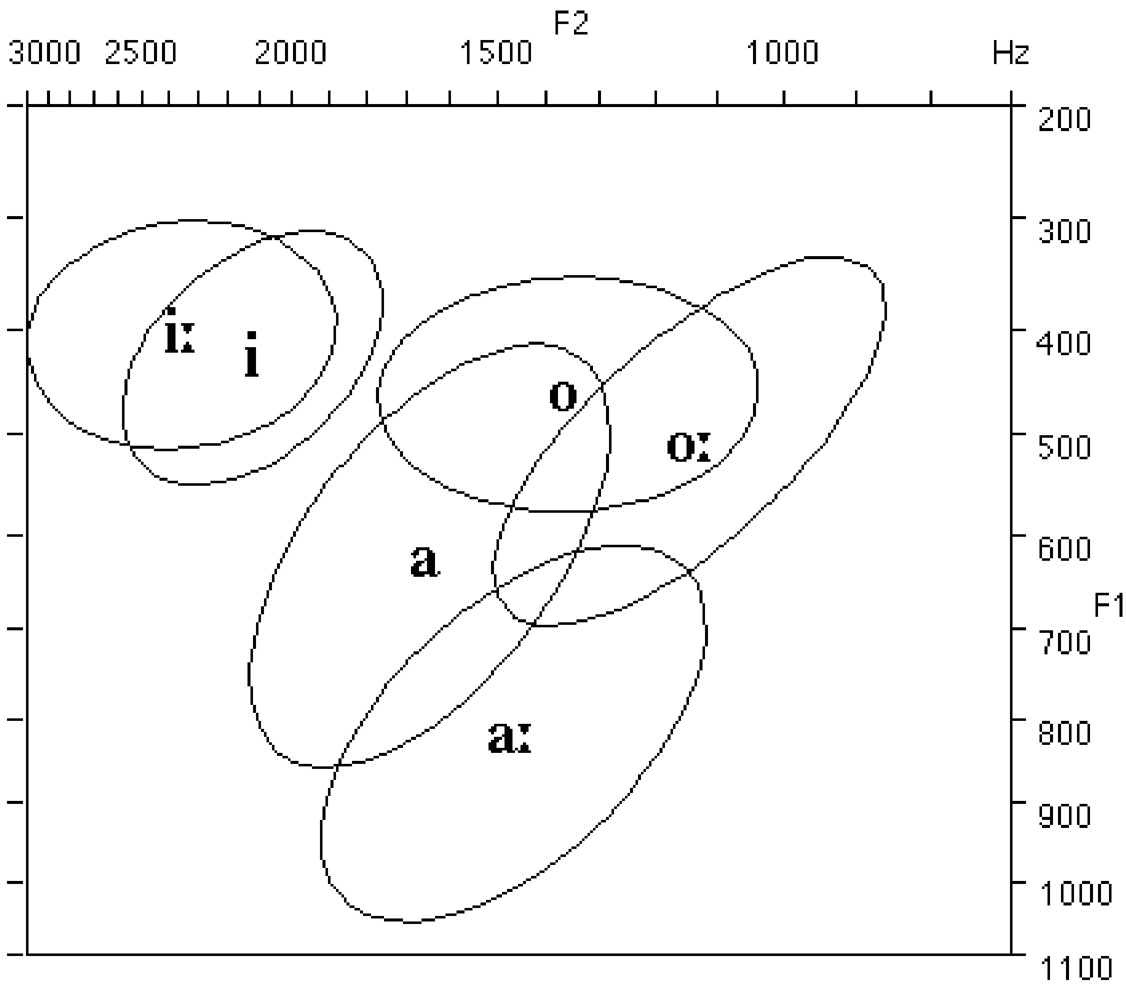

Figure 2. Plot of the first two formants for eight female speakers (phonemically long and lengthened vowels are collapsed).

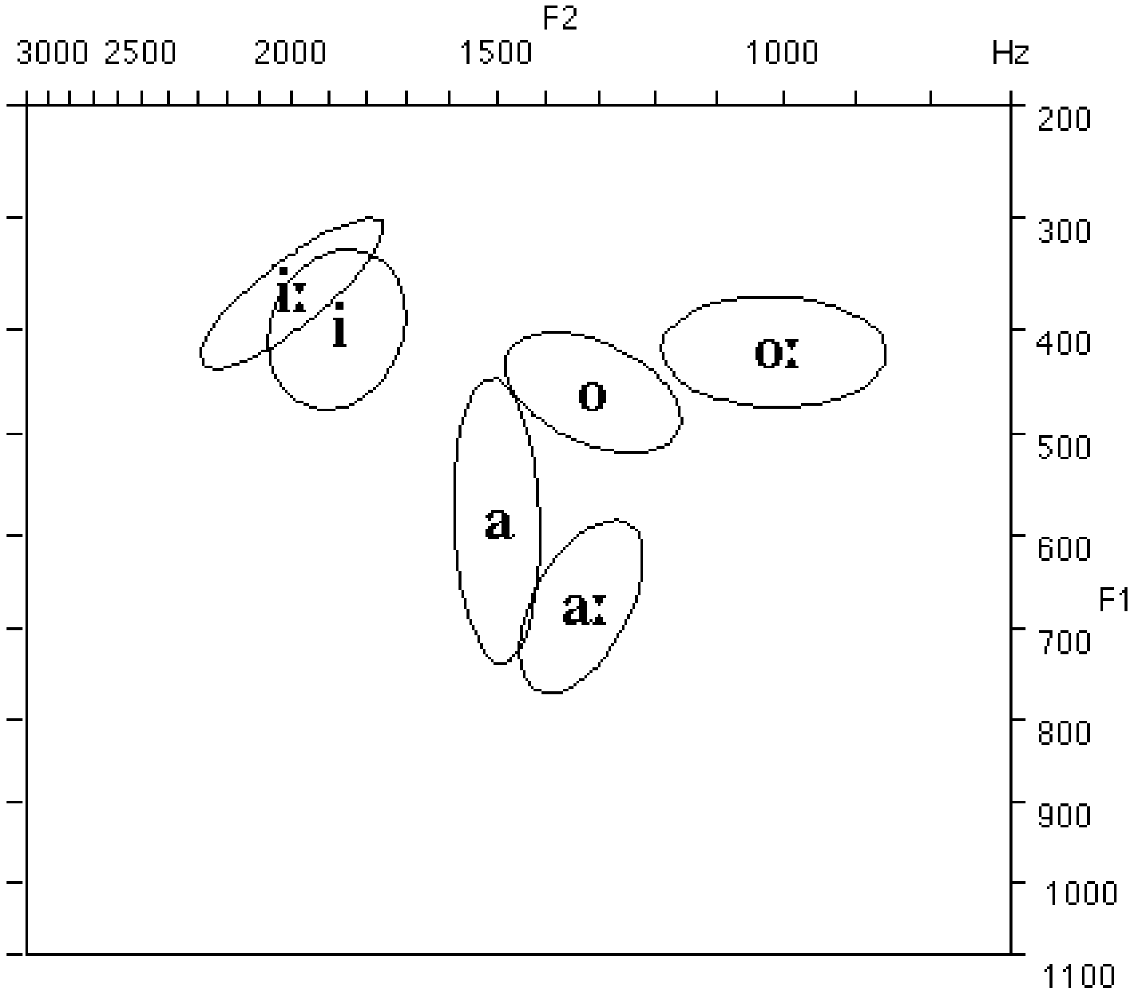

Figure 3. Plot of the first two formants for five male speakers (short vs. phonemically long vowels).

