ABSTRACT

A PHONETIC ACCOUNT OF THE CHUKCHANSI YOKUTS VOWEL SPACE

Yokuts was the topic of much research during the latter half of the 20th century. Profound phonological and phonetic conclusions have been drawn without appeal to spectrographic data. This study presents the case of Chukchansi Yokuts, a near extinct dialect of Northern Valley Yokuts. We employ contemporary methods of acoustic phonetic analysis in order to quantify a vowel space sorely lacking in such attention. These methods result in several discoveries beyond simple description. We show General Yokuts employs vowels argued to be absent by other researchers. We show also that the lowest vowel in Chukchansi has not been properly classified. We confirm that Chukchansi does not employ diphthongs. Finally, we support arguments that pitch has a fundamental pattern correlating with vowel height.

Isaac Gregory Martin
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A PHONETIC ACCOUNT OF THE CHUKCHANSI YOKUTS VOWEL SPACE

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CHAPTER 1: INTRODUCTION

"Chukchansi" is the name given a dialect of the Native American language "Yokuts". Yokuts is native to the great Central Valley of California. Geographically distinct groups of Yokuts speakers possess distinct dialects. Referring to these subordinate linguistic entities as "dialects" instead of "languages" is appropriate as they are mutually intelligible. Phonological, syntactic, and phonetic features are largely shared among them. The greatest distinction lies in vocabulary (Kroeber, 1963). In 1963, members of each dialect were familiar with common vocabulary variances of neighboring dialects. Mutual intelligibility was therefore common despite significant differences in vocabulary. Our subjects report this practice to persist today.

Our classification of Chukchansi is borrowed from Blevins who herself has reworked a classification made by Whistler and Golla (Blevins, 2004; Whistler, 1986). The classification given here is not as exhaustive as that given by Whistler and Golla. It serves rather for basic orientation (see Figure 1).

- **Yokuts**
  - Poso Creek: *Palewyami*
  - **General Yokuts**:
    - Buena Vista: *Tulamni, Hometwoli*
    - **Nim-Yokuts**:
      - Tule-Kaweah: *Wikchamni, Yawdanchi*
      - **Northern Yokuts**:
        - *Gashowu*
        - Kings River: *Chukaymina, Michahay, Ayticha, Choynimni*
        - **Valley Yokuts**:
          - Far Northern Valley: *Yachikumne (Chulamni), Lower San Joaquin, Lakisamni?,Tawalimni*
          - **Northern Valley**: *Noptinte, Merced?,Chawchila,* ***Chukchansi****, Kechayi, Dumna*
          - Southern Valley: *Wechihit, Nutunutu, Tachi, Chunut, Wo'lasi, Choynok, Koyeti, Yawelmani*

Figure 1. Language classification

Yawdanchi, Yawelmani and Chukchansi are the dialects of Yokuts commonly attended to in literature(Collord, 1968; Gamble, 1994; Kroeber, 1907, 1963; Kuroda, 1967; Newman, 1944; Pullum, 1973). However, Chukchansi itself has received little exclusive attention (Collord, 1968). What attention it has received is bereft of phonetic data now considered critical (Bohn, 2004; Flemming, Ladefoged, & Thomason, 2008) for accurate description of a Native American language or dialect.

Collord (Collord, 1968) provides a cursory analysis of Chukchansi phonological and phonetic features. He also identifies the phonemic inventory. Recent unpublished work by Chris Golston, Niken Adisasmito-Smith, Brian Agbayani and others at California State University, Fresno has produced an inventory of the Chukchansi sound system similar to that supplied by Collord. We include that inventory below in Figure 2.

Collord provides perceptual feedback regarding these segments, for example: “The lateral, /l/, is a voiced dental lateral. It is generally high-tongued, especially after front vowels, and is only slightly lower elsewhere” (p. 4).

One should note the lack of objective data in the above claim. There is no mention of Voice Onset Time (VOT). The analysis lacks also musings on possible frication, relative amplitude, length, or any other feature which is lent to by the implementation of spectrograms and waveforms. The lack of such implementation throughout the literature results in a clear need both in order to confirm previous findings and to investigate new hypotheses.

It is this poverty of data which motivates our study. We present the first work on Chukchansi (and indirectly on Yokuts itself) which satisfies contemporary standards for a phonetic account of the dialectal vowel space; that no such account exists either for Chukchansi or Yokuts seems sufficient

	Bilabial	Dental	AlveoPalatal	Velar	Glottal
voiceless unaspirated	p	t	ʧ	k	ʔ
voiceless aspirated	p^h	t^h	ʧ’	k^h	
ejective	p’	t’	ʧ’	k’	
voiceless fricative		s	ʃ	x	h
nasal	m	n			
glottalized nasal	m’	n’			
approximant	w	l	j		
glottalized approximant	w’	l’	j’		

Short	i	e	a	o	u
Long	ii	ee	aa	oo	uu

Figure 2. Chukchansi sound inventory

motivation in itself. We are, however, further motivated by the endangered status of the Chukchansi dialect.

The Chukchansi people no longer utilize their ancestral dialect as a primary mode of communication. As of 2011, we can directly confirm only that a small few native speakers still exist. Our two consultants report roughly six native speakers to exist in total. Some may come to learn the dialect as a second language (L2) through revitalization efforts currently underway. However, a continuing chain of native speakers seems doubtful. It is reasonable to suspect the vanishing population of native Chukchansi speakers will result in the extinction of Chukchansi during this century. It is critical that this dialect be documented presently lest it be forever lost.

CHAPTER 2: SCIENTIFIC METHOD

Subjects

The subject population for this study is highly atypical. Traditional phonetic accounts tend to use older male speakers as consultants. Further, subject pools tend to number at least five. The extraordinary circumstances surrounding Chukchansi Yokuts make adherence to these norms impossible.

Our subject pool consists of two speakers, a pair of sisters. Both live in or near Fresno, California. The sisters are native speakers of Chukchansi. This constitutes about 30% of the remaining Chukchansi speaker population. The speakers are relatives of Collord's 1954 consultant Nancy Wyatt. They were raised primarily by Nancy Wyatt, herself a native Chukchansi speaker. The sister's sole language was Chukchansi until entering elementary school around age 5-6. At that time they were taught English, though their home language continued to be Chukchansi. The chief biographical differences between the sisters include birth place and date. Speaker 1 ("Holly") was born 1941 at Picayune Rancheria. Speaker 2 ("Jane") was born 1943 in Madera.

Neither speaker uses Chukchansi as their primary tongue. Each occasionally uses the language in communication with the few others who speak it. Each also speaks Chukchansi with school age children to whom the language is taught as an L2.

Materials

Recordings were made using a portable audio recording device. The device was a Marantz sound recorder model PMD661. We used the included omnidirectional boundary microphone rated as sensitive up to 16khz. Recordings made by this device were analyzed via Praatv5.1.31 (Boersma, 2002). The resulting data was stored and presented using Microsoft Excel 2010.

Elicitation

The recordings were made at Picayune Rancheria over the course of several sessions in Spring of 2011. Each session occurred within the Chukchansi library. The room was relatively quiet. Initial elicitations were made useless due to signal interference. It was discovered the close proximity to cellular phones caused significant signal interference in the sound recorder. Elicitations were redone with all cell phones and nearby electronics turned off.

Vowels were elicited in four closed syllable environments. These were classified chiefly according to place of articulation for neighboring consonants. All vowels were elicited in alveolar, bilabial, and glide/lateral environments. Nasals and ejectives were generally avoided despite having the appropriate place of articulation. We omitted these sounds to avoid difficulties such sounds tend to introduce in the interpretation of spectrograms.

All vowels were elicited both in stressed and unstressed position. These elicitation sets were compiled mostly using a Chukchansi corpus developed by researchers at California State University, Fresno. Some gaps in the data set were filled by prompting the consultants to supply appropriate tokens. We also elicited Collord's word set intended to demonstrate prototypical examples of each vowel.

For all tokens the sisters were first consulted regarding both whether they recognized each token and whether the token actually contained the sounds transcribed. Tokens unrecognized by the sisters were discarded. Our consultants recognized only a small number of tokens from the Collord data set. For this reason the data from that set went mostly unused during analysis.

It bears accounting for that our speakers, raised by a Collord consultant, recognized only a few of the Collord prototypes we exposed them to. There are several reasons we suspect underlie why the sisters did not recognize most of the Collord set. Firstly, Chukchansi does not traditionally utilize orthography. We are using a newly developed orthography based roughly upon the International Phonetic Alphabet. Our reproductions of these words were several steps removed from native intuition. We ourselves are not native speakers, nor was Collord. Plenty of room therefore exists for the effect of "foreign pronunciation." Even minor errors could result in recognition failure when presented by us to consultants. Secondly, Collord's writing suggests the prototypes were almost certainly not gleaned from Nancy herself. Speaker variation between Nancy and whoever actually supplied these prototypes may have played a significant role.

