VOWEL DISPERSION AS A CUE FOR PROMINENCE IN SORA

Luke Horo

Living Tongues Institute for Endangered Languages
luke.horo@livingtongues.org

ABSTRACT

This paper proposes that vowel dispersion is directly correlated to prominence in Sora, a South Munda language of the Austroasiatic language family. Prominence in Sora is known to be marked by duration, intensity and f0. This paper provides evidence that vowel dispersion is also correlated with prominence in Sora. Data comes from the speech of twenty-five male and twenty-five female Sora speakers, recorded in Assam and Odisha of India while performing speech production tasks in the field. The analysis is based on formant frequency measurements and statistical measurements of Euclidean distance. Results reveal that formant frequencies of all vowels in the prominent syllable change relative to vowels in the non-prominent syllable. Also, expansion/compression of vowel space is shown to be affected by this phenomena. Finally, results are discussed in the light of lesser described syllable properties in Munda languages and conflicting views of sesquisyllables in Austroasiatic languages.

Keywords: Vowel, Dispersion, Prominence, Munda, Austroasiatic).

1. INTRODUCTION

Prominence is a perceptual property of speech which is used to indicate salience, focus, contrast or emphasis. Also, the word 'stress' is used to define similar attributes of speech. In this regard, Kohler [12] mentions that, while there can be three different referents of stress, an important referent of stress is syllable prominence which refers to the physical attributes of stress. Thus, it is suggested that syllables are the units that bear prominence and that their properties are detectable. Generally, prominence in a syllable is detectable from the effects it has on the segments that constitute the syllable. This implies a systematic variance across syllables in terms of different acoustic cues of syllable prominence. Accordingly, there are evidences that longer vowel duration, higher pitch ($f0$) and greater acoustic energy (intensity) are the acoustic correlates of prominence in languages of the world [9]. Hence, following Kohler [12] this paper also refers to prominence in terms of its physical attributes only and examines the correlation of syllable prominence with vowel dispersion.

In the typology of Austroasiatic languages, word stress in is often related to the presence of a unique syllable type known as 'sesquisyllable'. Presence of sesquisyllabic word prosody is reported to be atypical to Austroasiatic languages as well as to many other languages spoken in Southeast Asia [15]. On the other hand, it is argued by Donegan [6] and Donegan and Stampe [7, 8] that sesquisyllabic word prosody is lacking in the Munda branch of the Austroasiatic language family. Evidences suggest that sesquisyllabic words once existed in proto Munda, but the modern Munda languages lost it due to rhythmic and syntactic reorganization in various languages. However, Anderson and Zide [4] and Anderson [2] propose that phonological words in Munda languages exhibit iambic stress and they argue that the iambic stress resembles to the sesquisyllable word prosody of non-Munda Austroasiatic languages. Significantly, this is also evident in Sora (a Munda language of the Austroasiatic family) which has a basic (C)V(C).(C)V(C) syllable structure and prominence marked by duration, intensity and $f0$ is always present on the second syllable [10]. Thus, this work provides further evidence that prominence in the second syllable of Sora can also be correlated with the vowel dispersion.

2. METHODS

2.1. Database

Sora text corpus used in this work includes disyllabic lexical data compiled from various sources. The primary sources are Hora and Sarmah [10], Ramamurti [16] and Anderson and Harrison [3]. Text data compiled from these sources consists only disyllables that also represent vowel minimal sets and consonant minimal sets. Taking all these data together, a total of 1160 Sora lexical items is compiled in this work.

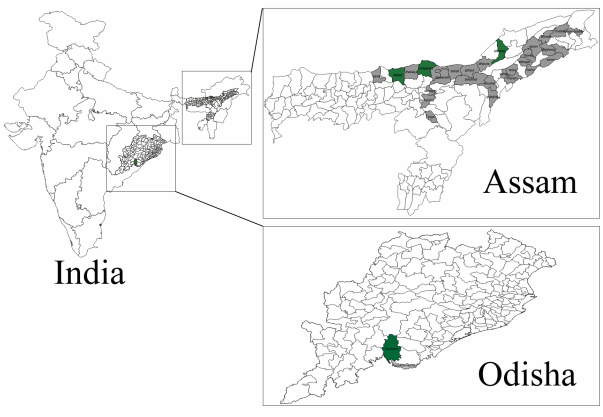
Subsequently, Sora speech data is generated by recording the cumulative text corpus through field studies that were conducted in Assam and Odisha.