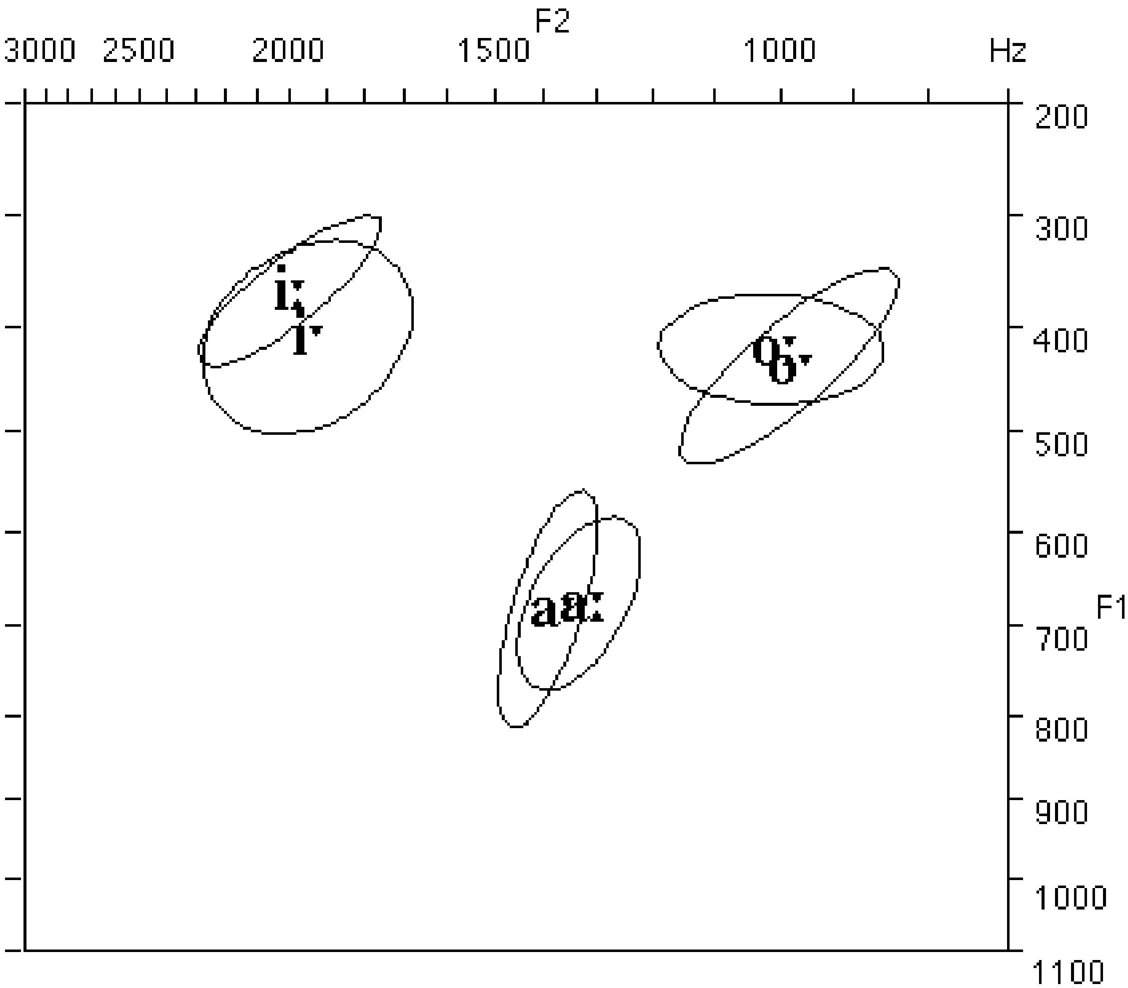

Figure 4. Plot of the first two formants for long and lengthened vowels for five male speakers.

Looking at the lengthened and long vowels in figure 4, F2 for lengthened ***a***ˑ is slightly higher than for phonemically long ***a***ː, and F1 for lengthened ***i***ˑ is somewhat higher than for phonemically long ***i***ː. Comparing figures 3 and 4, the lengthened variants of ***i*** and ***a*** tend to be somewhat intermediate in quality between short and phonemically long vowels for the male speakers.

One of the interesting properties of Chickasaw vowels for both male and female speakers is that the non-low back vowel is not as high as the corresponding non-low front vowel, as the transcription (and the orthography) suggest. Though this difference in height reaches statistical significance only in the case of the female speakers' long vowels, it is nevertheless apparent for all vowels in both Figures 2, 3, and 4. It is quite common for languages with three vowel qualities to have ***o*** and ***i*** as their non-low vowels, rather than ***u*** and ***i***. For example, Mura-Pirahã (Sheldon 1974) and Hupa (Golla 1970, Gordon 1996) both have ***o*** rather than ***u*** as their non-low back vowel. The lack of a phonetic high back round vowel in languages that have a high front vowel is also attested in languages with a greater number of contrastive vowel qualities, e.g. Navajo (McDonough and Austin-Garrison 1994) and Banawá (Ladefoged and Everett 1997), which have four phonemic vowels, Nootka (Sapir and Swadesh 1939), which has five vowel qualities, as well as Wari' (MacEachern, Kern, and Ladefoged 1996), which has six vowel qualities. Based on Crothers' (1978) typology of vowel systems, there is a particularly strong tendency for back vowels to have a relatively low articulation (i.e. more like [o]) in three vowel systems as compared to systems with a greater number of contrastive vowel qualities.

Before concluding the discussion of vowel quality, it is worth mentioning an interesting difference between male and female speakers apparent if one compares figures 2 and 3. The female speakers generally show fairly large variation (relative to the male speakers) for any single vowel, as reflected in the relatively large (compared to figure 3) ellipses in figure 2. Looking at values for individual speakers in table 3, the greater variation for female speakers seems to be largely attributed to differences among the female speakers.

In order to examine quantitatively the apparently greater variation in formant values for female speakers as opposed to male speakers, the coefficient of variation was calculated for each vowel quality (front, central, and back; all vowel quantities collapsed for a single vowel quality) for three random sets of five female speakers and compared with the coefficient of variation for the same vowel produced by the five male speakers. The results appear in table 4.

Table 4. Coefficients of variation for Chickasaw vowels by vowel and gender

VOWEL	FORMANT	MALES	FEMALES		
			FS3, FS5, FS6, FS7, FS8	FS1, FS2, FS3, FS5, FS6	FS1, FS2, FS3, FS7, FS8
a	F1	.120	.196	.199	.215
	F2	.062	.129	.147	.151
	F3	.063	.108	.163	.159
i	F1	.111	.151	.113	.120
	F2	.074	.120	.112	.133
	F3	.076	.093	.100	.104
o	F1	.088	.162	.170	.177
	F2	.154	.168	.177	.128
	F3	.094	.099	.159	.165

In all cases, the coefficient of variation for a given formant of a given vowel is larger for the randomized groups of female speakers than for the male speakers. This result offers quantitative support for the impressionistic observation that variation in formant values among female speakers is greater than variation in formant values among male speakers.

3.2. Vowel duration. The durations of short, lengthened, and long vowels were also measured from a waveform (in conjunction with a spectrogram) using the same corpus used to measure vowel quality in table 2. Non-lengthened short vowels are (not surprisingly) shortest, and phonemically long vowels are longest, with rhythmically lengthened vowels falling between the two non-derived vowel lengths. The duration difference between phonemically long vowels and rhythmically lengthened vowels was less than that between rhythmically lengthened and short non-lengthened vowels, as shown in figure 5.

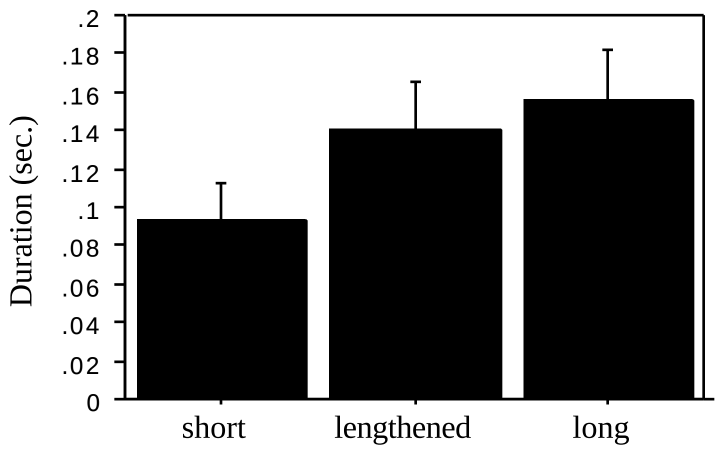

Figure 5. Duration of short, long, and rhythmically lengthened vowels over 13 speakers.

An analysis of variance with vowel quality (front, low, back), duration category (short, rhythmically lengthened, phonemically long), and repetition number demonstrated a significant effect of both vowel quality (F(2, 191)=9.787, p<.0001) and duration category (F(2, 191)=153.595, p<.0001), but not repetition number (F(1, 191)=.095, p=.7581) on duration. Fisher's PLSD posthoc tests revealed that low vowels were significantly longer than both the front (p=.0006) and the back vowels (p=.0019), though these differences were phonetically fairly small: low vowels minus front vowels = .013 seconds on average, low vowels minus back vowels = .012 seconds on average. Front vowels did not differ significantly from back vowels in terms of duration (p=.7236, .001 seconds).

Fisher's PLSD posthoc tests collapsed over all vowel qualities indicated that each of the three categories of duration were significantly different from one another. The mean for lengthened vowels was .048 seconds longer than that of short vowels (p<.0001). The mean for phonemically long vowels was .063 seconds longer than that of short vowels (p<.0001). Finally, the mean for long vowels was only .014 seconds longer than that of lengthened vowels, a difference which nevertheless reached statistical significance (p=.0002) according to Fisher's PLSD posthoc tests tied to the main analysis of variance described in the preceding paragraph.

