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# ACOUSTIC SPACE AND FORMANT PATTERNS OF VOWELS IN MAITHILI AND ANGIKA: A COMPARATIVE AND DESCRIPTIVE STUDY

**Mohammad Asad***

## Abstract

*The present paper aims to provide a descriptive and comparative investigation of the acoustic space and formant patterns of vowels in Maithili and Angika. Angika is considered as a variety of Maithili (Jha 1958). Acoustic space is an adequate tool to determine objectively the vowel space in a language. Acoustic space also helps us to revisit Dispersion Theory, and Quantal Theory. The speech data were recorded from twenty native speakers in the Speech and Language lab at Jawaharlal Nehru University. The results of the study present that the formant frequencies (F1 and F2) and acoustic spaces of vowels are distinct in Maithili and Angika. Further, it reflects that the formant frequencies (F1 and F2) and acoustic space of Maithili vowels are greater than that of Angika vowels. The work finally discusses Jha's (2001) observation with respect to formant frequencies and the positioning of the vowels in acoustic space and claims that the present finding differs from the Jha's observation.*

***Key Words:*** *Maithili, Angika, Acoustic space, Formant Patterns (F1 & F2), Oral Vowels*

## Introduction

Acoustic space is a tool that is used to portray how the formant frequencies help to determine the vowel space objectively in languages. It helps us to empirically test the hypotheses of the Quantal Theory (Steven 1972, 1989) and the Dispersion Theory (Liljencrants and Lindblom 1972, Lindblom 1986, 1990). Dispersion Theory (DT) claims that speech sounds are selected through the constraints that are based on a principle of sufficient perceptual contrast. According to this theory, a language's vowels are arranged and ordered in the acoustic vowel space to reduce the possibilities of perceptual confusion between the distinct vowel categories. This hypothesis about the examination of vowel inventories has been apparently established (Lindblom 1975 and 1986, Disner 1984). In fact, a different approach to vowel systems is advocated by Bradlow (1995) using the

* K. L Deemed University , Andra Pradesh, India

Quantal Theory (Steven 1972, 1989). This assumption is based on the finding that there is a non-monotonic relationship between variation in the articulatory configuration and its acoustic effects for some articulatory domain parameters. In short, according to this theory, there are specific areas of stability in the phonetic space. It is asserted that the vowel points /i/, /a/, and /u/ belong to the stable regions and these peripheral vowels occur most frequently in the languages of the world (Maddieson 1984). According to Ladefoged (2001), "The acoustic vowel space can be considered to be an area bounded by the possible ranges for the frequencies of the first two formants". Catford (1988) notes that the production of vowels adheres to a limit or space in the oropharyngeal cavity, which establishes the acoustic space of vowels in a language. A slight deviance in the space results in the production of an approximant type of sound. The most important point is that the Cardinal Vowel chart, created by Daniel Jones, was influenced by the concept of the vowel limit or acoustic vowel space. Ohala (1999) points out that vowels are classified in terms of an 'abstract vowel space which is fairly characterized by a four-sided dimension known as'Vowel Quadrilateral'. The Vowel Quadrilaterals can be used to objectively represent the extent of the vowel space.

Formant is genetically a German word. The German physicist Hermann first used the word "formant" in the second half of the nineteenth century. It is an acoustic term for a sound quality that significantly separates one vowel from another by the variations in overtone pitches. It is a resonating frequency of the air in the vocal tract which reflects the way at which the lung air vibrates in the vocal tract and changes the shape and size of the vocal cord. The vocal cord may vibrate more quickly or slowly, changing the pitch of the sound, but the formant frequency will stay constant if the vocal tract's shape does not change. For any vowel, the lung air vibrates in the vocal tract at several different frequencies and the most dominant frequencies combine to produce the distinctive vowel qualities. Three major formants for each vowel: F1, F2 ,and F3 are found to provide the primary descriptions of vowel sounds: the first formant (F1) is the lowest, and the second and third formants (F2, F3) are respectively higher (Shriberg and Kent 2003, Ladefoged 2006).

**Main Objectives**

The main goals of the present study are as follows.

(1) To investigate the formant patterns (F1 and F2) of vowels in Maithili and Angika.

(2) To explore the acoustic space of vowels in both languages.

(3) To contrast the formant patterns and acoustic spaces of vowels in Maithili with Angika.

**Research Questions**

The present work aims to focus on several objective questions. These questions are as follows.

a) What are the similarities or differences in the patterns of formants and the acoustic spaces of vowels between Maithili and Angika?

b) Despite being varieties of the same language, is there any difference between Maithili and Angika in the vowel formant patterns and acoustic spaces?

