VOWEL SPACE AREAS ACROSS DIFFERENT REGIONAL DIALECTS OF KANNADA

Sahana Srinivasan

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May, 2016

CERTIFICATE

This is to certify that the dissertation entitled “Vowel space areas across different regional dialects of Kannada” is the bonafide work submitted in part fulfillment for the degree of Master of Science (Speech-Language Pathology) of the student (Registration No.14SLP026). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore,

May, 2016.

Dr. S. R. Savithri

Director

All India Institute of Speech and Hearing,
Manasagangothri, Mysuru-570006

CERTIFICATE

This is to certify that the dissertation entitled ***Vowel space areas across different regional dialects of Kannada*** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

Dr.N. Sreedevi

Guide

Reader and Head
Department of Clinical services
All India Institute of Speech and Hearing
Manasagangothri, Mysuru

Mysore

May, 2016.

DECLARATION

This is to certify that this dissertation entitled ***Vowel space areas across different regional dialects of Kannada*** is the result of my own study under the guidance of Dr. N. Sreedevi, Department of Speech Language Sciences, All India Institute of Speech and Hearing, Mysore, and has not submitted earlier in any other University for the award of any Diploma or Degree.

Mysore **Register No: 14SLP026**

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DEDICATED TO MY DEAR LORD KRISHNA, AMMA AND APPA

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CHAPTER – 1

INTRODUCTION

Vowels are the most illuminated letters in the alphabet. Vowels are the colors and souls of poetry and speech

Patti Smith, 1976.

Speech is a vocalized form of communication or expression of thoughts in spoken words which involves production of sounds that make up speech sound utterances. Speech is the actual behavior of producing the code by making vocal sound patterns.Speech exists in an objective and physical world which is measurable.

Speech mechanism involves the coordination of the structures such as jaw, lips, tongue, vocal cords, vocal tract and respiration. It is considered as waves of air pressure created by airflow pressed out of the lungs and going out through the mouth and nasal cavities. During speech production, acoustic signal is formed as the vocal organs move, resulting in the patterns in the air molecules in the air stream. According to Fant (1960) speech waveform is the result of interaction of source and vocal tract filter system. Articulatory phonetics and acoustic phonetics play a crucial role in understanding the production of speech. Articulatory phonetics describes the mechanism in which the individual articulators contribute to produce speech. Acoustic phonetics is focusedon describing the different kinds of acoustic signal associated with the movement of the vocal organs that results in the production of speech.

Speech gets modified as vowels and consonants as it passes through the vocal tract and vocal cords.Vowels appear in the beginning of speech development and are essential to understanding acoustic properties of speech. Vowels as the syllabic sounds in which there is no central obstruction in the oral tract and are produced by voiced excitation of the open vocal tract.

Vowels can be produced in isolation without changing the position of the articulators, and uses the glottis as the primary source of sound. During the production of vowels, the velum is normally elevated to prevent the excitation of nasal tract. Acoustically, vowels are longer in duration and higher in energy and hence carry more information. Vowels are traditionally described in terms of the relative position of the constriction of the tongue (front, central, back), height of tongue (high, mid, low), lips (spread, rounded), position of the soft palate (closed, open), phonemic length (short, long), and tenseness of the articulator (lax, tense). Tense vowels have longer duration and are produced with greater muscular effort as compared to lax vowels.

In the articulatory space, the three primary vowels are /a/ (low-central), /i/ (high-front), and /u/ (high-back). Acoustically, vowels are characterized by formant pattern, spectrum, duration, and fundamental frequency.In the production of vowel sounds, the air in the vocal tract vibrates at a number of different frequencies simultaneously. Changes in the position of the articulators will modify the shape of the vocal tract, and the location of formant frequencies. A formant frequency is a bandwidth containing concentration of energy. Formant frequency location is the critical determinant of vowel quality rather than the position of the articulators.

Vowels are mainly characterized by the first three formants (F_1, F_2, and F_3). The First formant frequency (F_1) varies inversely with tongue height, the second formant frequency (F_2) varies directly with the tongue advancement, and all formant frequencies decrease with increased lip rounding (Hixon, Weismer, &Hoit, 2008).$F_1$is high for vowel /a/ and low for vowel /i/. $F_2$is high for vowel /i/ (front tongue constriction), and low for vowel /a/ (larger oral cavity compared to pharyngeal cavity). The frequencies of all the formants are lowered for vowel /u/ due to lip rounding and reduction in the overall length of the vocal tract. Vowels are produced by vibration of the vocal folds as the air flow moves through the mouth which is held in an open and fixed position. The shape of the organs- tongue and lips alter the shape of oral cavity and give different vowels of their characteristic sound quality. To describe vowels, the position of tongue, duration/extent of phonation and lip shape are important. The formant frequencies (F1 and F2) considered in the present study are depicted in a spectrogram as shown in figure 1.1.