Paired (by speaker) t-tests collapsing all vowel qualities also indicated a significant duration difference between the three durational categories: short vs. lengthened vowels (t (2, 65)=15.811, p<.0001); short vs. long vowels (t (2, 65)=18.778, p<.0001; lengthened vs. long vowels (t (2, 63)=4.770, p<.0001). Paired (by speaker) t-tests separated by vowel quality and comparing short vowels with long vowels indicated highly significant durational differences between the two categories: for the low vowel, t (2, 17)=13.621, p<.0001; for the front vowel, t (2, 22)=8.173, p<.0001; for the back vowel, t (2, 24)=13.758, p<.0001. Likewise, the short and lengthened categories were also durationally distinct from each other according to paired t-tests: for the low vowel, t (2, 20)=13.729, p<.0001; for the front vowel, t (2, 21)=7.276, p<.0001; for the back vowel, t (2, 22)=11.101, p<.0001. However, paired t-tests separated by vowel quality indicate that the duration difference between lengthened and long vowels only reached statistical significance for the front vowel (t (2, 22)=5.460, p<.0001), but not for the low vowel (t (2, 17)=1.474, p=.1588) or the back vowel (t (2, 22)=1.794, p=0865). The relatively small magnitude of the duration difference between the long and lengthened vowels and its inconsistency across vowel qualities raise interesting questions about its perceptual robustness. Future work on Chickasaw vowel duration will hopefully include perception experiments designed to test the distinctness of the three-way length contrast in the perception domain.

Turning to results for individual speakers shown in table 5, the short vowels are substantially shorter than both the long and the lengthened vowels for all speakers. Looking at the means averaged over all speakers in table 5, phonemically long /aː/ is 1.78 times longer than its non-lengthened phonemically short counterpart. Phonemically long /oː/ is 1.72 times as long as long as non-lengthened /o/, whereas long /iː/ is only 1.55 times as long as non-lengthened /i/. These long-to-short duration ratios fall at the lower end of those reported for vowels in other languages (see Lehiste 1970 for representative data from several languages). However, the relatively small duration differences between long and short vowels is consistent with the relatively small length differences between long and short consonants in Chickasaw (see section 4.2).

Interestingly, there is some variation in whether the phonemically long vowels are longer than the rhythmically lengthened vowels, as a function of both speaker and vowel quality. For the low vowel, eight of ten speakers for whom the comparison could be made show a length difference between long and lengthened ***a***. For one of these speakers (FS4), the difference is only one millisecond. Another speaker (FS1) shows no difference between lengthened and long ***a***, while MS1 actually displays a reversal: his long ***aː*** is actually shorter than his lengthened ***aˑ***. For the high front vowel, all speakers follow the same pattern for lengthened ***iˑ*** to be shorter than phonemically long ***iː***, though the difference is negligible in the case of speaker FS3. The non-low back vowel displays the greatest interspeaker variation. For six speakers (FS1, FS4, FS6, MS3, MS4, MS5), long ***oː*** is more than negligibly longer than lengthened ***oˑ***. Speakers FS3, FS5, FS6, and FS7 essentially show no difference between long and lengthened ***o***. Speakers FS2, MS1, and MS2 have a longer lengthened ***oˑ*** than long ***oː***. In summary, the overall tendency is for lengthened vowels to be slightly shorter than phonemically long vowels.

Table 5. Duration of short, long, and rhythmically lengthened vowels by speaker

	a			*i*			*o*		
SPEAKER	SHORT	LENGTH'D	LONG	SHORT	LENGTH'D	LONG	SHORT	LENGTH'D	LONG
FS1	.088	.179	.179	.073	.126	.186	.089	.173	.197
FS2	.070	.117	.141	.073	.079	.096	.042	.120	.105
FS3	.090	.156	----	.113	.147	.148	.088	.144	.146
FS4	.090	.175	.176	.088	.128	.170	.075	.148	.163
FS5	.090	.148	.158	.083	.127	.146	.078	.156	.157
FS6	.100	----	----	.096	.105	.126	.096	.106	.159
FS7	.091	.167	.175	.103	.132	.157	.110	.156	.160
FS8	.078	.146	.196	.074	.126	.159	.093	.150	.145
MS1	.093	.170	.131	.086	.106	.118	.072	.133	.116
MS2	.130	.177	.189	.119	----	----	.093	.129	.121
MS3	.101	.129	----	.106	.126	.146	.088	.121	.148
MS4	.111	.163	.178	.109	.149	.184	.113	.160	.170
MS5	.101	.149	.174	.141	.160	.168	.103	.146	.166
Means	.095	.156	.169	.097	.126	.150	.087	.141	.150

Regression analyses were performed to examine whether the magnitude of duration differences between long and lengthened vowels acts as a reliable predictor of formant differences between long and lengthened vowels. The hypothesis being tested was that some speakers systematically rely principally on duration to differentiate the long and lengthened vowels while others rely more on vowel quality. A test was performed to see whether differences in values for the first and second formant between lengthened and long vowels correlated with differences in duration between the two length categories. Results indicated that duration differences did not as a reliable predictor of quality differences along either the F1 (R^2 = .001) or F2 (R^2 = .019) dimensions, arguing against the hypothesis that length and quality differences between the long and lengthened vowels are correlated.

4. Consonants. Chickasaw has an inventory of sixteen consonant phonemes, with an additional velar nasal ***N***, which occurs predictably on the surface before an underlying velar stop followed by a voiced consonant in certain morphologically derived forms, called the n- and hn- grades (see Munro and Willmond 1994 for discussion of Chickasaw grades). The consonants of Chickasaw appear in table 6 below.

Table 6. The consonants of Chickasaw

	BILABIAL	LABIO-DENTAL	DENTAL/ ALVEOLAR	POST ALVEOLAR	LABIAL-VELAR	VELAR	GLOTTAL
STOPS	***p b***		***t***			***k***	***/***
AFFRICATES				***t^{S}***			
FRICATIVES		***f***	***s, 0̀***	***S***			***h***
RESONANTS	***m***		***l, n***				
GLIDES			***j***		***w***		

The bilabial stop ***b*** is voiced throughout its entire closure and is often lenited to a voiced fricative or approximant for some speakers. Geminate ***b***ː more rarely undergoes lenition as well. Singleton but not geminate ***k*** is sometimes lenited to a fricative; it also may be voiced, particularly before sonorants, as discussed below. It also appears to be occasionally realized with a more backed articulation than velar stops in English, though it is clearly phonetically distinct from phonemic uvular stops in other languages. Some younger speakers, including one of the speakers examined for this study (F8), produce the lateral fricative as an interdental fricative ***T***. The voiceless stops are characterized by very short voice-onset times which fall within the range of values for unaspirated stops in languages with an aspiration contrast for stops (Cho and Ladefoged 1997). However, there is a longer aspiration phase in word-initial than word-medial position, though this observation has not been quantitatively tested (see section 4.1. for discussion of voice onset time). All consonants except glottal stop appear as both singletons and geminates.

Most possible combinations of consonants are attested in bisegmental clusters. However, glottal stop may not be the second member of a cluster (Munro 1996). For many speakers, an epenthetic vowel is inserted in clusters consisting of ***k*** or *h* followed by a sonorant (Munro 1996). This vowel is typically realized with a schwa-like quality and the ***k*** is often voiced in such clusters (Munro 1996). An example of an epenthetic vowel as spoken by speaker F6 is found in the spectrogram in figure 6.

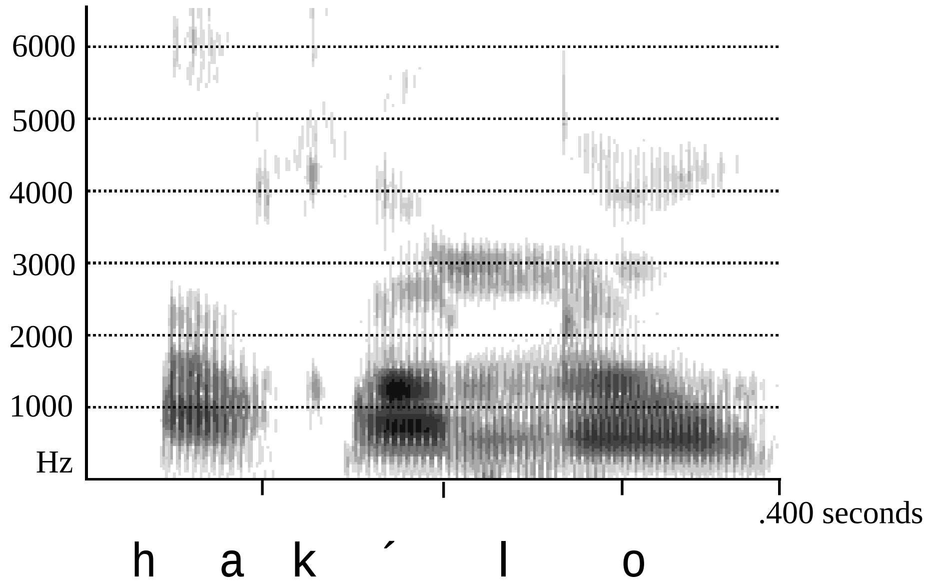

Figure 6. Example of an epenthetic vowel breaking up a stop + sonorant cluster in the word *haklo* 'he hears' (speaker F6).