During the field study, all the participants were recorded saying every word once in isolation and once in the sentence frame '*ɲen ____ gamlai*' translated as 'I ____ said'. The speakers were recorded with a Shure unidirectional head-worn microphone connected to a Tascam linear PCM recorder via xlr jack. The sampling frequency was 44.1 kHz, 24 bit in WAV format.

2.2. Participants

The Sora speech database is built by recording 50 native Sora speakers including 40 Sora speakers of Assam and 10 Sora speakers of Odisha. Both male and female speakers are recorded whereby 50% of the speakers are males and 50% are females. Average age of both male and female speakers is 49 years. Field studies in Assam were conducted in four villages including Singrijhan and Sessa tea estate in Sonitpur district, Lamabari tea estate in Udalguri district and Koilamari tea estate in Lakhimpur district. In Odisha, the field study was conducted in a village named Raiguda in Rayagada district. Figure 1 shows the map of Assam and Odisha, highlighting Sora villages in light grey and highlighting areas of data collection in dark green.

Figure 1: Locations of data recording.



2.3. Acoustical Measurements

Sora has six vowels including /i, e, a, ə, o, u/ [10], [11]. This work examines the acoustic properties of the six vowels individually in prominent and non-prominent syllables. For this purpose, digital speech data described in §2.1, was manually annotated in Praat [5] for (a) word boundary (b) syllable boundary and (c) phoneme boundaries. While vowels are marked between steady state formants, obstruents consonants are marked between release of the obstruents and onset of the glottal pulse of the following vowel and sonorant consonants are marked between the beginning and end of weaker formants.

Acoustic measurement of the vowels is based on formant frequencies of the first two formants (F1 and F2). Formant frequencies for F1 and F2 are extracted at vowel midpoints for steady state formants using a script for Praat. Also, in order to show the perceptual distances between the vowels [13], formant frequency values for F1 and F2 are converted from Hertz to Mel using an inbuilt function in Praat.

Additionally, in order to control the variation in formant frequencies caused due to the speaker's physiological differences, F1 and F2 frequencies of all six Sora vowels are normalized in this work. In this regard, Adank [1] has shown that vowel normalization method proposed by Lobonov [14] effectively removes the speaker's physiological influence, and preserves the phonemic and sociolinguistic information contained in the formant frequency of vowel sounds. Therefore, this work also adopts the vowel normalization method proposed by Lobonov [14] to reduce speaker effect on the six Assam Sora vowels /i, e, a, o, u, ə/ using equation 1.

(1) $$z = \frac{x-\mu}{\sigma}$$

In equation 1 z represents the normalized formant frequency calculated for the individual formant value x; μ represents the mean value of individual speaker's formant frequency values and σ represents the standard deviation in individual speaker's formant frequency values. Thus, with the help equation 1 the six vowel sounds are normalized separately for every speaker.

2.4. Statistical Measurements

In order to measure vowel dispersion, in terms of perceptual distance, euclidean distance between all the vowels in prominent and non-prominent syllable is calculated for the Sora vowel system. Euclidean distance measurement is commonly used to show vowel dispersion in terms of perceptual distance between two vowels in the F1 and F2 plane of a vowel space [13]. In other words, euclidean distance basically measures the distance between the points which represent the position of two vowels in a vowel plot. Also, since vowel points represent a combination of F1 and F2 frequencies, the distance considers both F1 and F2 frequencies of the two vowels for which the euclidean distance is calculated. Therefore, euclidean distance between two vowels represent the combined effect of F1 and

F2 frequencies of the two vowels. Thus, in order to measure vowel dispersion, in terms of perceptual distance, euclidean distance is calculated in this work using equation 2.