Actual elicitation occurred over four sessions. Subjects were exposed to each token via successive powerpoint slides containing one token each. They were asked to read each token aloud in isolation. Subjects were instructed to repeat each token three times between short pauses of about two seconds. A list of elicited tokens is included in the Appendix. There were a total of 162 tokens elicited, 81 tokens from each speaker.

Recordings were made using a 44.1khz sampling rate. These recordings were saved in .wav format.

Analysis Methodology

All acoustic analysis was performed using Praat. Like Bohn, vowels were defined as beginning with the zero crossing of the initial amplitude spike (Bohn, 2004). Vowels end with two points in mind. Firstly, vowels were considered complete with the zero crossing where amplitude became similar to the following consonant. Secondly, they were considered complete when periodicity changed significantly from the pattern observed vowel internally. An example of this method is given below in Figure 3.

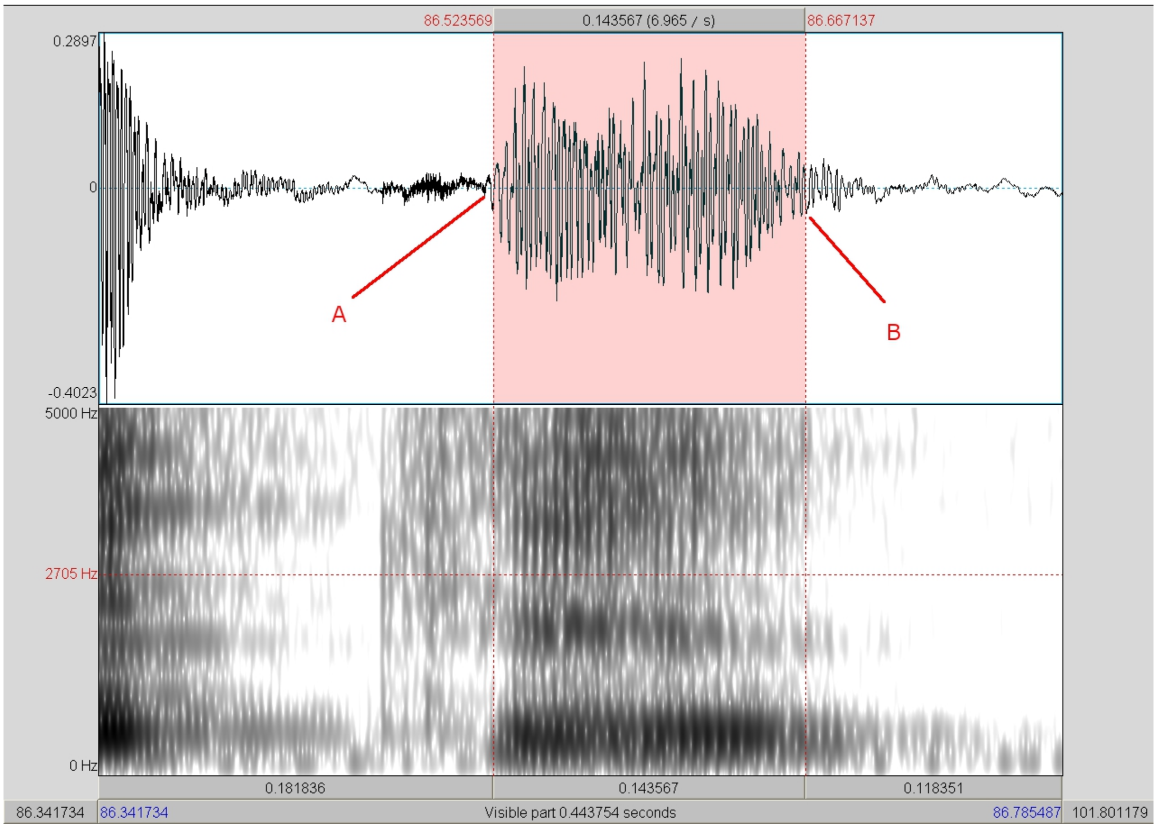


Figure 3. Jane /i/ segment

In Figure 3, A points out the zero crossing of the initial amplitude spike where the vowel is considered to begin. B points to the time at which the signal develops a pattern dramatically different to the pattern observed vowel internally. This is made more evident by observing the vanishing formant frequencies in the spectrogram.

Frequencies were measured also in keeping with Bohn. Values were measured at 25%(T_1), 50%(T_2) and 75%(T_3) of the complete vowel. T_2 was used for most analyses. Using values from T_2 ensures minimal interference from neighboring consonants upon formant values. The full gamut of time sections were required in order to perform an analysis of vowel inherent spectral change.

Formants f1 through f3 were measured using a semi-automatic procedure similar to that proposed by Nearey, Assmann, and Hillenbrand (2002). LPC (autocorrelation algorithm) was employed with a signal resampled to 11khz. All values automatically obtained through this method were checked by hand. On rare occasion this method failed to output useful values. In those cases the token was omitted from the overall analysis. The fundamental frequency (f0) was found using Boersma's method (Boersma, 1993).

Our consultants being female, we employ the practice of vowel normalization. Normalization presents readers with a kind of vowel space more readily comparable to the space presented by other studies. Our primary concern is therefore choosing a procedure which eliminates the gender feature from phonetic data. To this end we have employed the vowel normalization technique developed by Lobanov (Lobanov, 1971). The formula for Lobanov's normalization is given below in Figure 4.

$$\text{Normalized } F_i = (F_i - Z_i) / X_i$$

Figure 4. Lobanov's normalization

Where the index refers to formant number, F refers to Formant, Z refers to the average of formant values and the X refers to the standard deviation of the average represented by Z.

Vowel spaces are also presented in a traditional manner via the Bark scale. Like Adank, Smits, and Van Hout (2004), we employ the Bark conversion formula proposed by Traunmüller (Traunmüller, 1990). The formula is given in Figure 5.

$$\text{Bark} = 26.81 (F_i / 1960 + F_i) - 0.53$$

Figure 5. Traunmüller’s Bark scale formula

Where the index of F refers to formant number.

One will find scattered references to stress and stress effects in our analysis. We assumed stress to be in keeping with the findings from earlier researchers (Collord, 1968, Newman, 1944). Stress falls on the penultimate syllable of each word. The major exception to this stress rule is in emphatic words. Specifically, these include “shiishwilit” and “k’ayuush.” Suprasegmental stress effects should be mostly eliminated through elicitation of each token in isolation and through our selection of the second example in each three-exemplar set.

All unit values for formants were rounded to the nearest whole number. Timestamp values were rounded to the nearest millisecond.

CHAPTER 3: THE CHUKCHANSI VOWEL SPACE

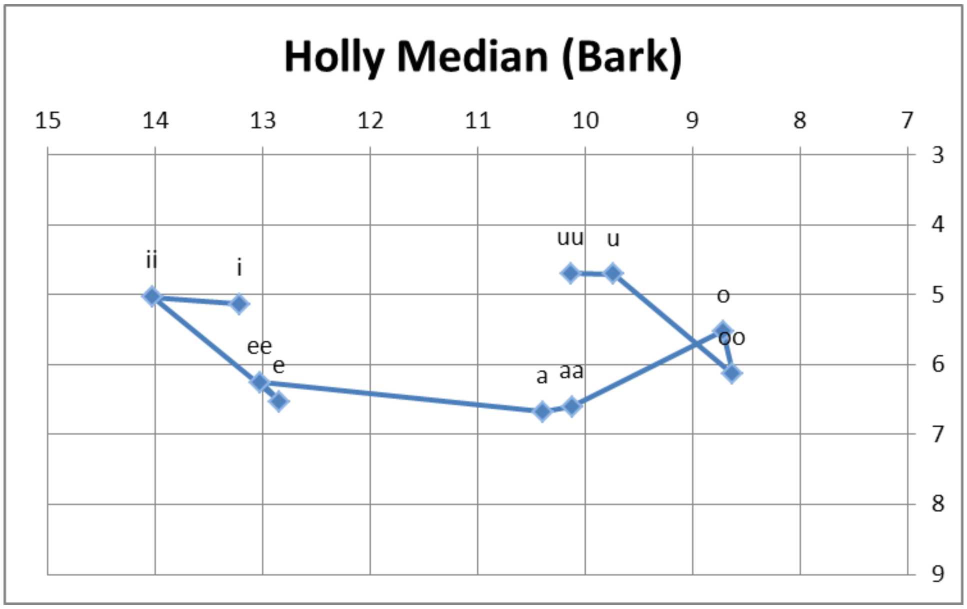
This chapter begins by giving a general overview of the Chukchansi vowel space. We then employ the patterns and relationships described in the overview to address several issues within the field of phonetics. The first issue concerns the methodological practice of presenting a language specific prototypical space as the average of values across all speaker subjects. The second issue is a debate concerning phonetic universals. It concerns the notion that certain segments hold static positions in vowel space across languages.

Overview

Chukchansi distinguishes ten surface vowels. It uses the vowels [i, e, a, o, u] as well as a long/short contrast for each vowel. An illustration of the space from each speaker is given in Figure 6.