4.1. Voice onset time (VOT) and closure duration for voiceless stops. Voice onset time (the period from consonant release to the onset of voicing of the following vowel, abbreviated VOT) was measured for the three voiceless unaffricated stops before the vowel ***a***. Measurements were made from a waveform in conjunction with a spectrogram for the single (non-geminate) stops in the three words: ***0̀ipa*** 'worn out, ragged', ***ayiːmita*** 'he's excited', ***hika*** 'stand up!'. Two tokens of each consonant were recorded in most cases for each speaker, except where the consonant underwent lenition. Because of lenition, there are no measurements for ***k*** for speaker MS1. Results of the VOT measurements pooled over the 13 speakers appear in figure 7. Results for individual speakers appear in table 7 along with mean values averaged over all speakers.

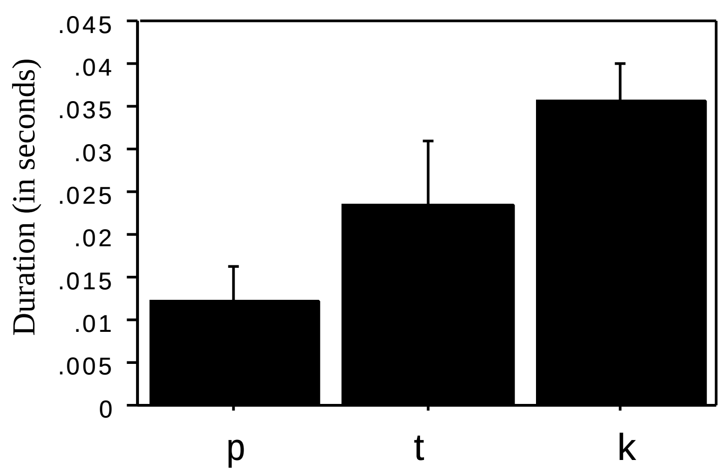

Figure 7. VOT for voiceless unaffricated stops before ***a***.

Table 7. VOT for unaffricated stops (in seconds)

SPEAKER	CONSONANT *p*	*t*	*k*
FS1	.030	.027	.037
FS2	.014	-.008	.025
FS3	.013	.028	.039
FS4	.007	.012	.023
FS5	.014	.011	.029
FS6	.005	.008	.022
FS7	.030	.016	.041
FS8	.017	.037	.044
MS1	.013	.020	lenited
MS2	.010	.025	.034
MS3	.008	.014	.051
MS4	.015	.074	.042
MS5	-.008	.022	.040
Means	.012	.021	.036

The VOT of Chickasaw stops is comparable with that of stops in other languages of the world that have been classified as voiceless unaspirated (Cho and Ladefoged 1997). A two-factor analysis of variance with place of articulation and repetition number as independent variables indicated a significant effect of place of articulation (F(2, 73)=19.834, p<.0001) but not repetition number (F(2, 73)=.230, p=.6333) on VOT. Fisher's posthoc tests demonstrated that all three voiceless stops were significantly different from one another in terms of VOT (for ***p*** vs. ***t***, p=.0011; for ***p*** vs. ***k***, p<.0001; for ***t*** vs. ***k***, p=.0040), with the bilabial displaying the shortest average VOT, followed by the dental/alveolar, and finally the velar stop. In addition, a series of t-tests paired by speaker indicated significant differences in VOT duration between the three places of articulation: ***p*** vs. ***t***, t (2, 24)=2.843, p=.009; ***p*** vs. ***k***, t (2, 21)=7.632, p<.0001; ***t*** vs. ***k***, t (2, 21)=2.902, p=.0085.

Four female speakers (FS1, FS2, FS3, FS5) did not display the trend for bilabials to have a shorter VOT than alveolars. For all speakers except MS4, alveolars had shorter VOTs than velars. For none of the speakers was VOT longer for bilabials than for velars. The differences in VOT associated with the different places of articulation are also similar to those found in other languages (Cho and Ladefoged 1997).

Stops made at different places of articulation differ not only in VOT but also in the duration of the articulatory closure. An analysis of variance with place of articulation and repetition number as independent variable showed a significant effect of place of articulation (F(2, 74)=27.831, p<.0001) but not repetition number (F(2, 74)=.234, p=.6301) on closure duration. Across speakers, closure duration for the voiceless bilabial stop is longest followed by the dental/alveolar stop followed by the velar stop, as shown in figure 8. All of these place dependent differences reach statistical significance according to a Fisher's posthoc test tied to the main analysis of variance just reported: for ***p*** vs. ***t***, p<.0001; for ***p*** vs. ***k***, p<.0001; for ***t*** vs. ***k***, p=.0404. T-tests paired by speaker also indicated significant closure duration differences between the three places of articulation: for ***p*** vs. ***t***, t (2, 25)=6.299, p<.0001; for ***p*** vs. ***k***, t (2, 22)=9.082, p<.0001; for ***t*** vs. ***k***, t (2, 22)=3.063, p=.0057. Measurements of closure duration for individual speakers and mean values averaged over all speakers appear in table 8. One speaker (MS4) shows a longer closure duration for ***k*** than for ***t***, an exception to the general pattern. An additional three speakers (FS4, FS5, and FS8) do not display a substantial difference in closure duration between ***t*** and ***k***. Closure duration for ***p*** is longer than for either ***t*** or ***k*** for all speakers.

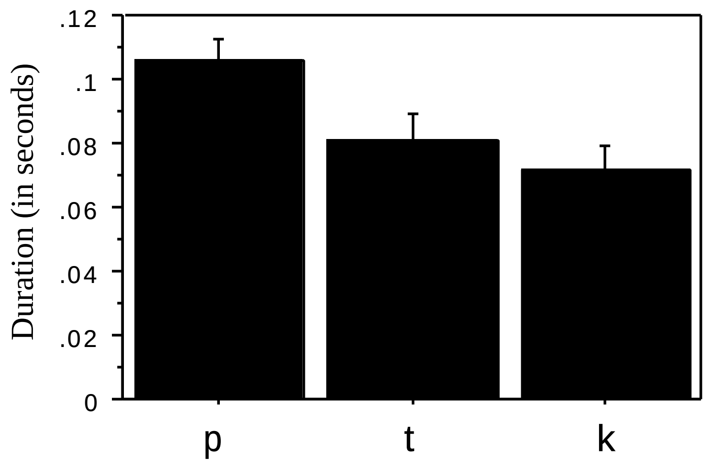

Figure 8. Closure duration for voiceless unaffricated stops before *a*.

Table 8. Closure duration for unaffricated stops before *a* (in seconds)

	CONSONANT		
SPEAKER	***p***	***t***	***k***
FS1	.110	.097	.075
FS2	.084	.071	.064
FS3	.113	.101	.083
FS4	.124	.095	.096
FS5	.114	.100	.098
FS6	.112	.101	.082
FS7	.115	.089	.067
FS8	.111	.060	.059
MS1	.080	.058	lenited
MS2	.083	.073	.052
MS3	.117	.093	.066
MS4	.092	.044	.060
MS5	.119	.071	.044
Means	.109	.081	.069

A possible reason for the shorter closure duration for the more posterior stops is that the seal for these stops may be more difficult to hold in the face of increased air pressure (Maddieson 1997). When the oral closure is further back, the cavity behind the closure is smaller, and the air pressure reaches a maximum more quickly. The faster the increase in pressure, the shorter the closure is held, perhaps due to a biomechanical feedback mechanism. Following this logic, the seal for a velar will be maintained for a shorter period of time than the closure for an alveolar stop, which should, all else being equal, have a shorter closure than a bilabial stop. The Chickasaw data are compatible with this account, as velars show the shortest closures, whereas bilabials have the longest closures.

If one compares figures 7 and 8, the duration hierarchy for VOT is the opposite of the pattern seen for closure duration. For the dental and velar stops the difference in closure duration is almost exactly compensated by the difference in VOT, so that the sum of the closure plus VOT is almost identical for both places of articulation (.102 seconds for ***t*** and .105 seconds for ***k***). However, in the case of the bilabial stops, the compensation is not so exact. The duration of the closure plus VOT is slightly less than twenty milliseconds longer than the corresponding duration for the other two stops. The inverse correlation between VOT and closure duration for stops at different places of articulation appears to be another general cross-linguistic property attested in a large number of languages. In discussing this, Weismer (1980) offers a possible explanation of the place-dependent nature of both the closure duration and VOT, suggesting that the temporal duration of the vocal fold opening may be considered to be fixed, so that when the closure duration is relatively longer, the following VOT becomes relatively shorter (and vice versa).