(2) $$eud = \sqrt{(F1_x - F1_y)^2 + (F2_x - F2_y)^2}$$

In equation 2 *eud* represents the euclidean distance between two vowels based on their F1 and F2 frequencies. $F1_x$, $F1_y$ and $F2_x$, $F2_y$ represent the F1 and F2 frequencies of the two vowels between which the euclidean distance is calculated.

Subsequently, in order to compare vowel space in prominent and non-prominent syllable, vowel area space of Sora vowel system in the two syllables is estimated. For this purpose, the vowel system is divided into three parts representing three vowel triangles such as /i-e-a/, /i-a-u/ and /u-o-a/. Then area of the three vowel triangles is calculated using equation 3.

(3) $$area = \sqrt{s(s-a)(s-b)(s-c)}$$

In equation 3 *'a'*, *'b'*, *'c'* represent lengths of the three sides of a vowel triangle and *'s'* represents the summation of a, b and c or (a+b+c). Also, lengths of the three sides of every vowel triangle basically represents the euclidean distance between two vowel points. For example, in the the vowel triangle /i-e-a/, *'a'* represents the euclidean distance between /i/ and /e/, *'b'* represents the euclidean distance between /e/ and /a/ and *'c'* represents the euclidean distance between /a/ and /i/ in the vowel triangle. Subsequently, after calculating the area of the three vowel triangles in a vowel system, overall vowel area space of the vowel system is estimated by adding the areas of the three vowel triangles.

3. RESULTS

3.1. Vowel formants in prominent and non-prominent syllables

By examining the formant frequencies of Sora vowels separately in prominent and non-prominent syllables, it is revealed that formant frequencies of all vowels change as a function of syllable prominence. Table 1 shows the average F1 and F2 of all Sora vowels in non-prominent syllables and Table and 2 shows average F1 and F2 of all Sora vowels in the prominent syllable.

From Table 1 and Table 2 it is observed that while both F1 and F2 frequencies of all vowels change in prominent and non-prominent syllables, in case of back vowels, greater change is usually observed in F2 frequency, whereas in case of front and central vowels greater change is usually observed in F1 frequency. This indicates that Sora back vowels are often fronted or retracted, and front vowels are often raised or lowered depending on the prominence patter in Sora. This kind of movement is also evident in Sora vowel plots presented in Figure 2.

Table 1: Average F1 and F2 of Sora vowels in non-prominent syllable with standard-deviation in parenthesis.

	F1	F2
i	271.98 (35.84)	912.82 (66.71)
e	339.54 (38.49)	864.47 (61.76)
a	448.67 (70.25)	758.55 (66.46)
ə	319.16 (44.20)	788.75 (68.53)
o	397.66 (43.18)	639.52 (76.72)
u	307.13 (38.30)	591.27 (86.99)

Table 2: Average F1 and F2 of Sora vowels in prominent syllable with standard-deviation in parenthesis.

	F1	F2
i	284.20 (40.82)	914.82 (64.89)
e	382.02 (42.54)	841.17 (60.34)
a	479.78 (57.65)	735.54 (50.86)
ə	342.65 (51.25)	796.38 (66.52)
o	416.80 (46.51)	603.44 (49.73)
u	318.68 (41.60)	613.59 (96.82)

Figure 2: Speaker normalized Sora vowel plots in prominent and non-prominent syllables.