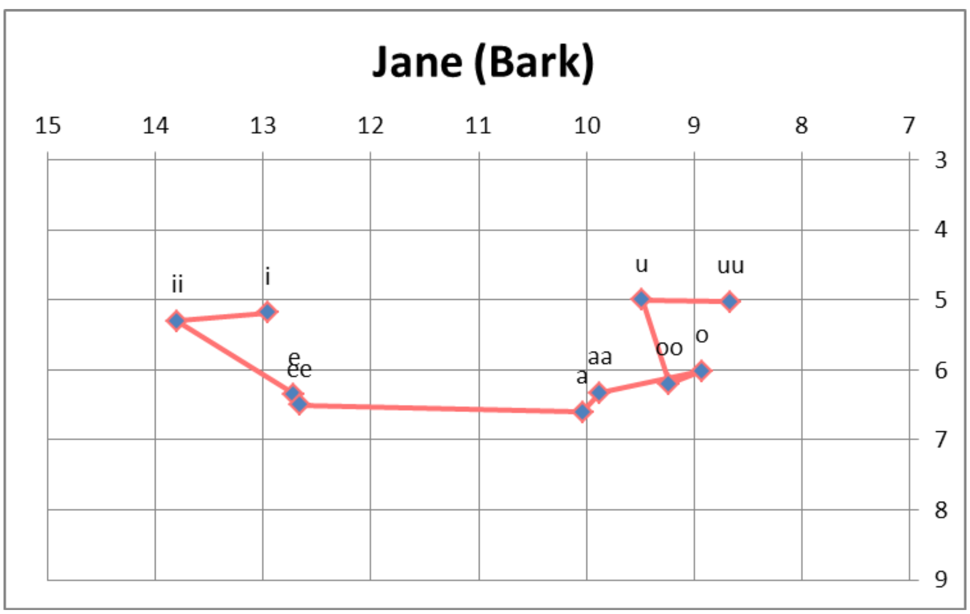
Figure 6 shows the vowel space inhabited by each of our two consultants. It is customary to present prototypical vowel space as the averaged values of all participant speakers in a study. Figure 6 does not present average values. It presents the arithmetic median of each speaker. Such a value is calculated by selecting the "middle" number from a data set. For example, in the odd numbered set [1, 5, 100] the median value is 5. Even numbered sets derive a median value by averaging the two middle values together.

Each vowel point therefore represents an actual vowel spoken during elicitation, or something otherwise very close in the event of an even numbered set. Measurements for each point were taken at precisely half the duration (T_2) of each vowel in order to minimize impact of neighboring consonants. The overview in Figure 6 is the result of our sampling the full range of consonantal environments discussed in chapter 2 including both stressed and unstressed positions. Figure 7



Raw F1/F2 Values

	F1	F2
i	525	2061
ii	514	2327
e	701	1950
ee	664	2004
a	721	1346
aa	711	1291
o	571	1031
oo	648	1016
u	476	1215
uu	475	1293



Raw F1/F2 Values

	F1	F2
i	531	1983
ii	545	2251
e	676	1913
ee	697	1899
a	710	1275
aa	674	1243
o	633	1068
oo	657	1122
u	509	1168
uu	512	1023

Figure 6. Holly and Jane median vowel space (BARK). Each point represents the median value for that segment from each speaker. These values are presented in the BARK scale. The representation includes stressed and unstressed tokens.

presents the same data normalized through the use of Lobanov's method discussed in chapter 2.

Lobanov's method is not yet widely employed to eliminate such properties as gender. We also include a chart representing the vowel space of English. This chart gives context to the normalized values seen above in Figure 7. It calibrates the reader for Lobanov's method. This chart is based on data gathered by Bradlow for a comparative acoustic analysis of English and Spanish (Bradlow, 1995). The chart is below in Figure 8.

Figure 8 shows Bradlow's values post normalization for vowels found in English CVC environments. We limited the included segments to vowels shared between Chukchansi and English. Lobanov's technique is shown by Adank et al. to effectively remove the gender feature from phonetic data (Adank et al., 2004). This is a powerful method for comparing data from languages whose representative subjects possess substantively different qualitative features controlled for through Lobanov's normalization. For example, we can conclude that the Chukchansi and English vowel spaces share similar /i/ and /o/ segments. The three other segments differ significantly from their counterparts. Chukchansi appears to have a relatively lowered /e/ along with raised /u/ and /a/ segments.

These conclusions can be drawn despite the representative data for each language having been taken from speakers of differing sex. Similar charts will therefore be useful to future researchers comparing Chukchansi with more traditional vowel space studies which use males exclusively or a male/female mix. Bradlow's chart is excerpted and presented below in Figure 9 for context.

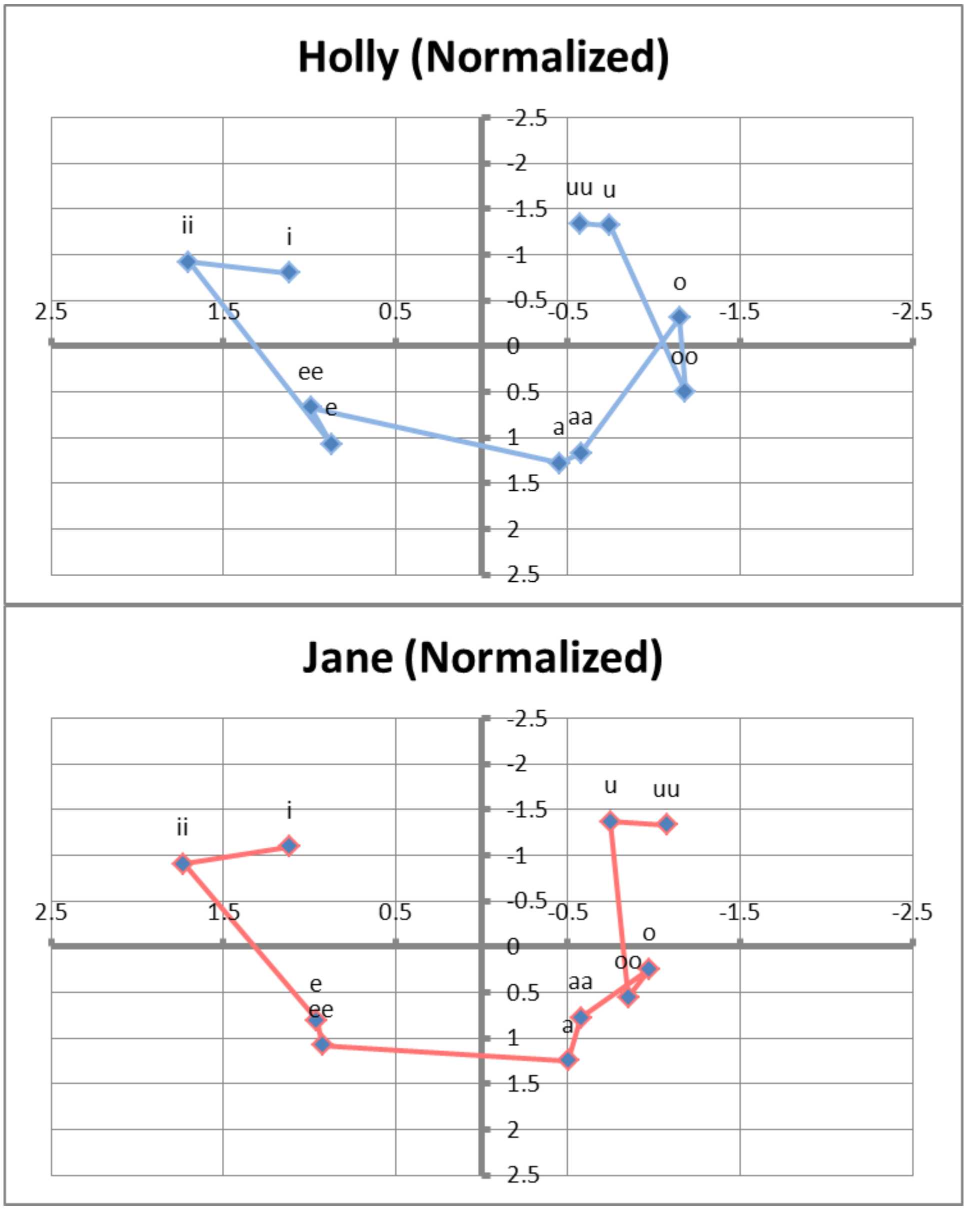


Figure 7. Normalized median speaker values.
Each point represents the median value for that segment from each speaker. These values have been normalized using Lobanov's method. The representation includes stressed and unstressed tokens.