VOT for geminate stops was also measured and compared to that of the corresponding single stops. Relatively little literature has examined differences in VOT between single and geminate consonants, and the existing work shows different results depending on the language. Lahiri and Hankamer (1988) found that VOT is significantly longer for single ***t*** and ***k*** than for geminate ***t*ː** and *k*ː***,*** respectively, in Turkish, though not all speakers show a significant difference. A similar pattern is evident in Han's (1994) data on Japanese VOT for ***p***, ***t***, ***k***. On the other hand, Lahiri and Hankamer's study found no significant difference in VOT between single and geminate ***t*** in Bengali. A third pattern is attested in Estonian. An unpublished study of VOT in Estonian conducted by Gordon (1995) showed significantly longer VOT values for geminate *t*ː than for single ***t*** for one speaker. The other speaker in the study did not distinguish between single and geminate ***t*** in terms of VOT.

In the present study of Chickasaw, single and geminate ***p*** and ***t*** were measured before the vowel ***a*** , and single and geminate ***t*** and ***k*** were measured before the vowel ***i***. The words from which the targeted consonants were measured appear in table 9.

Table 9. Words used to measure VOT for singleton and geminate stops

BEFORE ***a***		
p	***0̀ipa*** 'worn out, ragged'	***Sipːa*** 'it dries up'
t	***ayiːmita*** 'he's excited'	***okSitːa*** 'he closes it'
BEFORE ***i***		
t	***iti*** 'mouth'	***itːi/*** 'tree'
k	***tˢiːki*** 'early'	***hikːi/ya*** 'he's standing up'

Results of the measurements pooled over all speakers appear in figures 9 (before ***a***) and 10 (before ***i***). Results for individual speakers appear in table 10. Speaker FS4 produced a cluster of ***ph*** rather than a geminate; hence these values are not included in figure 9.

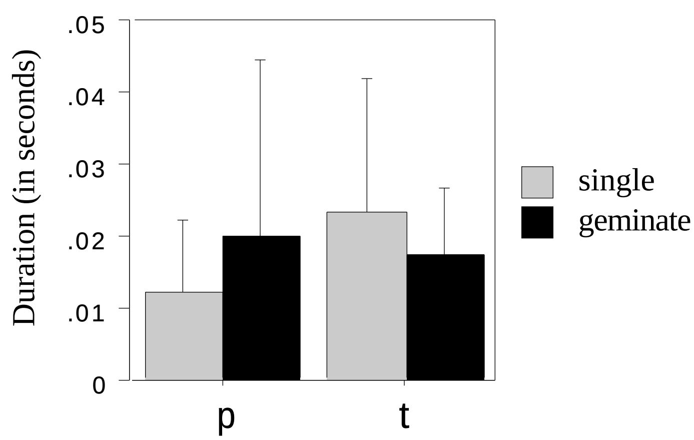

Figure 9. VOT for single and geminate stops before ***a***.

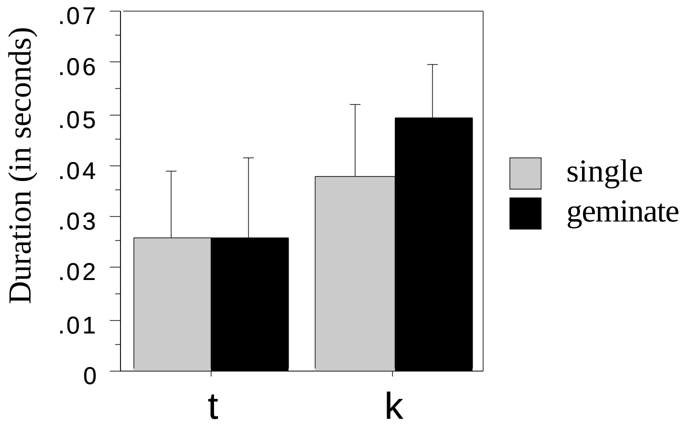

Figure 10. VOT for single and geminate stops before ***i***.

Two separate analyses of variance were performed on the data: one for single and geminate ***p*** and ***t*** before ***a*** and one for single and geminate ***t*** and ***k*** before ***i***. Each of these analyses included three independent variables: place of articulation, length (single vs. geminate), and repetition number.

First, let us consider results of the VOT analysis of ***p*** and ***t*** before ***a***. Neither place of articulation (F(1, 94)=1.464, p=.2293), nor length (F(1, .94)=.092, p=.7621), nor repetition number (F(1, 94)=.187, p=.6667) exerted a significant influence on duration values. There was a (barely) significant interaction, however, between place of articulation and length as factors (F(1, 94)=4.187, p=.0435). This result is not surprising based on figure 9 which shows that VOT for single ***p*** is slightly but statistically insignificantly (t (1, 24)=1.554, p=.1332 as revealed by a t-test paired by speaker) longer than VOT for geminate ***p*ː**, whereas VOT for geminate ***t*ː** is longer than VOT for single ***t***, a difference which barely reaches statistical significance in a paired t-test (t (1, 24)=2.143, p=.0425).

The second analysis of variance looked at VOT values for single and geminate ***t*** and ***k*** before ***i*** taking place of articulation, length, and repetition number as independent variables. Both place of articulation (F(1, 93)=43.755, p<.0001) and length (F(1, 93)=4.511, p=.0363), but not repetition number (F(1, 93)=1.127, p=.2911), were found to significantly influence VOT. There was also a significant interaction between place of articulation and length (F(1, 93)=4.621, p=.0342). The reason for this interaction was the fact that VOT differed between single and geminate ***k*** but not between single and geminate ***t***. Paired t-tests show that the geminate ***k*ː** has a significantly longer VOT than single ***k*** (t (1, 22)=4.914, p<.0001), but the VOT difference between geminate ***t*ː** and single ***t*** is insignificant, t (1, 25)=.027, p=.9760. The overall picture which emerges is that geminate stops are neither consistently associated with longer nor with shorter VOT values than single stops in Chickasaw. The Chickasaw data combined with the conflicting cross-linguistic data from Turkish, Japanese, Estonian, and Bengali suggest that VOT differences between single and geminate consonants are a function of multiple properties.

Table 10. VOT for single vs. geminate unaffricated stops (in seconds), S = Single, G = Geminate

	BEFORE *a*				BEFORE *i*			
	p		*t*		*t*		*k*	
SPEAKER	S	G	S	G	S	G	S	G
FS1	.030	.010	.027	.027	.030	.025	.036	.042
FS2	.014	.013	.011	.018	.014	.011	.021	.047
FS3	.013	.019	.028	.021	.028	.021	.057	.069
FS4	.007	--	.012	.005	.043	.019	.038	.046
FS5	.014	.013	.011	.011	.021	.016	.035	.049
FS6	.005	.006	.008	.010	.011	.017	.018	.054
FS7	.030	.010	.016	.010	.016	.018	.033	.040
FS8	.017	.053	.037	.035	.046	.071	.030	.057
MS1	.013	.013	.020	.021	.019	.016	.029	.045
MS2	.010	.009	.025	.018	.041	.030	.042	.054
MS3	.008	.006	.014	.014	.013	.030	.033	.047
MS4	.015	.020	.074	.028	.030	.042	.060	.045
MS5	-.008	.000	.022	.007	.025	.020	.040	.047
Means	.012	.020	.023	.017	.026	.026	.038	.049

4.2. Closure duration for single and geminate pairs. In order to examine the durational relationship between single and geminate consonants, closure durations for several singleton and geminate pairs were measured from a waveform in conjunction with a spectrogram and an energy display. Geminate/singleton contrasts for ***j***, ***w***, and ***h*** were not measured due to the difficulty of determining precisely where in the waveform these segments began and ended. The other consonants were measured in two environments: between ***i*** and ***i*** and between ***i*** and ***a***. An attempt was made to measure both members of each singleton and geminate pair in prosodically similar environments, ideally in disyllabic words between two short vowels. Occasionally, however, words that had more than two syllables were used. In such cases, the target consonant followed a short vowel whenever possible. The measured words appear in table 11. Results of the duration measurements are depicted graphically in figure 11 (before ***a***) and figure 12 (before ***i***), which pools together results for all thirteen speakers. Results for individual speakers appear in table 12. Omissions in table 12 indicate that the speaker did not produce the targeted word. Note that ***m*** before ***a*** could not reliably be measured for speaker MS2.

In considering the results, note that for some consonants, the duration data may be confounded by other factors. For some pairs, the word in which the geminate appears had more syllables than the word in which the corresponding singleton appears. This would reduce the absolute duration difference between single and geminate consonants, under the assumption that segmental duration is inversely correlated with the total duration of the word (Lehiste 1970). Furthermore, the single ***S*** in ***biSa0̀t***^{s}***i*** falls at the end of a morphological boundary, which could plausibly have induced lengthening of the ***S***.