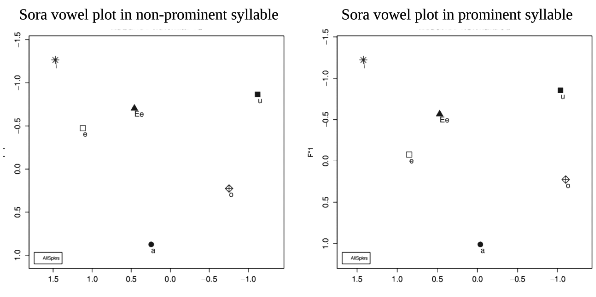


Figure 2 shows the speaker normalized Sora vowel plots in prominent and non-prominent syllables. The vowel plots reveals that while mid front vowel /e/ is raised in the non-prominent syllable, it is lowered in the prominent syllable. Likewise, it is revealed that while the mid back vowel /o/ is fronted in the non-prominent syllable, it is retracted in the prominent syllables. Hence, the formant frequency analysis of Sora vowels confirms the fact that vowel formants particularly F1 and F2 of all vowels change as a function of prominence in Sora.

3.2. Vowel dispersion in prominent and non-prominent syllables

As a result of variation in foramnt frequencies of Sora vowels, caused due to syllable prominence, it observed that vowel dispersion (perceptual distance) between Sora vowels is also effected. It is observed that, depending on the prominence patterns, Sora vowels have different dispersion in the vowel system. Table 3 shows the dispersion between Sora vowels, in terms of Euclidean distance, in the non-prominent syllable and Table 4 shows the same in the prominent syllable.

Table 3: Euclidean distance between Sora vowels in non-prominent syllable.

	i	ə	u	o	a
ə	132.73				
u	323.46	197.85			
o	300.81	168.63	102.58		
a	234.55	132.98	219.12	129.50	
e	83.07	78.41	275.11	232.34	152.08

Table 4: Euclidean distance between Sora vowels in prominent syllable.

	i	ə	u	o	a
ə	132.08				
u	303.20	184.35			
o	338.45	206.70	98.64		
a	265.32	150.02	202.05	146.35	
e	122.45	59.63	236.23	240.27	143.93

By examining the euclidean distance between Sora vowels in prominent and non-prominent syllables it is revealed that dispersion between all vowels is generally minimized or maximized as a function of syllable prominence. It evident that front vowels /i/ and /e/ are relatively close to each other in non-prominent syllable, but separated further in the prominent syllable. Similarly, the central vowels /a/ and /ə/ are relatively closer to each other in the non-prominent syllable than in the prominent syllable. Likewise, the back vowels also differently dispersed from the mid central vowel depending on their prominence patterns. Hence, it is confirmed that dispersion between all Sora vowels in the vowel system is reduced or expanded to a certain degree as a function of syllable prominence.

3.3. Vowel Area Space in prominent and non-prominent syllables

Variation in vowel dispersion between Sora vowels in prominent and non-prominent syllables also effects the overall shape and size of Sora vowel system. This phenomenon is revealed by estimating the vowel area space of Sora vowel system separately in prominent and non-prominent syllables. Estimated vowel area space of Sora vowel system in prominent and non-prominent syllables is presented in Table 5.

Table 5: Vowel area space of Sora vowels in prominent and non-prominent syllables.

	Non-Prominent Syllable	Prominent Syllable
VAS	30791.67	34733.08

Estimation of vowel area space presented in Table 5 reveals that vowel area space of Sora vowel system is essentially different in the prominent and the non-prominent syllables. This indicates that, the vowel space encompassing all the vowel sounds in Sora vowel system is normally effected as a function of syllable prominence. Consequently, it is observed that vowel area space is usually larger in the prominent syllable than in the non-prominent syllable.

4. DISCUSSION

Formant frequency measurements and statistical measurements in this work have revealed that F1 and F2 frequencies of Sora vowel system change as a function of syllable prominence. Specifically, it is shown that Sora vowel system has different formant frequencies in prominent and non-prominent syllables, vowels are differently dispersed in prominent and non-prominent syllables. Consequently, resulting in different vowel spaces of Sora vowel system in prominent and non-prominent syllables. Thus, it is shown that syllable prominence significantly effects the Sora vowel system. Hence, it is suggested that in addition to the temporal measures of syllable prominence namely, duration, intensity and $f0$, vowel dispersion can also be a significant correlate of prominence in the Sora language.

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