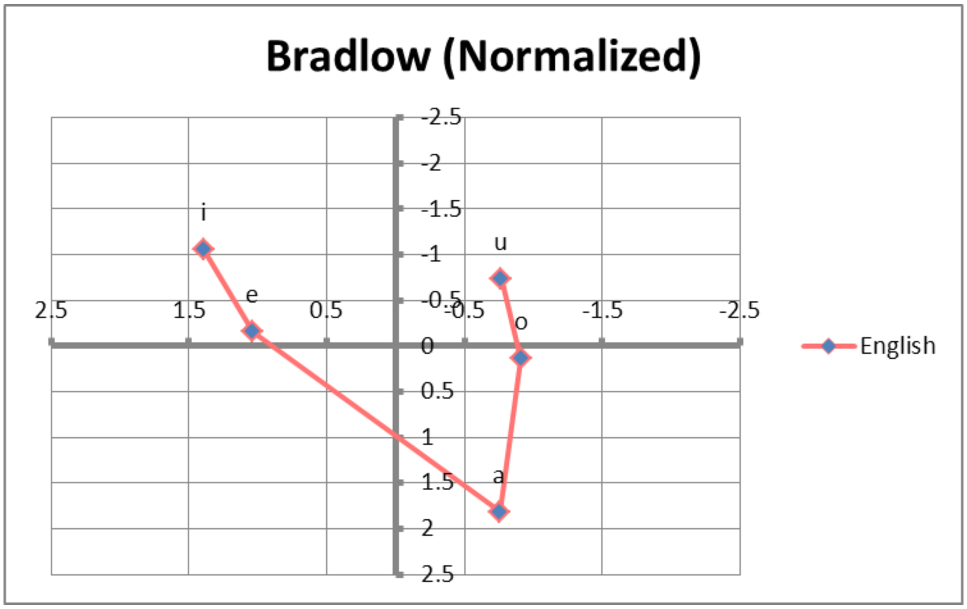
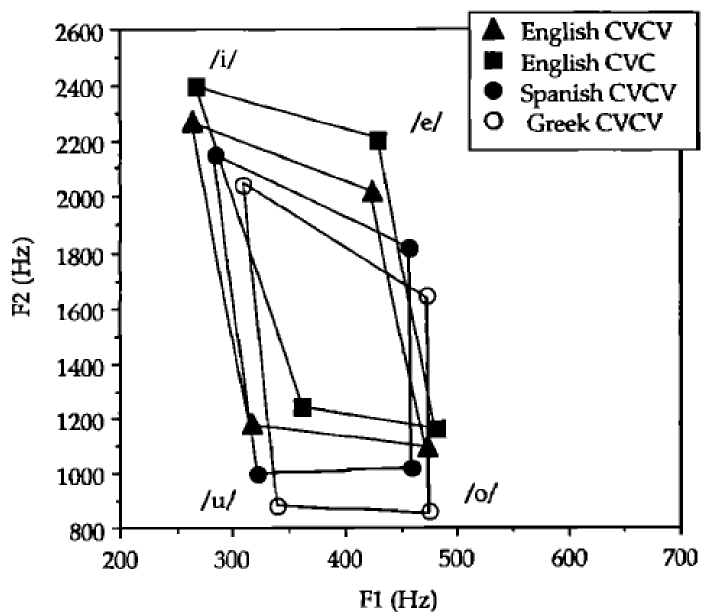


Figure 8. Bradlow's English CVC with Lobanov Normalization



Bradlow English CVC Values		
Segment	F1	F2
/i/	268	2393
/e/	430	2200
/a/	780	1244
/o/	482	1160
/u/	326	1238

Figure 9. Bradlow's original vowel space chart and corresponding pertinent values

<u>Abandoning Averages</u>

The need to show prototypical vowel space across larger populations is the primary motivator for the use of averaged vowel spaces. Though customary, presenting averaged values has the curious effect of representing a kind of Platonic vowel space. Prototypes are preferably things which actually exist. When we ask to see an example of a thing, we hope to see an actual picture of it. Imagine we are asking for an example of American pocket change. We do not wish for an average derived from all the different kinds of pocket change available in the States. We wish to see a nickel, or a dime, or some other real example. There are dangers in viewing an averaged value in place of a real example. To look at an averaged vowel space is to look at a space inhabited by no real speaker of the language. The danger in averaging values across speakers is that it may obfuscate common patterns of relationship between vowels. An averaged chart is presented in Figure 10, for example.

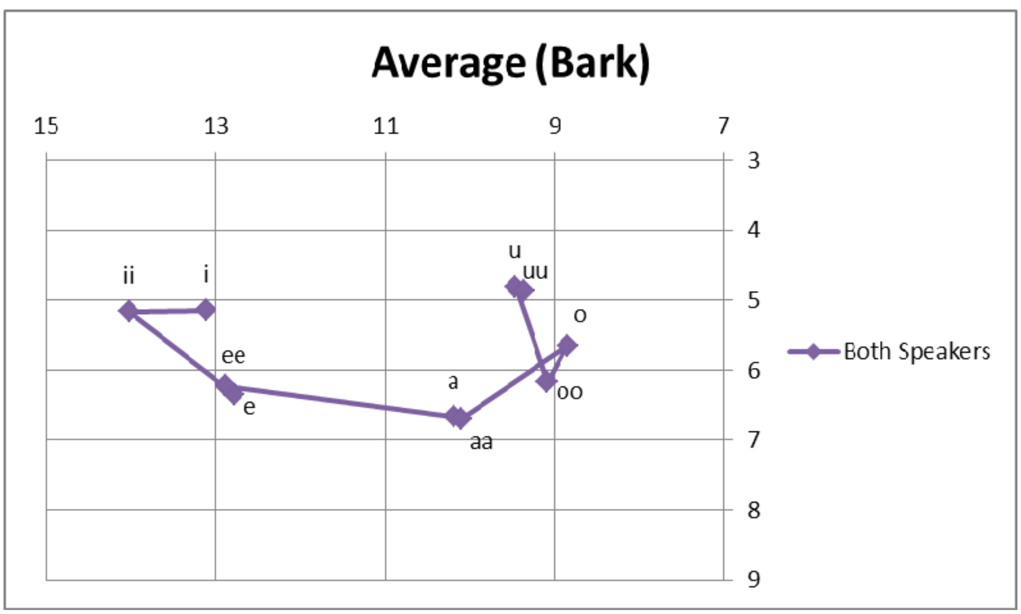


Figure 10. Chukchansi averaged vowel space (BARK)

Raw F1/F2 Values		
	F1	F2
i	526	2032
ii	528	2326
e	677	1932
ee	661	1960
a	720	1305
aa	724	1289
o	587	1054
oo	653	1096
u	487	1165
uu	493	1148

Indeed, much of the chart in Figure 10 could be sufficient for our purposes. Holly and Jane show remarkable similarity in their production of /i/, /e/, and /a/ as well as the long vowel counterparts. However, note the relationship between /u/, /o/ and the long counterparts of those vowels. Holly and Jane differ in their production of these segments. Figure 7 shows Jane lowering her /o/, fronting her /oo/, and backing her /uu/ in comparison with Holly. That these are the most extreme examples of inter-speaker variation is lost through the use of Figure 10. Further, this method not only obfuscates possibly important relationships, it presents a vowel space spoken by *no real speaker of the language.* This outcome is undesirable for a chart intended as prototypical.

It is a simple matter for this study to eschew amalgam charts in general. Our speaker sample is such that presenting a separate chart for each subject is not impractical. The situation is different for a study utilizing five, ten, or more speakers. We suggest the need for a prototypical overview can be met in a more informative manner than has been the norm. The "averaged vowel space" practice can be avoided in two ways.

One method of better representing vowel space is to first aggregate all values across speakers. One then selects the minimum and maximum formant frequency values for each segment. These values are used in order to derive coordinates for vowel space boundaries. For example, consider a segment which has minimum and maximum formant values as in Table 1.

Table 1. Hypothetical Formant Values

	F1	F2
Minimum	100	200
Maximum	1000	2000

Coordinates for boundaries can be had by mixing the minimum and maximum values from Table 1. Such a procedure produces a coordinate set as seen below in Table 2.

Table 2. Boundary Coordinates

	F1	F2
Coordinate 1	100	200
Coordinate 2	1000	2000
Coordinate 3	100	2000
Coordinate 4	1000	200

These values define the boundary for the space inhabited by a given segment. Figure 11 below includes a chart implementing this method with our Chukchansi speakers.