Table 11. Words used for comparing the duration difference between single and geminate consonants in Chickasaw

		ENVIRONMENT ***i* __ *a***
C	SINGLETON	GEMINATE
p	***Òipa*** 'it's worn out'	***Sipːa*** 'it dries up'
b	***aÒt^{S}iba*** 'it's late'	***koSibːa/*** 'poke salad'
t	***ayiːmita*** 'he's excited'	***okSitːa*** 'he closes it'
t^S	***malːit^{S}a woːt^{S}i*** 'he jumps and barks'	***ibit^{S}ːala/*** 'nose'
s	***pisa*** 'look!'	***impat isːa*** 'he finishes eating'
S	***biSaÒt^{S}i*** 'it's milked'	***ibiSːano*** 'he has a cold'
		ENVIRONMENT ***i* __ *i***
C	SINGLETON	GEMINATE
b	***itːibi*** 'they fight'	***t^{S}ikibːi*** 'it's all piled up'
t	***iti*** 'mouth'	***itːi/*** 'tree'
k	***t^{S}iːki*** 'early'	***hikːi/ya*** 'he's standing up'
f	***Òifi/li*** 'he drags himself around'	***pit^{S}ifːi*** 'he crushes it'
s	***kisili*** 'he bites'	***isːi/*** 'deer'
Ò	***yiÒibli*** 'he demolishes it'	***kiÒːi*** 'he gnaws it'
S	***iSi*** 'he takes it'	***aÒpiSːi/*** 'pillow'
m	***hatiːmimi/*** 'type of insect'	***yimːi*** 'he believes it'
l	***pihlili*** 'I sweep it'	***ilːi*** 'he dies'
n	***kostini*** 'he sobers up'	***lowak inːi*** 'he warms himself by the fire'

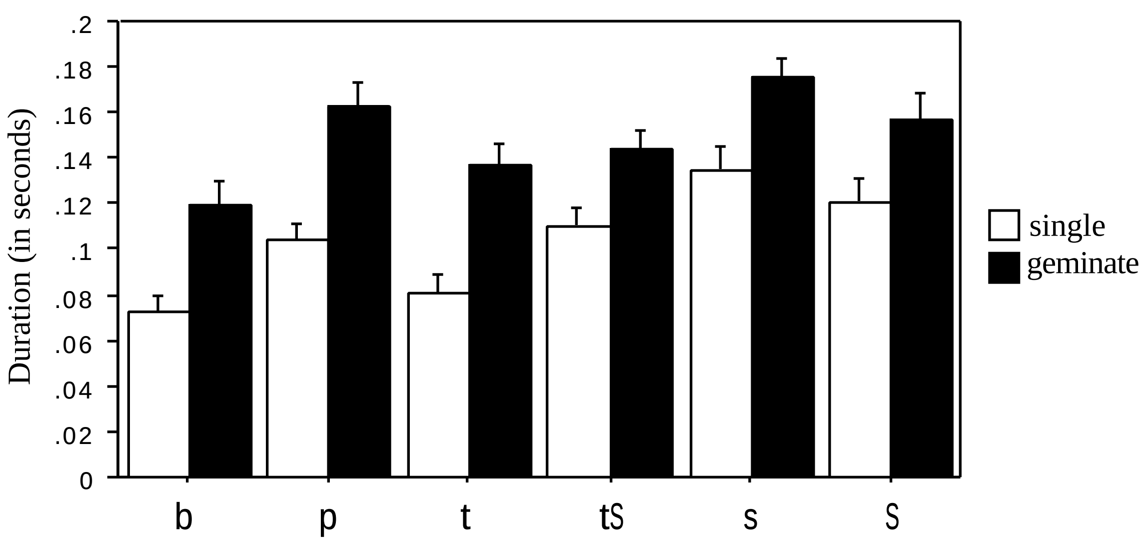

Figure 11. Duration of single and geminate consonants before ***a*** (all speakers together)**.**

Interestingly, if results for all speakers are pooled, for very few of the consonants is the geminate twice as long as its corresponding single consonant in the same vowel environment. Only the sonorant geminates ***m***, ***n***, ***l*** are twice as long as their corresponding single consonants. For all other single and geminate pairs, the duration ratio between single and geminates is much smaller than 2:1. In some, the small magnitude of the duration difference may be due to independent factors like those mentioned above, such as number of syllables and morphology. However, relatively small duration differences between single and geminate consonants are found even for pairs in which these factors are controlled for, suggesting that the length contrast in consonants does not reside only in the duration of the consonant constriction itself. For example, the contrast between single and geminate ***b*** also appears to be associated with differences in amplitude of voicing: geminate ***bː*** has stronger voicing than single ***b***. This difference in amplitude appears to be the principal acoustic cue to the single vs. geminate contrast for speaker FS2, FS7, and MS1 who show virtually no length distinction between single and geminate ***b***. In fact, geminate ***bː*** is shorter than single ***b*** for speaker MS1. Similarly, the contrast between single and geminate ***k*** appears to involve differences in VOT (see figure 10) in addition to length differences: geminate ***kː*** has a consistently longer VOT than single ***k***. Additional prosodic cues considered later in this section also help to distinguish single and geminate consonants.

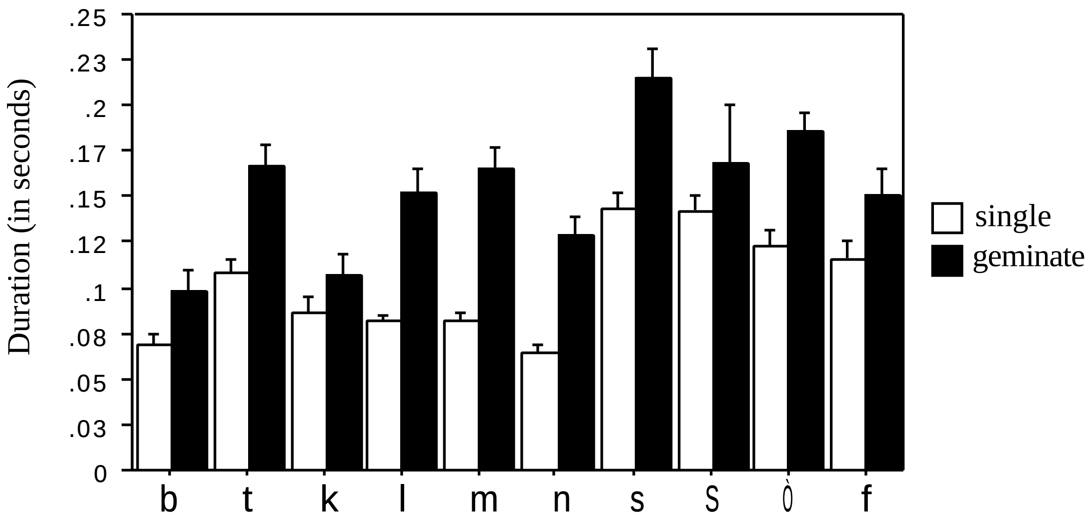

Figure 12. Duration of single and geminate consonants before ***i*** (all speakers together).

Table 12. Duration measurements for single and geminate consonants for individual speakers (all measurements in seconds), S = Single, G = Geminate

Sp. & C	Before ***a***			Before ***i***			Sp. & C	Before ***a***			Before ***i***		
FS1	S	G	Ratio	S	G	Ratio	FS2	S	G	Ratio	S	G	Ratio
p	.110	.193	**1.75**				***p***	.084	.150	**1.79**			
t	.097	.128	**1.32**	.105	.173	**1.65**	***t***	.071	.110	**1.55**	.088	.145	**1.65**
tS	.116	.142	**1.22**				***tS***	.113	.171	**1.51**			
k				.088	.102	**1.16**	***k***				.077	.082	**1.06**
f				.102	.132	**1.29**	***f***				.114	.132	**1.16**
s	.139	.165	**1.19**	.170	.198	**1.16**	***s***	.136	.149	**1.10**	.108	.150	**1.39**
S	.115	.139	**1.21**	.171	.138	**0.81**	***S***	.103	.128	**1.24**	.110	.121	**1.10**
ʒ				.097	.166	**1.71**	***ʒ***				.108	.155	**1.44**
b	.069	.106	**1.54**	.066	.124	**1.88**	***b***	.071	.073	**1.03**			
m				.080	.147	**1.84**	***m***				.093	.143	**1.54**
n				.075	.155	**2.07**	***n***				.055	.099	**1.80**
l				.082	.114	**1.39**	***l***				.068	.095	**1.40**