**Hypothesis**

These two languages are the major varieties of the same language. It is hypothesized that there is no difference in formant patterns and acoustic spaces of vowels between Maithili and Angika.

**Methodology**

**Participant Selection**

There were twenty adult participants; 10 native speakers of Maithili and 10 native speakers of Angika: who voluntarily participated in the speech data elicitation process. They were undergraduate students at Jawaharlal Nehru University. They were born and brought up in their native places for more than 20 years. No subject had any kind of speech, articulatory, hearing, and neuro-cognitive symptom. The participant selection was based on an informal face-to-face interview. It assisted in achieving two key objectives: firstly, determining whether a speaker met the screening requirements, such as geographic region, education and age, and secondly, determining whether the speaker has any physical or neurological abnormalities.

**Language Sample**

There are five major geographical and regional varieties of the Maithili language, widely spoken in Bihar. For the present study, the data was collected from only two main varieties of Maithili, i.e., Standard Maithili *(Central Maithili)*, spoken in the district of

Madhubani, and Angika (*Southern Maithili*), spoken in the district of Bhagalpur.

**Data Elicitation**

There were a total of eight pure oral vowels and eight nasal vowels in Maithili. However, for the present study, only pure oral vowels were chosen for the voice sample recordings. Each of the targeted vowels occurs at the middle position of the real word in a monosyllabic pattern (CVC). Stop consonants functioned as the phonetic environment of vowels. To ensure the highest possible level of speech data quality, each subject articulated the targeted word three times so that it can be employed for further acoustic examination. Consequently, there were roughly 960 recorded tokens (8 vowels x 20 speakers x 2 varieties x 3 repetitions= 960). However, only the middle repetitions of the recorded tokens were taken for the additional offline acoustic analysis. Finally, 320 recorded tokens in total were selected for the acoustic investigation.

**Data Recording**

The chosen word samples were printed separately before the speech data collection operation. Each participant was then given a printed copy of the page and instructed to read each word in his or her own natural manner. To have the perfect repetition of the recorded voice samples, each of the utterances were repeated three times (three repetitions) after taking a normal breath with a brief pause during the data elicitation method. In Speech and Language Lab at Jawaharlal Nehru University, New Delhi, all speech samples were captured using a Sony IC voice-recorder with a microphone placed between 05 and 10 cm from the subjects' mouths and a sample rate of 44.1 kHz. All the recorded speech samples were converted into WAVE files to do the acoustic study.

**Data Analysis**

All the recorded voice samples, saved in WAVE files were loaded in PRAAT software (Boersma and Weenik, 2009) which was installed on a Mac Book Air laptop, to extract temporal acoustic properties of the targeted vowel. After loading the data in the software, it was opened to segment the vowel duration. Consequently, a wideband spectrogram and visual waveforms were produced and shown. For the present work, the segmentation procedure was followed as described by (Bradlow, 1995) as well as (Burris et al. 2014) in their research works. By visually inspecting the spectrogram and waveform, as well as by

hearing the sound segment, the onset and offset of the vowel were identified. The primary criteria was the presence of vowel formants (F1 and F2) and the steady state of the vowel. To identify the steady state selection, first two vertical cursors were placed in the spectrogram; the first cursor indicated the end of the formant transitions leaving the first consonant and the second cursor denoted the start of formant transitions entering the final consonants. The primary concern of the vowel segmentation was to determine the steady state portion, and formant frequencies (F1 and F2) of the vowel segment. The calculation of the formants (F1 and F2) in Hz was conducted for each monophthong or oral vowel from the visual spectrogram. All the formants (F1 and F2) were clearly visible in the spectrogram. Formant chart was computed for each vowel according to average values of F1 and F2. The F1 and (F2-F1) values were plotted negatively on the Microsoft Excel sheet to arrive at acoustic spaces of vowel in both languages.