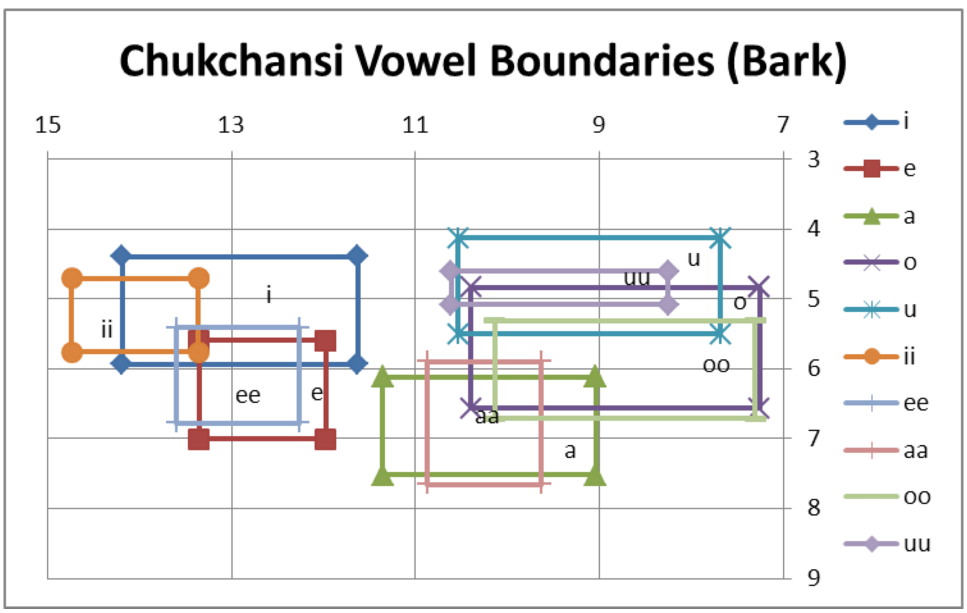


Figure 11. Chukchansi vowel boundaries
Represents the same data set as our Bark and Normalized charts. The representation includes stressed and unstressed tokens.

Figure 11 may appear messy at first glance. There is significant overlap between segments because different speakers inhabit different absolute areas of vowel space. However, this method has the advantage of presenting us with real values. The method could be further refined by populating the space with points representing each elicited token a la Flemming (Flemming, 2008). One could also use real points rather than two real and two derived by simply drawing the boundary connecting whichever points outlie the space.

A second method for presenting a realistic prototype can be found through the median speaker of a candidate set. The goal here would be to determine which speaker in a researcher's set of subjects most closely approximates the median values for all segments. One may then present the median vowel space of that speaker in a manner similar to the way Holly and Jane are here presented in Figure 7. Should this speaker not highlight all vowel patterns the researcher feels are important, further speakers may be presented in order to represent those patterns. The critical point here is that we represent the space of an actual speaker rather than a hypothetical one which likely does not exist.

Phonetic Universals

The Quantal theory of speech (QTS) postulates stable regions in vowel space for particular segments (Stevens, 1989; Stevens & Keyser, 2010). These stable regions result from acoustic features of human speech. A non-linear pattern appears to surface from the interaction of articulatory configuration with the acoustic signal. That the perception scale is logarithmic has been well established. It is for that very reason we view vowel space through lenses such as BARK. The implication of nonmonotonicity to acoustic behavior is less well understood.

The QTS predicts certain segments experience little perceptible change despite changes to the articulatory configuration. These segments are termed "quantal vowels". Quantal vowels are thought to exist as a natural kind. The segments [/i/, /a/, /u/] are held as the most likely candidates for such vowels (Clements & Ridouane, 2006). Their position in vowel space is asserted to be universally stable across languages. Further, the within-language distribution pattern is expected to be tighter for quantal vowels than others (Bradlow, 1995).

Bradlow points out her data are in contradiction to theories which propose that similar phoneme segments share similar space across languages. Her finding was that Spanish and English f2 differ significantly for the /i/ segment. Our own data clearly agree with Bradlow. Chapter 3 shows the English /i/ segment to have a higher f2 value than our Chukchansi speakers. A similar relationship is seen in /u/. English shows a higher f1 value for /u/ than our Chukchansi speakers. There is no apparently consistent shift in the position of these points. In other words, their positions do not appear based upon a universal position for any of the segments.

Further evidence can be drawn from the distribution pattern of the vowels. Figure 11 shows a combined overview of the vowel space for both subjects. Surface areas for speaker-specific segment zones are given below in Table 3.

Table 3. Surface Area of Vowel Space Distribution

Segment	Holly Segment Surface Area	Jane Segment Surface Area
i	2.48	1.87
e	1.26	1.47
a	1.34	3.25
o	3.11	3.81
u	3.90	2.23

The /e/ segment in table 3 shows the lowest degree of variance. This is in contradiction to quantal theory which would predict the set [/i/,/a/,/u/] to have the least variance. Instead, we see the order e < a < i < o < u for Holly and e < i < u < a < o for Jane. These findings are similar to Bradlow's. She also discovered no special distribution pattern for the quantal vowels. Based on these findings we consider it unlikely that the quantal vowel phenomenon exists.

CHAPTER 4: VOWEL INHERENT SPECTRAL CHANGE

Vowel Inherent Spectral Change (VISC) was measured primarily in order to investigate the possibility that diphthongs were overlooked in earlier treatments. VISC was calculated as a percentage of change when comparing the points at 25% and 75% of total vowel duration. When selecting vowels in glide environment we excluded ascending and descending frequency slopes which connected the vowel to its neighboring consonant. An example of that procedure is seen in Figure 12.

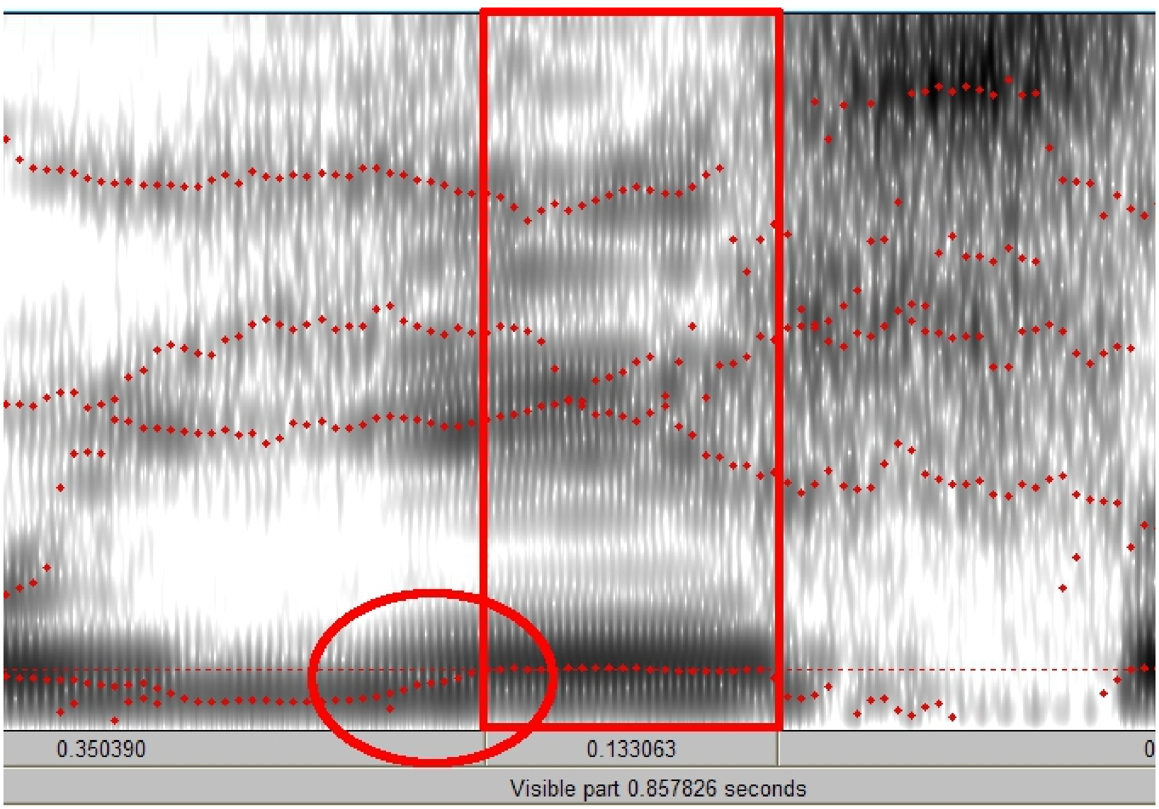


Figure 12. Holly "oyiisan" glide exclusion during measurement

Figure 12 is a spectrographic representation of the /i/ in "oyiisan." The dots in this image serve to track the formants as they change over time. The red square represents our selection of a long /ii/. The circle highlights where the lower formant is rising due to the glide preceding the /ii/.

The formula used to calculate VISC is given in Figure 13.

$$VISC = (1-(fx/fy))*100$$

Figure 13. Formula for VISC calculation

Where fX is equal to the formant frequency value at 25% of the vowel duration and fY is equal to the formant frequency at 75% of the vowel duration.

Table 4 below shows the average VISC for each segment including all tokens elicited during the study.