FS3							FS4						
p	.113	.189	**1.67**				***p***						
t	.101	.149	**1.48**	.119	.209	**1.76**	***t***	.095	.166	**1.75**	.141	.197	**1.40**
tʃ	.122	.159	**1.3**				***tʃ***	.138	.142	**1.03**			
k				.109	.130	**1.19**	***k***				.089	.148	**1.66**
f							***f***				.160	.214	**1.34**
s	.174	.189	**1.09**	.157	.245	**1.56**	***s***	.173	.195	**1.13**	.166	.256	**1.54**
ʃ	.146	.196	**1.34**	.152	.220	**1.45**	***ʃ***	.132	.184	**1.39**			
ð				.132	.232	**1.76**	***ð***				.121	.199	**1.64**
b	.076	.144	**1.89**	.073	.106	**1.45**	***b***	.096	.134	**1.40**			
m				.093	.194	**2.09**	***m***				.074	.206	**2.78**
n							***n***				.072	.177	**2.46**
l				.095	.177	**1.86**	***l***				.080	.212	**2.65**
FS5							FS6						
p	.114	.167	**1.46**				***p***	.112	.194	**1.73**			
t	.100	.167	**1.67**	.130	.201	**1.55**	***t***	.101	.151	**1.50**	.125	.170	**1.36**
tʃ	.118	.156	**1.32**				***tʃ***	.115	.147	**1.28**			
k				.121	.120	**0.99**	***k***				.115	.129	**1.12**
f				.153	.186	**1.22**	***f***				.109	.139	**1.28**
s	.152	.191	**1.26**	.164	.224	**1.37**	***s***	.130	.195	**1.50**	.140	.242	**1.73**
ʃ	.141	.175	**1.24**	.169	.220	**1.3**	***ʃ***	.104	.142	**1.37**	.132	.116	**0.88**
ð				.128	.200	**1.56**	***ð***				.131	.190	**1.45**
b	.076	.147	**1.93**				***b***	.060	.105	**1.75**	.073	.093	**1.27**
m				.093	.180	**1.94**	***m***				.084	.154	**1.83**
n				.070	.140	**2**	***n***				.046	.119	**2.59**
l				.087	.171	**1.97**	***l***				.083	.140	**1.69**
FS7							FS8						
p	.115	.158	**1.37**				***p***	.111	.139	**1.25**			
t	.089	.139	**1.56**	.116	.196	**1.69**	***t***	.060	.109	**1.82**	.101	.113	**1.12**
tʃ	.111	.143	**1.29**				***tʃ***	.124	.156	**1.26**			
k				.092	.079	**0.86**	***k***				.080	.090	**1.13**
f				.110	.155	**1.41**	***f***						
s	.141	.178	**1.26**	.166	.284	**1.71**	***s***				.140	.183	**1.31**
ʃ	.153	.171	**1.12**	.173	.124	**0.72**	***ʃ***	.127	.148	**1.17**	.158	.172	**1.09**
ð				.144	.172	**1.19**	***ð***				.151	.154	**1.02**
b	.082	.119	**1.45**	.075	.080	**1.07**	***b***				.069	.090	**1.30**
m				.068	.147	**2.16**	***m***				.067	.122	**1.82**
n				.072	.120	**1.67**	***n***				.063	.112	**1.78**
l				.078	.159	**2.04**	***l***				.076	.118	**1.55**
MS1							MS2						
p	.080	.133	**1.66**				***p***	.083	.135	**1.63**			
t	.058	.154	**2.66**	.088	.175	**1.99**	***t***	.073	.107	**1.47**	.079	.135	**1.71**
tʃ	.089	.123	**1.38**				***tʃ***	.087	.108	**1.24**			
k				.056	.119	**2.13**	***k***						
f				.089	.120	**1.35**	***f***				.117	.138	**1.18**

MS1	S	G	Ratio	S	G	Ratio	MS2	S	G	Ratio	S	G	Ratio
s				.128	.199	**1.55**	***s***	.110	.157	**1.43**	.146	.198	**1.36**
S							***S***	.084	.127	**1.51**	.136	.116	**0.85**
Ò				.126	.166	**1.32**	***Ò***				.128	.198	**1.55**
b	.077	.111	**1.44**	.081	.076	**0.94**	***b***	.051	.107	**2.1**	.048	.079	**1.65**
m				.079	.179	**2.27**	***m***						
n				.068	.123	**1.81**	***n***				.051	.132	**2.59**
l				.083	.133	**1.6**	***l***				.066	.157	**2.38**
MS3							MS4						
p	.117	.188	**1.61**				***p***	.092	.149	**1.62**			
t	.093	.145	**1.56**	.118	.154	**1.31**	***t***	.044	.118	**2.68**	.096	.151	**1.57**
t^S	.105	.140	**1.33**				t^S	.095	.135	**1.42**			
k				.073	.096	**1.32**	***k***				.071	.071	**1**
f				.116	.150	**1.29**	***f***				.099	.130	**1.31**
s	.132	.172	**1.30**	.141	.190	**1.35**	***s***				.124	.210	**1.69**
S	.123	.144	**1.17**	.134	.163	**1.22**	***S***	.135	.138	**1.02**	.132	.108	**0.82**
Ò				.097	.187	**1.93**	***Ò***				.119	.203	**1.71**
b	.068	.139	**2.04**				***b***	.081	.099	**1.22**	.070	.097	**1.39**
m				.063	.173	**2.75**	***m***				.090	.182	**2.02**
n				.059	.135	**2.29**	***n***				.073	.126	**1.73**
l				.087	.155	**1.78**	***l***				.085	.192	**2.26**
MS5							Ave.						
p	.119	.158	**1.33**				***p***	.109	.165	**1.51**			
t	.071	.135	**1.90**	.103	.145	**1.41**	***t***	.081	.135	**1.67**	.109	.165	**1.51**
t^S	.099	.143	**1.44**				t^S	.110	.143	**1.3**			
k				.049	.148	**3.02**	***k***				.087	.106	**1.22**
f				.104	.156	**1.50**	***f***				.126	.158	**1.25**
s	.096	.156	**1.63**	.119	.219	**1.84**	***s***	.130	.165	**1.27**	.143	.216	**1.51**
S	.086	.196	**2.28**	.121	.272	**2.25**	***S***	.121	.152	**1.26**	.141	.157	**1.11**
Ò							***Ò***				.124	.187	**1.51**
b	.059	.122	**2.07**	.065	.146	**2.25**	***b***	.073	.116	**1.59**	.070	.100	**1.43**
m				.085	.162	**1.91**	***m***				.082	.165	**2.01**
n				.068	.113	**1.66**	***n***				.062	.132	**2.13**
l				.093	.157	**1.69**	***l***				.080	.151	**1.89**

The closure duration ratio between geminates and singletons in Chickasaw is smaller than in many other languages. In standard Finnish, most geminates are at least twice as long as their corresponding single consonants (Lehtonen 1970). Similar durational ratios between geminates and singletons are reported for Estonian (Lehiste 1966, Ojamaa 1976) and Bengali (Lahiri and Hankamer 1988). In Japanese (Han 1994), Italian (Farnetani and Kori 1984), and Levantine Arabic (Miller 1987), geminates are generally more than twice the duration of single consonants. In Turkish (Lahiri and Hankamer 1988) and Hungarian (Meyer and Gombocz 1908), geminates are almost three times as long as their corresponding single consonants.

Chickasaw is not alone, however, in showing less than a 2:1 ratio in the duration of geminates relative to single consonants. Other languages display smaller differences between single and geminate pairs, at least for certain consonants, e.g. Dogri (Ghai 1980), Icelandic (Ores#ik and

Pétursson 1977), Norwegian (Fintoft 1961), and Sinhala (Letterman 1994). Of these languages, Sinhala and Dogri come the closest to having a 2:1 ratio between the duration of geminates vs. that of singletons. In Sinhala, geminates are 1.8 times as long on average as singletons after short vowels, and 1.69 times as long after long vowels. Dogri displays great variability in the relative duration of geminates; single consonants range from being 38% to 66% as long as corresponding geminates depending on the consonant and the speaker. In Icelandic, particularly in southern dialects, geminates are less than 1.5 times longer than single consonants. However, it is unclear in Icelandic whether the length contrast is a property of the consonant itself or is a property of the preceding vowel (see Ores#ik and Pétursson 1977 for discussion): vowels are long before short consonants and short before long consonants. In Norwegian, another language in which consonant and vowel length stand in a close trading relationship, geminates are only slightly longer than their singleton counterparts, 1.10 to 1.38 times as long.