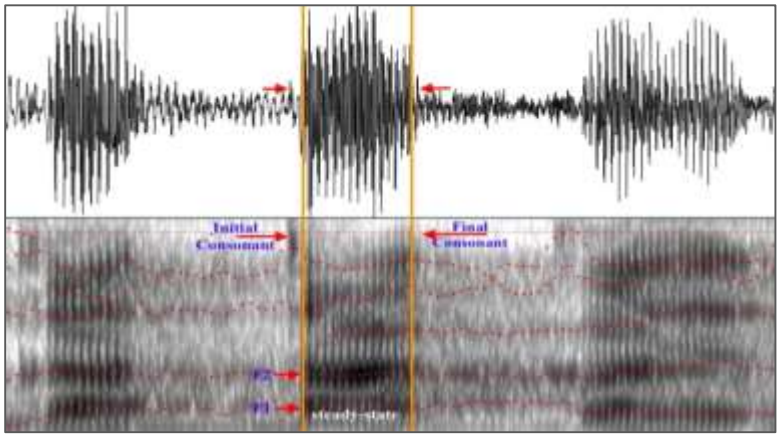


**Figure 01.** Segmentation of Speech Sound /pat/

**Result**

Grand mean values of formant patterns F1 and F2 of the eight oral vowels were measured from 320 recorded voice tokens, produced by ten Maithili and ten Angika male speakers. The detailed observations have been discussed in the following subsections separately.

**Formant Pattern**

Formant frequency is an integral portion of the vowel speech sounds. Each vowel is clearly distinguished from another by the formant frequencies (F1, F2, and F3). For the current work, only

F1 and F2 were considered. Table 01 provides the grand average values of formant patterns F1 and F2 comparatively in both languages.

| **Comparison of Formant Patterns** | | | | |
|---|---|---|---|---|
| **Languages** | **Maithili** | | **Angika** | |
| **Vowels** | **F1** | **F2** | **F1** | **F2** |
| /i/ | 299 | 2334 | 355 | 2214 |
| /e/ | 452 | 1987 | 423 | 1862 |
| /æ/ | 605 | 1832 | 552 | 1740 |
| /a/ | 711 | 1347 | 690 | 1222 |
| /ə/ | 589 | 1422 | 556 | 1313 |
| /ɔ/ | 534 | 949 | 561 | 942 |
| /o/ | 439 | 846 | 455 | 858 |
| /u/ | 355 | 982 | 388 | 1023 |

**Table 01.Grand average values of F1 and F2 of all eight oral vowels measured from 320 voice samples, produced by 10 Maithili and 10 Angika native speakers**

From Table 01, it is clear that in both the languages high vowels /i/ and /u/ have the lowest F1, whereas low vowels /æ/, /a/ and /ɔ/ have higher F1. Further, it is noticed that F2 is higher for the front vowels /i/, /e/, and /æ/, while low for the back vowels /ɔ/, /o/ and /u/. Furthermore, it is found that lip rounding can reduce all formant frequencies (F1 and F2). Therefore, F1 and F2 of the unrounded vowels are higher than of rounded vowels.

In addition, Table 01 provides a fundamental description for each oral vowel in terms of F1 and F2 in Maithili and Angika. It is certainly viewed that F1 and F2 values for each vowel are similar in Maithili and Angika, respectively. ANOVA test was conducted to find out whether there is any difference in F1 and F2 values for each vowel, respectively between Maithili and Angika. The statistical results clearly reveal that there is no significant difference ($p > 0.01$) in F1 and F2 values for each vowel, respectively, between Maithili and Angika. Moreover, reconsidering the fact may serve as evidence that Maithili and Angika are indeed regional varieties of the same language.

**Acoustic Vowel Space**

Acoustic space demonstrates how formant frequencies facilitate to define objectively the vowel space in a language. Grand average values of negative (F2-F1) and F1 of eight oral vowels were computed from 320 voice samples, articulated by 10 Maithili and 10 Angika native speakers. The same data are tabulated in Table 02 below. Figure 01 presents a comparison of

the acoustic space of vowels in Maithili and Angika, respectively. Acoustic vowel space is exactly defined and determined by plotting (F2-F1) for front-back criteria against (-F1) for high-low criteria.

| Varieties | Maithili | | Angika | | Average |
|---|---|---|---|---|---|
| Vowels | -(F2-F1) | -F1 | -(F2-F1) | -F1 | |
| /i/ | -2035 | -299 | -1860 | -355 | |
| /e/ | -1535 | -452 | -1439 | -423 | |
| /æ/ | -1227 | -605 | -1188 | -552 | |
| /a/ | -637 | -710 | -532 | -690 | |
| /ə/ | -833 | -589 | -757 | -556 | |
| /ɔ/ | -415 | -534 | -381 | -561 | |
| /o/ | -407 | -439 | -403 | -455 | |
| /u/ | -627 | -355 | -706 | -388 | |

**Table 02. Grand average values of -(F2-F1) and -F1 of all 8 vowels computed from 320 voice samples, produced by 10 native speakers of Maithili and Angika respectively**