Table 4. Average Spectral Change

Segment	F1 Holly	F2 Holly	F1 Jane	F2 Jane	F1 Total	F2 Total
i	9.36%	8.21%	8.62%	4.93%	8.97%	6.47%
ii	9.17%	7.61%	4.74%	3.56%	6.95%	5.59%
e	7.99%	5.09%	4.46%	10.90%	6.22%	7.99%
ee	6.91%	2.92%	6.79%	8.90%	6.84%	6.09%
a	6.80%	8.17%	8.99%	6.21%	7.96%	7.14%
aa	11.25%	7.74%	6.84%	7.31%	9.25%	7.55%
o	10.35%	7.41%	8.54%	8.68%	9.44%	8.05%
oo	7.90%	7.30%	9.27%	7.31%	8.59%	7.30%
u	4.75%	19.99%	7.23%	13.28%	5.99%	16.63%
uu	18.24%	4.52%	15.38%	4.32%	16.52%	4.40%

Chukchansi has notably steady spectral patterns across all vowels. The greatest variance occurs in the /u/ segment. Reanalysis of these segments suggest the more significant changes to be occurring in segments neighboring glides.

These variances are too small and too environment specific to award the title of "diphthong."

Some may take issue with our methodology which excludes major spectral shifts in the vowel onset and end when neighboring glides. After all, diphthongs are characterized by spectral shifts. Excluding such shifts may ignore the presence of diphthongs by mistaking a single segment for a vowel-glide pair. There is no danger of such a mistake in our case. Vowel-glide pairs are obviously a vowel consonant pairing as evidenced by their combined length and spectral characteristics. For example, higher formant frequencies in a vowel-glide pair require a high dynamic decibel range in order to detect the glide. A diphthong would show a much steadier degree of amplitude throughout the segment. These findings are consistent with reports of earlier researchers who did not include diphthongs as valid Chukchansi segments (Collord, 1968; Kroeber, 1963; Newman, 1944).

CHAPTER 5: VOWEL LENGTH

Length Discussion

Chukchansi shows clear distinctions in length between long and short vowels. These distinctions are visualized below in Figure 14.

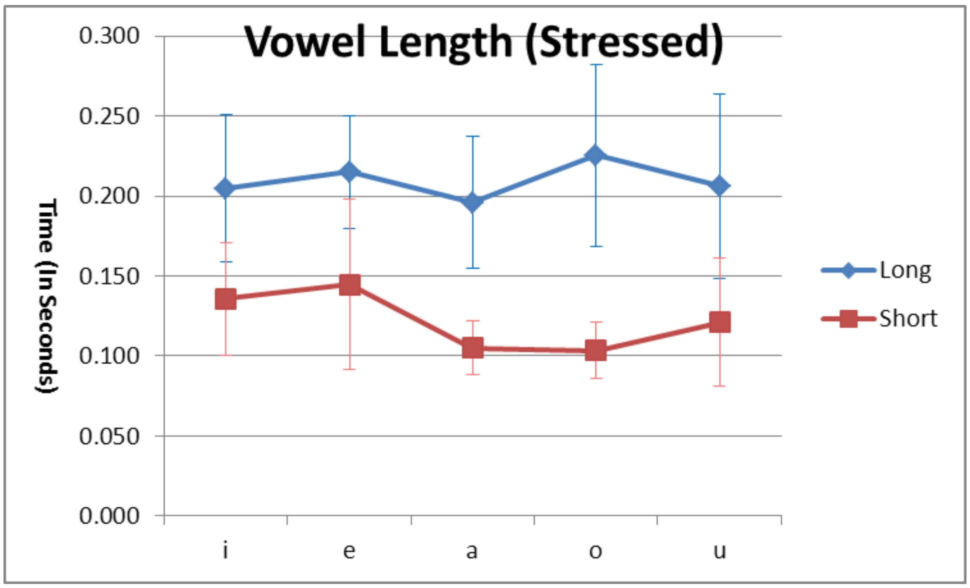


Figure 14. Average lengths of Chukchansi vowels

Error bars represent standard deviation from each point.

Figure 14 is an average of length measurements taken from all tokens. The relationships between each long/short pair are also displayed below in Table 5. This table illustrates the degree to which a long vowel has a greater duration than its short counterpart.

Table 5 and Figure 14 make clear that distinctions between long/short vowels in Chukchansi are significant. These illustrations include all elicited environments with a segment in stressed position. Neighboring consonants appeared to have little effect on vowel length. The exception to this is a varying propensity to conflate long vowels with the neighboring consonant when that consonant is a glide.

Table 5. Long and Short Vowel Length Comparison

Segment Pair	Percentage Ratio
i vs. ii	151%
e vs. ee	149%
a vs. aa	187%
o vs. oo	218%
u vs. uu	148%

As discussed above, parts of a vowel showing positive or negative slope in the spectrum moving toward stabilization with the following consonant were not included. The result was that in some cases the “stable” spectral section of the vowel was much shorter than would otherwise be expected for the vowel in question. An example is Holly’s pronunciation of /ojiisan/ (see Figure 15).

In Figure 15 we have selected the long vowel /ii/ following the completion of the /j/ glide. Note the length of the vowel is 133 milliseconds. This value is below the threshold of a Chukchansi long vowel. If the slope is also selected, the vowel appears to be roughly 177 milliseconds in length. This value is within the range of other Chukchansi long vowels. Holly appears to be unconsciously including the ascending slope of the glide as part of her long vowel.

Such a large spectral shift may raise questions concerning a possible diphthong. We are, after all, admitting that Holly likely considers part of the onglide as part of the vowel. These concerns are easily met. The points discussed above in the VISC section still hold. Holly believes a glide to precede this /ii/. Also, fully selecting both glide and vowel gives a total duration of 857

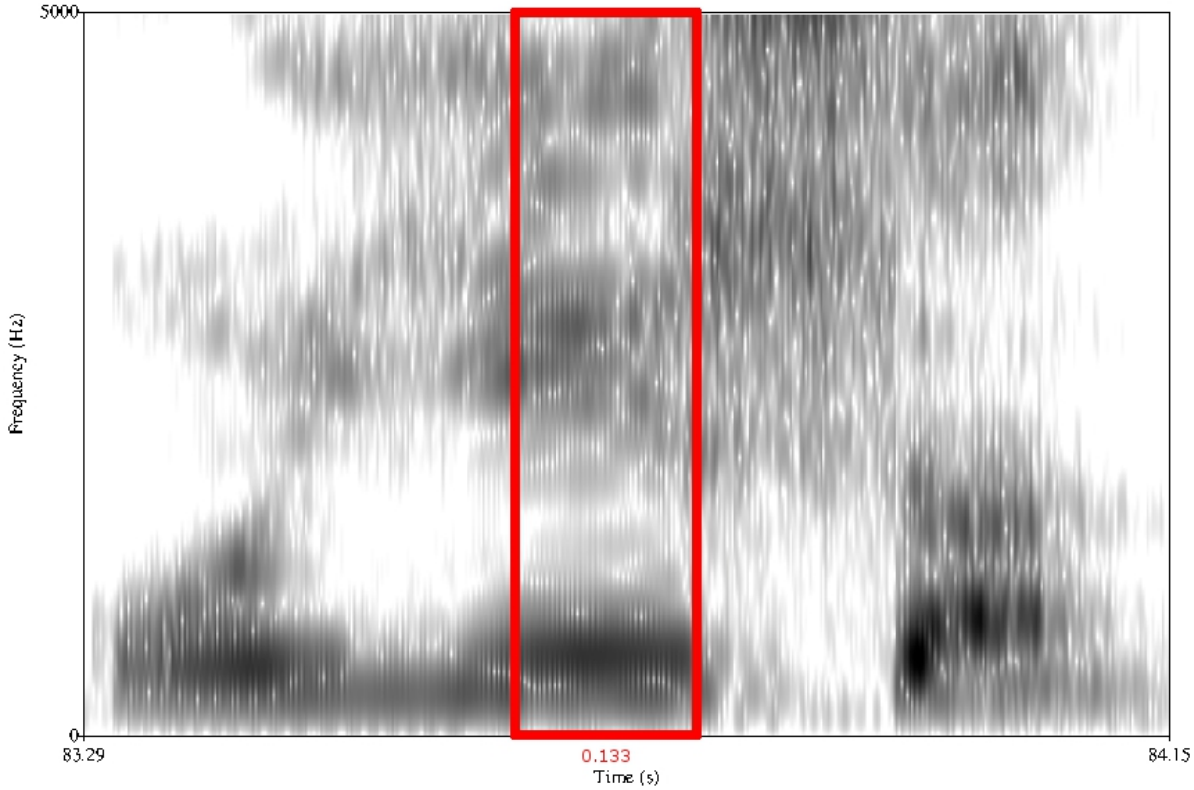


Figure 15. Holly /ojiisan/

milliseconds. Such duration is far too long for a single vowel segment. Further, the spectrogram shows a clear qualitative distinction between higher formant frequencies of the /ii/ and /j/ segments. The /j/ segment is evidently not vowel-like. It is a consonant. These points apply to all elicited tokens in which a glide neighbors a vowel segment.

Our data are not comprehensive enough to perform rigorous investigation of stress effects upon vowel length. A preliminary analysis suggests stress to affect the length of vowels.

Table 6 shows at least a 20% difference in length between stressed and unstressed versions of each vowel. The difference is sufficient that a stressed short vowel can on occasion match the length of an unstressed long vowel. This pattern is in keeping with current understanding of stress interaction with vowel length. It has long been understood that stress increases the relative length of a vowel segment (Fry, 1958).