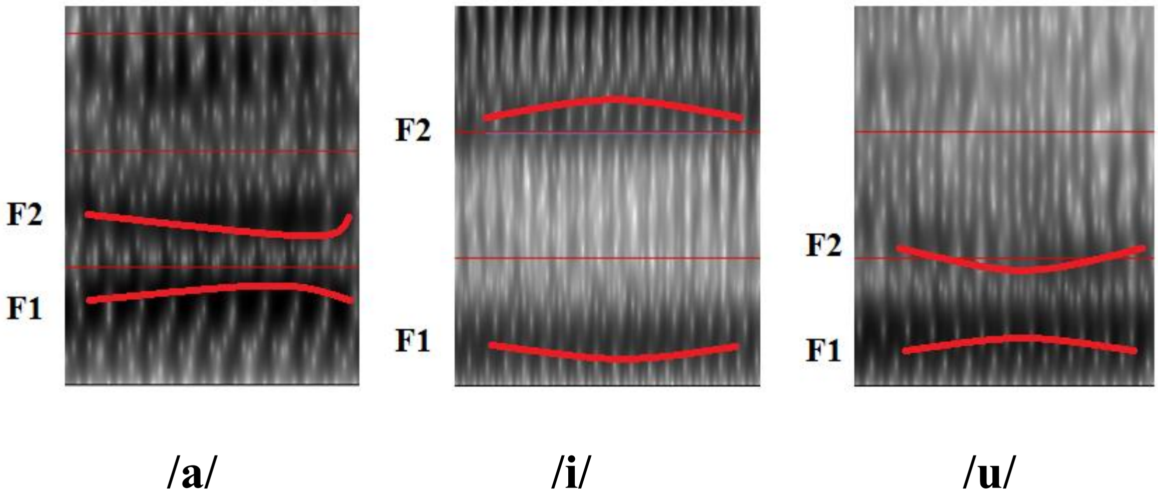

*Figure 1.1.*Spectrograms of vowels /a/, /i/, and /u/.

Acoustic vowel space

The vowel space is a graphical method to represent speech sounds, such as vowels, and their location in both "acoustic" and "articulatory" space. In majority of languages, the vowel system is triangular (Vowel triangle). In English language, the vowel system is quadrilateral (Vowel quadrilateral). Vowel space area (VSA) refers to the two-dimensional area bounded by lines connecting first and second formant frequency coordinates (F_1/F_2) of vowels. The first two formants are used to plot the vowel space, where the vertical axis represents the first formant frequency (F_1) and the horizontal axis shows the frequency gap between the first two formants (F_2-F_1). This two dimensional representation corresponds, to a certain degree, to tongue body position, in an articulatory space (Krishna & Rajasekhar, 2012). Vowel space area is described as an index of the accuracy of vowel articulation, which signifies gross motor control ability of the tongue and jaw coordination. To examine the vowel working spaces of individual talkers, the ''corner'' vowels, such as /i/, /a/, and /u/, are frequently selected as these vowels are the most common in human languages (Ladefoged &Maddieson, 1996). The acoustic vowel space representation of corner vowels /a/, /i/, and /u/ are represented in figure 1.2.