Interestingly, in most of the languages (except Sinhala) that display relatively small duration differences between single and geminate consonants (less than 2:1), closure duration appears to be closely related to the duration of neighboring vowels, in particular the preceding vowel. In most of these languages, vowels are substantially shorter before geminates than before single consonants. In Dogri, short vowels preceding single consonants are 1.72 times longer than short vowels preceding geminates. Similarly, in Icelandic and Norwegian, vowels are substantially shorter before geminates than before single consonants. As mentioned above, however, it is unclear whether the length contrast in Icelandic and Norwegian is a property of the vowel or the following consonant.

In languages that display greater durational differences between geminates and singletons, vowels tend not to differ greatly as a function of whether they precede a geminate or a single consonant. This appears to be true of most of the languages discussed earlier for which measurements were available. For example, in Turkish, where geminates are almost three times as long as single consonants, short vowels preceding single consonants are only 3.5% longer on average than short vowels before geminates (Lahiri and Hankamer 1988). In standard Estonian, which has a similar but slightly greater duration ratio between vowels before geminates and before singletons, phonemic short vowels before geminate ***t***ː are 9.1% shorter than phonemic short vowels before single ***t*** (Ojamaa 1976). In standard Finnish, phonemic short vowels are 20.3% shorter before geminate ***p***ː and ***s***ː than before geminate ***p*** and ***s*** (results pooled over both pairs from Lehtonen 1970). In Japanese, vowels are surprisingly between 1.1% and 8.7% longer before geminates than before singletons, depending on the consonant (Han 1994). In Sinhala, vowels are also slightly longer before geminates, 19.6% longer in the case of short vowels, 4.4% longer in the case of long vowels (Letterman 1994). Italian seems to be somewhat exceptional in manifesting the single vs. geminate contrast in both the consonant itself and the preceding vowel: vowels are 30%-50% shorter before geminates than before single consonants, and geminates are twice as long as singletons (Farnetani and Kori 1984, 1986).

Like other languages with relatively small duration differences between geminates and singletons, there is evidence that the contrast in consonant length in Chickasaw may be cued by other properties in addition to the consonant closure durations themselves. Recall from section 3 that Chickasaw displays a process of rhythmic lengthening, which lengthens the second in a series of two consecutive phonemically short vowels in non-word-final open syllables. Vowels fail to lengthen in closed syllables, including syllables closed by a geminate, even if other conditions for the process are satisfied. Thus, the absence of rhythmic lengthening where it would otherwise be expected to occur may signal that the following consonant is a geminate. Rhythmic lengthening patterns thus can provide valuable aid in perceiving contrasts in consonant closure duration in many environments.

Rhythmic lengthening, however, is not available as a potential cue to consonant closure duration in all environments. For example, in a two syllable word, rhythmic lengthening is independently blocked from occurring due to the restriction against word-final lengthened vowels. Thus, rhythmic lengthening provides little information about the duration category of intervocalic consonants in two syllable words. In order to test whether phonetic differences in duration between vowels before single consonants and vowels before geminates also exist in Chickasaw, vowels were measured before single and geminate consonants in the disyllabic near minimal pairs ***iti*** vs. ***itːi/*** and Ò***ipa*** vs. ***Sipːa***. Recall from figures 9 and 10 that the difference in closure duration between singletons and geminates in both of these pairs is relatively small. Thus, we might expect there to be large differences in vowel duration as a function of the phonemic length of the following consonant.

Results averaged across speakers are depicted graphically in figure 13. Results for individual speakers appear in table 13. Both figure 13 and table 13 show fairly large durational differences between vowels preceding geminates and vowels preceding singletons, particularly before the bilabial stop. Vowels preceding single consonants are generally longer than those preceding geminates.

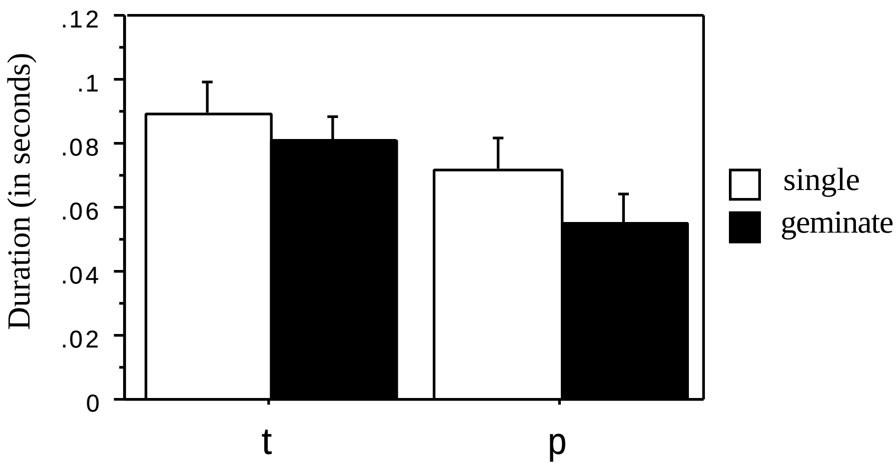

Figure 13. Duration of vowel preceding single and geminate consonants.

Not all speakers in table 13 show substantial differences in vowel length as a function of the duration of the following consonant; however, there is a general trend apparent in figure 13 for vowels before single consonants to be longer than vowels before geminate consonants. This result is particularly robust in the case of ***p***. Taken over all speakers (MS4 excluded; see below), ***i*** before single ***t*** is 8% longer than before geminate ***tː***, while ***i*** before single ***p*** is 27% longer than before geminate ***pː***. (Vowels before single and geminate ***t*** for one speaker (MS4) were not included in the measurements presented in figure 13, since ***i*** was substantially longer before the geminate than before the single ***t*** in his speech, a pattern which contradicts that found for other speakers.)

Paired t-tests including all speakers indicate a significant duration difference between vowels before single ***p*** versus those before geminate ***pː*** (t (1, 25)=4.618, p=.0001), but not between vowels preceding single ***t*** versus those preceding geminate *tː* (t (1, 24)=.811, p=.4251). The result comparing single and geminate ***t*** does not become significant even if speaker MS4 is excluded, t (1, 22)=1.825, p=.0816. Smaller reversals of the dominant trend for vowels to be longer before singletons are also seen for speaker FS6 for ***t***, speaker MS2 for ***t***, speaker FS4 for ***t*** and speaker FS5 for ***p***, though these results are included in figure 13. On an individual speaker basis, there does not seem to be a relationship between the magnitude of vowel length differences as a function of the following consonant and the duration difference between single and geminate consonants.

Table 13. Duration (in seconds) of vowel preceding single and geminate consonants

Speaker	***p*** Before singleton	***p*** Before geminate	***t*** Before singleton	***t*** Before geminate
FS1	.070	.042	.101	.078
FS2	.030	.021	.064	.055
FS3	.074	.054	.082	.081
FS4	.081	.052	.112	.116
FS5	.059	070	.072	.073
FS6	.065	.056	.049	.068
FS7	.072	.049	.092	.072
FS8	.062	.031	.073	.076
MS1	.062	.033	.110	.075
MS2	.117	.090	.090	.096
MS3	.071	.055	.091	.086
MS4	.105	.094	.082	.124
MS5	.070	.070	.132	.086
Means	.072	.055	.088	.084

In summary, at least for ***t*** in the present corpus, the duration of the preceding vowel does not provide a particularly robust cue to the phonemic length of the following consonant, suggesting that the phonemic contrast in consonant closure duration might be signaled by properties other than the duration of the consonant and the preceding vowel. For example, VOT appears to provide a cue to the length contrast in ***k*** and ***t*** in certain environments. Likewise, voicing is stronger in geminate ***b*** than in single ***b***. Perhaps consonant closure duration may also be cued by acoustic properties other than those measured in this paper, such as vowel quality or burst amplitude. In addition, the rhythmic lengthening patterns discussed earlier provide useful cues to consonant closure duration in many environments. Finally, the single vs. geminate contrast is also signaled in many cases through the morphology in Chickasaw, for example, in the choice of suffixes or through grade formation (see Munro and Willmond 1994, Munro et al. in preparation for discussion).

5. Conclusion. This paper describes some of the basic phonetic properties of Chickasaw, including measurements of closure duration and VOT for consonants, and formant and duration measurements for vowels. Some of the important results are as follows. The three-way length contrast in vowels is phonetically manifested principally in terms of duration. Long vowels are longer than rhythmically lengthened vowels, which, in turn, are generally longer than short vowels subject to variability across speakers and vowel qualities. Long vowels are in general more peripheral than their short counterparts. Lengthened ***a*** and ***i*** are intermediate in quality between their non-lengthened short and phonemically long counterparts for the male speakers, but not for the female speakers. Duration differences between single and geminate consonants are relatively small from a typologically perspective. Other properties of Chickasaw (e.g. rhythmic lengthening, duration of the preceding vowel, VOT in the case of ***k***, strength of voicing in the case of ***b***) potentially provide important cues to consonant closure duration in the face of the less pronounced differences in the consonants themselves.

Notes

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