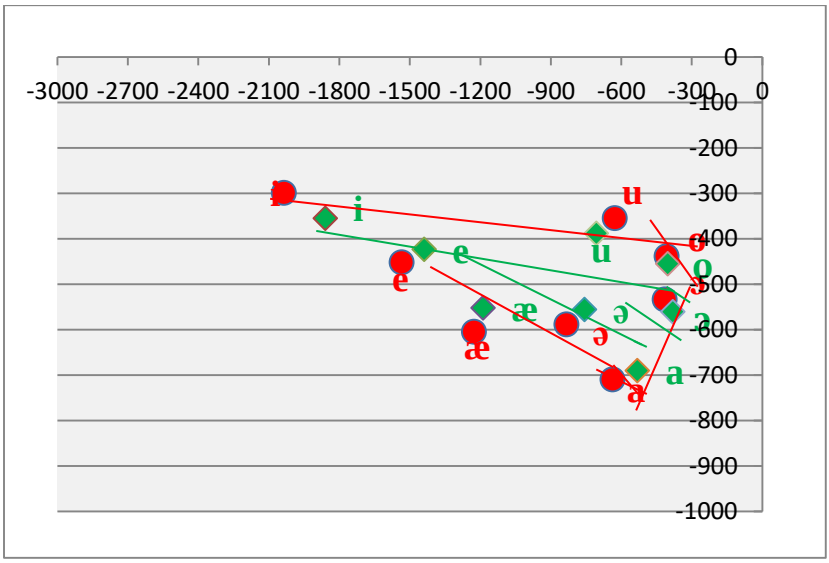


**Figure 01. Comparison of Acoustic Space of 8 oral vowels in Maithili and Angika**

Figure 01 clearly exhibits that there are one central and seven peripheral vowels in Maithili and Angika. In the Figure 01, it is discovered that the front vowels /e /, /æ/ are less fronted than /i/ in these languages. The central vowel /ə / is neither fronted nor backed. In fact, it exists in a central area as predicted. The low vowel /a/ is slightly back in languages. Besides, it is noted that

the back vowels /ɔ /, /o/ are more back than /u/ in the plot. The location of all seven peripheral vowels on the plot demonstrates that there is very little difference in acoustic vowel spaces between Maithili and Angika. The acoustic vowel space of Maithili is highlighted in red color and Angika in green color. Furthermore, Figure 01 indicates that vowel height-low is negatively correlated with F1 formant frequency. Thus, the high vowels have low F1, and low vowels have high F1. Similarly, the vowel frontness-backness is correlated with F2. Therefore, front vowels have high F2, and back vowels have low F2. The results of the present study denote that F1 varies from 290 Hz to 500 Hz, F2 from 780 Hz to 2500 Hz. F1 is correlated with the tongue height and F2 with the frontness-backness dimensions of the tongue during articulation. F3 co-relates to lip rounding.

Acoustic vowel space is calculated by using an online available program, i.e., Irregular polygon area calculator. The area of acoustic space of Maithili peripheral vowels is 307268.00 and of Angika peripheral vowels is 191929.50. After the calculation, the ratio of Angika and Maithili is 1:1.60. It is found that the acoustic space of Angika peripheral vowels in terms of area is 60% smaller as compared to Maithili vowels. The difference of 60% between acoustic vowel space between Angika and Maithili is due to the front vowel /i/. In fact, the front vowel /i/ is more fronted than other counterparts. Thus, the acoustic space of Maithili vowel is larger in area than that of Angika vowel. For the rest of the vowels, there is no difference in their locations in acoustic space.

**Discussion**

The main goal of the present paper is to investigate the formant patterns and acoustic space of vowels in Maithili and Angika. The findings of the current work reveal that the acoustic vowel space in Maithili slightly differs from Angika in the location of their vowel categories. Although both languages have common vowels, namely, /i/, /e/, /æ/, /a/, /ə/, /ɔ/, /o/ and /u/, Maithili vowels are slightly higher in F1 and F2 dimension than Angika counterparts. It was found that the Maithili vowels are articulated with a fronted tongue position relative to the Angika vowels. Although both languages have similar acoustic vowel spaces, the native speakers of each language speak their language distinctively in terms of phonetic variations. The similar claim is made by Bradlow (1995) who points that vowel categories have the same phonological feature specification and that occupy similar positions in the acoustic space across two different languages may have different precise phonetic realizations due to

different bases of articulation of each language. Likewise, Disner (1983) suggests that the vowels of one language may differ in a proper way from similar vowels of another language, based on cross-language comparison of acoustic vowel spaces.