Table 6. Stress Effects Upon Length

Stress	Word	Speaker	Segment	Length (In Seconds)
Stressed	pa'ch'ishat	Holly	i	0.158
Unstressed	banshit	Holly	i	0.128
Stressed	sheeden	Holly	ee	0.229
Unstressed	shopeeyanaw	Holly	ee	0.144
Stressed	hihiina	Holly	ii	0.290
Unstressed	shiishwilit	Holly	ii	0.221

Long High Vowel Contrasts

Several researchers have come forward arguing General Yokuts, a superordinate category to Chukchansi, neutralizes long high vowels. Kuroda begins this claim by proposing a phonological Yawelmani rule transforming [+long] vowels into [–diffuse] vowels (Kuroda, 1967). Kisseberth presents also a neutralization rule targeting high vowels (Kisseberth, 1969). Whistler and Golla give us a General Yokuts-specific lowering rule targeting "nearly all environments" (Whistler, 1986).

Blevins argues against this tradition of researchers by returning to primary data on the subject (Blevins, 2004). She points out that early researchers included numerous examples of such vowels in a variety of environments running counter to the notions of the researchers mentioned above. Blevins' argument is as thorough as is possible without including spectrographic measurements. It can be added to via data obtained through a study such as our own. While we have nothing to add regarding the Yawelmani specific claims of authors such as Kuroda and Kisseberth, we certainly have comment regarding the broader claim concerning General Yokuts. We support Blevins' argument by presenting hard data showing long high vowels to persist in General Yokuts even today. These data are given below as the value of f1 and f2 in Table 7.

Table 7. Incidences of Long High Vowels

Word (Chukchansi Orthography)	Word (English Gloss)	Speaker	Target Segment	F1 at 50% (T_2)	F2 at 50% (T_2)	Vowel Length (In Seconds)
hihiina	*n.* "Great Horned Owl"	Holly	ii	542	2415	0.290
yuk'shuusha'hiy'	n. "Washroom"	Holly	uu	464	1393	0.164
shiishwilit	*Dem.* "How Embarrassing"	Jane	ii	508	2330	0.195
k'ayuush	"Please"	Jane	uu	486	1023	0.283

The above table makes clear that Chukchansi Yokuts surfaces long high vowels in a variety of environments. Other examples abound. The shortest vowel among the set is 164 milliseconds. This value is certainly high enough to constitute a long vowel. Its shorter nature results from unstressed position. The length may have been further affected by syllable count. "Yuk'shuusha'hiy'" has four syllables in contrast to "hihiina"'s three.

CHAPTER 6: INTRINSIC F0

Pitch is a property of speech affected by a variety of factors. It is familiar to the English speaker as a prosodic feature. The Vietnamese speaker regards it as lexical (Pham, 2003). These differences are a significant source of confusion between L2 speakers. An English speaker will likely think a question is being asked should a Vietnamese speaker utter the “pho” with a high tone [˩˥fə]. The English speaker expects a question when encountering a rise in pitch. The Vietnamese is simply abiding by a lexically required tone. The question remains whether, other such considerations aside, certain segments have characteristic f0 values and why this phenomenon is observed. We do not address the question of why intrinsic patterns of f0 emerge. Our interest lies in using f0 as an aid for vowel classification.

Whalen and Levitt assert the investigation of intrinsic f0 to have begun with an early description of German (Meyer, 1897; Whalen & Levitt, 1995). Their own study surveyed 31 languages for signs of intrinsic f0. The study shows front/back distinctions in vowel space to be an insignificant factor. Vowel height is shown to almost certainly be significant ($p < 0.0001$).

Flemming and Ladefoged recently presented data in support of the notion that f0 corresponds to vowel height (Flemming et al., 2008). Their Montana Salish speakers showed the f0 pattern i, u > e, o > a. Our speakers showed a similar pattern. The long vowel values for f0 taken from our Chukchansi speakers followed the pattern i,u > e, o > a. Table 8 shows this pattern.

The long vowel alveolar environments used in this study were nearly universally stressed. The same is not true of our short vowel tokens. The data show a significant effect of stress upon f0. The effect is clearly visible below in Table 9.

Table 8. Average f0 Values for Long Segments in Stressed Alveolar Consonantal Environments at T_2

Segment	Holly	Jane
ii	241	261
uu	226	256
ee	220	226
oo	204	238
aa	200	218

Table 9. Stress Effects Upon f0

Stress	**Word**	**Segment**	**Holly**	**Jane**
Stressed	ʃuto’	u	251	255
Unstressed	buduʃ	u	187	195
Stressed	ʃaʃaʔ	a	250	223
Unstressed	dadatʃ’	a	166	195

The stress effect seen in Table 9 makes an average of our short vowels useless for this purpose. Our data nevertheless support the notion that f0 varies with vowel height. This notion taken as a premise introduces another useful method for enhancing the accuracy of vowel classification. When applied to Chukchansi, intrinsic f0 gives reason to question whether /a/ is a proper classification of the segment to which it refers. That hypothesis is treated in chapter 7.

CHAPTER 7: /a/ VS /ɜ/

All literature referring to Chukchansi classify the lowest back-central vowel as /a/. Our data suggest this classification to be inaccurate. The unrounded open /a/ segment is more accurately classified as an unrounded open-mid /ɜ/ segment. The evidence for this classification can be seen in our charts reporting vowel space position as well as our examination of the patterns in f0.

We must clearly outline our conception of vowel space before moving to suggest classifications. We conceive of vowel space in the manner of Ladefoged (Ladefoged, 2006). There is a universally finite area of vowel space which can be inhabited by any human. This space is chopped up without regard to any particular language. A chart illustrating this conception of vowel space is given in Figure 16.

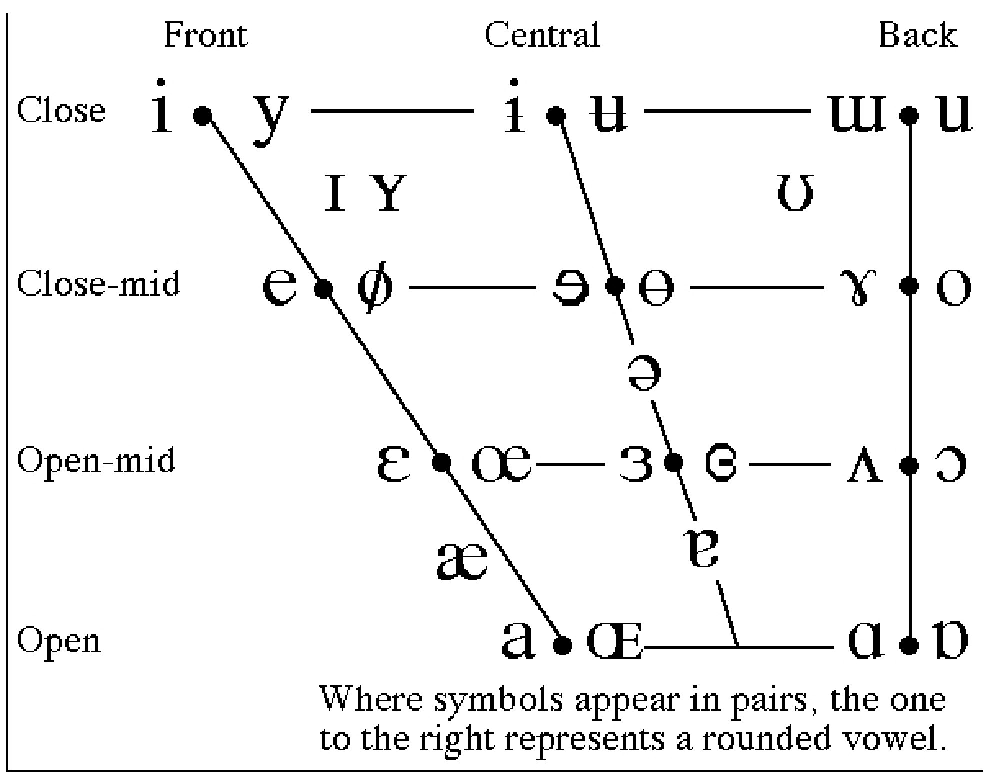


Figure 16. Ladefoged vowel space

Given the chart in Figure 16, we would classify as /i/ and /u/ only two segments which were in similar areas along the y axis of a perceptually representative chart such as BARK. Should we find a segment several BARK units lower than /i/, classification as /u/ would be inappropriate.

Consider the charts from figures 6 and 7 above. The /a/ segment is not substantially lower than /e/ for either Holly or Jane. It is therefore improper to classify the segment as two tiers lower in vowel space than the /e/ and /o/ segments. An example of an actual /a/ and close-mid relationship can be found in Bradlow's English vowel space seen in Figure 8. This space shows a significant difference in position on the y axis for /a/ in relation to both the /e/ and /o/ segments. As stated above, this relationship is not present in the Chukchansi vowel space.

Further evidence against /a/ as a classification can be taken from our f0 patterns. Table 7 shows only a small difference in f0 when comparing /a/ with mid vowels. The difference is not significantly greater than when one compares the mid vowels with one another. This is in contrast to the great difference seen when comparing mid and high vowels. By accepting the theory from chapter 6, that intrinsic f0 values reflect vowel height, we can surmise that /a/ is a vowel of roughly the same height as /e/ or /o/. The appropriate symbol to represent this segment is therefore /ɜ/.

The miscategorization of /ɜ/ as /a/ by earlier researchers is an understandable event. Literature regarding Chukchansi has been produced only by native American English speakers. English speakers make distinctions between an abnormally high number of vowels in the front and back portions of vowel space (Bradlow, 1995; Ladefoged, 2006). They are therefore well qualified to judge open or closedness in front and back vowels. Unlike British English, however, American English speakers do not distinguish between /a/ and /ɜ/. The intuition of an American English speaker may therefore be to hear /a/ when the speaker was producing an [ɜ]. This is a potent example for why using instrumentation is so crucial an exercise when classifying vowels.

CHAPTER 8: SUMMARY

Our exposition of Chukchansi begins by offering refinements to current methodology popular among phonetic researchers. The extraordinary conditions surrounding Chukchansi made collection of data from adult males impossible. We responded by implementing a normalization technique which renders that practice irrelevant from the position of making comparisons between speakers or languages. Researchers may employ this method to compare within-study speakers of different sexes. The procedure may also present an amalgamated vowel space devoid of sex induced variance. It could even be used to confidently compare studies where subject population varied dramatically on the basis of sex. Despite this refinement to analysis methodology, males remain preferable subjects in that their spectrograms tend to be more easily read.

We refine the manner by which phoneticians view prototypical vowel space. Specifically, we argue averaged charts must be abandoned in favor of charts utilizing a statistical method such as the arithmetic median. Utilizing averaged charts presents as prototypical a speaker which does not exist. Utilizing instead the arithmetic median presents whatever speaker or segment most closely approximates the average. This refinement is important because it preserves relationships between vowels otherwise distorted through the use of averaging.

Median and normalized vowel spaces are employed in order to address the notion of phonetic universals. Specifically, we respond to the quantal theory of speech as it applies to proposed point vowels [i, a, u]. Our data agree with findings of past researchers which cast doubt upon the QTS. English shows an overall tighter relationship between its vowels. This includes the point vowels which in English inhabit different absolute positions than their Chukchansi counterparts. A universal position in vowel space for these segments seems unlikely given these findings.

Previous Chukchansi researchers have not employed technical tools, such as spectrograms, in order to support segment classification. Our study considered both the possibility that diphthongs had been overlooked and also that certain segments may be misclassified. We employ an analysis of vowel inherent spectral change in order to evaluate the possibility that some segments are actually diphthongal. The results indicate previous researchers were correct in their evaluation of Chukchansi as a monophthongal language. We depart from tradition in our classification of one of those monophthongs.

An overview of Chukchansi vowel space suggests that the Chukchansi /a/ segment is more properly classified as/ɜ/. Further evidence for /ɜ/ is garnered from our discussion of intrinsic f0. In that discussion we lend support to researchers arguing that vowel height has significant impact upon f0. When all other variables are controlled, Chukchansi /a/ shows an f0 value approaching but not reaching that of a closed-mid vowel. It follows that this segment lies between fully open and closed-mid. This conclusion coincides with vowel space overviews in chapter 3 showing /a/ to possess only marginally a higher f1 than the closed-mid segments /e/ and /o/. Chukchansi therefore cannot be employing /a/. The vowel is best represented by /ɜ/.

Finally, our exposition of vowel length confirms that each short vowel has a long counterpart. This is the first application of instrumental data to the debate over whether General Yokuts surfaces long high vowels. Both /ii/ and /uu/ are attested numerous times in our data. We agree with Blevins that the relative scarcity of long high vowels likely stems from just such a rule existing in Yokuts' past. That rule no longer appears to persist. Chukchansi, and General Yokuts by extension, employ long high vowels in a variety of environments.

Future research would do well to focus upon Chukchansi stress. We have shown that stress clearly affects both vowel length and pitch. However, a thorough understanding of stress effects necessitates suprasegmental analysis as well as consonantal analysis. These analyses are beyond our scope.

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APPENDIX

Chukchansi	APA (Target Segment Underlined)	English Gloss
Sheeden	ʃeeten	Green Onion
dooshi'	tooʃi'	Tell *v., future/irrealis*
budush	putuʃ	Water Oak
hihiina	hihiina	Owl
pa'ch'ishat	p^{h}a'tʃ'iʃat^h	Fight *v., recent past*
shuto'	ʃut^{h}o'	Connect/Add v., *future/irrealis*
dadach'	tatatʃ'	Foot
yuk'shuusha'hiy	yuk'ʃuuʃa'hiy	Bathroom
xeeshix	xeeʃix	Fingernail
Banshit	panʃit^h	Brush *v., recent past*
hewetit	hewet^{h}it^h	Walk *v., recent past*
hedesh	heteʃ	Wood (for fireplace)
tesa'hi'	t^{h}esa'hi'	Lizard
shiishwilit	ʃiiʃwilit^h	How Embarrassing *dem.*
amata’ach'	amat^{h}a’atʃ'	End
tesech’	t^{h}esetʃ’	Door
taxnit	t^{h}axnit^h	Come *v., recent past*
noshosh	noʃoʃ	Aunt
chepute	tʃep^{h}ut^{h}e	White-Crowned Sparrow
Totono	t^{h}ot^{h}ono	(Place Name) Location of several Ghost Dances

cheexa	ʧeexa	Dog
noxox	noxox	Uncle
shasha	ʃaʃa	Eye
xata'an'	xat^{h}a'an'	They are eating *v., present progressive*
Dadaachi’	tataaʧi’	Foot
k'ayuush	k'ayuuʃ	Please!
lak'-lak'	lak'-lak'	Armpit
boyiida	poyiita	Chick
wooyi'	wooyi'	Ancient/Very Old
yaate'	yaat^{h}e'	Say *v.,future/irrealis*
somlela	somlela	Hat
shilish	ʃiliʃ	Hair
sawaadanaw	sawaatanaw	Saturday
wu'shul	wu'ʃul	Eagle
shiishwilit	ʃiiʃwilit^{h}	Embarrassing *v.*
oyiisan'	oyiisan'	Happy *adj.*
loowit	loowit^{h}	Husband
kuyu'	k^{h}uyu'	Salt
huuya	huuya	Caterpillar (of monarch butterfly)
hoyowush	hoyowuʃ	Name
dooyo'	tooyo'	Suck *v., future/irrealis.*
yeech'at	yeeʧ'at^{h}	Once *adv.*
yukshut	yuk^{h}ʃut^{h}	Wash *v., recent past*

ch'ipxele'	tʃ'ip^{h}xele'	Spit *v., future/ irrealis.*
yet’	yet’	One *number*
shopeeyanaw	ʃop^{h}eeyanaw	Wednesday
k'ebesh	k'epeʃ	Short *adj.*
nopop	nop^{h}oo p^{h}	Father/Uncle/Male Cousin
piichis	p^{h}iitʃis	Peaches
pich'it	p^{h}itʃ'it	Count *v., recent past*
aapulkat'	aap^{h}ulk^{h}at'	Apricot
aabula	aapula	Apple
lopish	lop^{h}iʃ	Fish
baabas	paapas	Potato
xap'eelit	xap'eelit^{h}	Hot
boch'on'	potʃ'on'	Son
chabiidiina'	tʃapiitiina'	Western Kingbird
dooshit	tooʃit^{h}	Tell *v., recent past*
epeesich'	ep^{h}eesitʃ'	Lawyer
saboosib	sapoosip	Western Brackenfern
t’apeele	t̓ap^{h}eele	Slapped *future/irrealis.*
bayanat	payanat^{h}	Pick *v., recent past*
bewnit	pewni'	Sew *v., recent past.*
poolayshi'	p^{h}oolayʃi'	Large Black Ant
poyit	p^{h}oyit^{h}	Pound *v., recent past*
dooro	tooro	Bull
bayna	payna	Acorn *n., acc.*

nopop	nop^{h}oop	Father/Uncle/Male Cousin
napash	nap^{h}aʃ	Grandson
sapaasep	sap^{h}aasep	Maidenhair Fern Roots
shoopin	ʃoop^{h}in	Three *quantifier*
luujaalewse'	luucaalewse'	To Wrestle *v., reciprocal, future/irrealis*
diyit	tiyit^{h}	It Stung *v. recent past*
diyeelich	tiyeelitʃ	Herder
oomis	'oomis	Mother
wamle'	wamle'	Throw Down *Future/Irrealis*
mugus	muk^{h}us	Grandmother
aalit	'aalit^{h}	Salt Grass
nobgo	nopko	Gather It *v., imp.*
hew	hew	Here