The major notion and concept behind Dispersion Theory (DT) is that vowels will tend to be maximally or sufficiently dispersed in the acoustic space to reduce the possible perceptual confusion between distinct vowel categories. Within this theory, it is typically assumed that the boundaries of the acoustic space are defined universally and the distance between the different vowel category locations is a measure of overall dispersion (Liljencrants and Lindblom 1972, Lindblom 1986, 1990). The boundaries of the acoustic vowel space are more precisely defined on a language-specific basis, as it is claimed by the cross-linguistic acoustic studies (Lindau & Wood 1977, Disner 1983, Bradlow 1995). The results of the present study efficiently support and agree with DT hypothesis and provide some indication of a positive correlation between inventory size and area covered in the vowel space.

The major idea behind Quantal Theory is that there are acoustically stable regions that works universally. Thus, according to QT, there are certain vowels, specifically, the point vowels, whose locations in the acoustic space should be constant across all languages. However, the finding of the present study exhibits that the second formant frequency (F2) of the Maithili high front vowel is relatively different from the Angika high front vowel and that clearly disconfirms prediction and assumption of the Quantal Theory. The QT claims that the high front corner of the acoustic space (the low F1 & high F2) is a strictly quantal region that demonstrated a stable phonemic category across languages. The present results indicate that there is some degree of flexibility regarding the accurate location of the /i/ vowel category in Maithili and Angika, respectively, within the region of the acoustic space. A study on acoustic vowel space that has been conducted by Bradlow (1995) also shows that within the boundary of the acoustic space, there is some degree of flexibility with respect to the location of the /i/ vowel across different languages. Thus, it is recommended to use the term ‘relatively stable regions’ as opposed to ‘absolute stable regions’ to maintain the basic principle of Quantal Theory, at least as it relates to the position of vowels in the acoustic space (Bradlow 1995). The results of the present study disagree with the claims that there are certain stable regions of vowels in the acoustic space. Rather, the data shows relative variability across

the two languages with respect to the locations of all vowels in the acoustic space.

Most of the present findings are in agreement with Jha's (2001) observations. The front vowels /i/,/e/,/æ/, central vowels /a,/ /ə/ and back vowels /ɔ/, /o/, /u/ judged by their positioning in the acoustic space. The front vowel /i/ is fronted more than another front vowels /e/, /æ/. The fact is that /i/ and /e/ are slightly positioned higher than /u/ and /o/ that agrees with Jha's observation. Further, it is noticed that the increase in F1 values as we move from /i/ to /a/ and decreasing F2 values along the same direction are also in agreement with Jha's observation.However, some findings of the present study tend to differ from Jha's observations. Jha states that central vowels /a/, /ə/ are more central (more fronted and less back), but the findings of the present study demonstrate that central vowels /a/ and/ə/ are slightly backward and less fronted in Maithili. Further, it shows that the back vowels /ɔ/, /o/ are more back than another back vowel /u/.

**Conclusion**

The present study provides a descriptive and comparative study of acoustic spaces and formant patterns of vowels in Maithili and Angika. The results of the present study can be concluded in the following bullet points.

- It is found that the high vowels /i, u/ have a low F1, whereas low vowels /æ, a, ɔ/ have higher F1. F2 is higher for the front vowel, viz., /i, e, æ/ and low for the back vowels /ɔ, o, u/ in Maithili and Angika.
- Each oral vowel differs from others by F1 and F2. The F1 goes up for the first four vowels i.e, æ, a/ and down for the last three vowels /ɔ, o, u/. The F2 goes downwards throughout the series /i , e, æ, ə, a, ɔ, o/ except /u/ vowel in both languages.
- Observed that except /i/ vowel, the front vowels /e, æ/ are less fronted. These vowels /ə/, /a/ exist in a central region. The back vowels /ɔ, o/ are more back than /u/ vowel.
- Noted that acoustic space is determined by plotting (F2-F1) for front-back criteria against (-F1) for high-low criteria.The area of acoustic space of Angika peripheral vowels is 60% smaller than that of Maithili vowels.

- Noticed that in acoustic vowel space, the Maithili vowels are slightly shifted upward in F2 and F1 dimensions relative to the Angika vowels because the Maithili vowels are higher in F2 and cover a greater area than the Angika vowels.
- Finally, the present results show that the location of vowels in the acoustic vowel space is determined by a language-specific basis, and articulation dimensions of speakers.

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