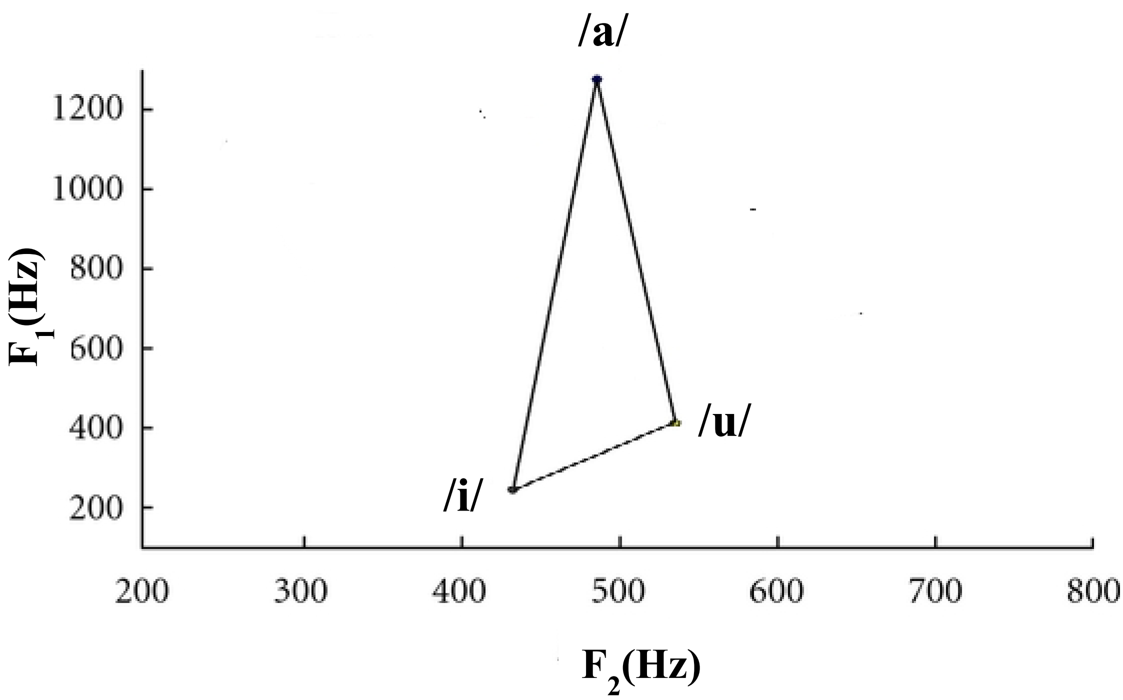

*Figure 1.2.*Acoustic vowel space representation of vowels /a/, /i/, and /u/.(Source: www.hindawi.com)

The formant frequency values differ across individuals, gender and dialects. Despite these variations, the vowels are perceived and produced in a similar manner and vowel space is used to understand the difference in the variability of the vowels. Ladefoged (1975) interpreted although the vowels of different languages are perceived as same, there are subtle differences between them. Hence, it is relevant to study the acoustic and temporal characteristics of vowels in different languages and age groups. Vowel space emerges gradually during infancy with linguistic exposure and by 18 months, vowel space defined by corner vowels is apparent. Fant, 1960 stated that as the vocal tract develops, its acoustic properties change. Specifically, as age increases and the vocal tract lengthens, formant frequencies decrease.For females, the pattern of vocal tract growth continues essentially unaltered through puberty and into adulthood. However, males show an additional disproportionate vocal tract lengthening during puberty, which is caused mainly by a descent of the larynx and consequent lengthening of the pharynx. Adult male vocal tract is longer than a female vocal tract (Male vocal tract: 18 cms, Female vocal tract: 15 cms) and thus the formant frequencies change across both the gender.

Many studies have been conducted to explore the relationship between vowel space and factors like intelligibility, gender, age, dialect etc. Larger vowel space and area has been considered as an indicator of clear speech and used for judging the speech intelligibility (Carrell, 1984; Blomgren, Robb & Chen, 1998; Ferguson &Kewley-Port, 2007).Cross dialectical variations in vowel space are majorly due to the distinctiveness of the neighbouring vowels and base of articulation. Variations in vowel space are observed in various disordered population such as dysarthria, voice disorders, and hearing impairment indicating a smaller vowel space.

Kannada language

Kannada language is one of the major Dravidian languages spoken primarily in Karnataka State in South India, and has a literature that is present from the ninth century. This language has a clear distinction between the spoken and written forms of the language. Spoken Kannada varies from region to region. The language has approximately 40 million native speakers who are referred to as Kannadigas (*Kannaḍigaru*) and is classified as among the top 40 languages in the world. There are about 20 dialects of Kannada that vary from standard to non standard forms. The standard dialects in the present study considered are namely: Mangaluru Kannada, Mysuru Kannada, Dharawad Kannada, and Kalaburagi Kannada. Figure 1.3 represents the map of Karnataka depicting the four districts.

Mangaluru Kannada

Mangaluru Kannada is the most common language spoken in Dhakshina Kannada comprising of Dravidian origin.

Mysuru Kannada

Mysore, officially referred to as Mysuru, is the third most populous city and located in the southernmost part of Karnataka. Kannada language of Mysore is one among the most prominent among the Dravidian group of languages.

Dharawad Kannada

Dharawad Kannada is a northern dialect spoken in the twin cities of *Dharawad*-Hubli. This language slightly varies from the Kannada spoken in southern districts of Karnataka.

Kalaburagi Kannada

Gulbarga Kannada referred to as Kalaburagi, is also a northern dialect spoken in the city of Gulbarga. This dialect has the influence of Urdu language.

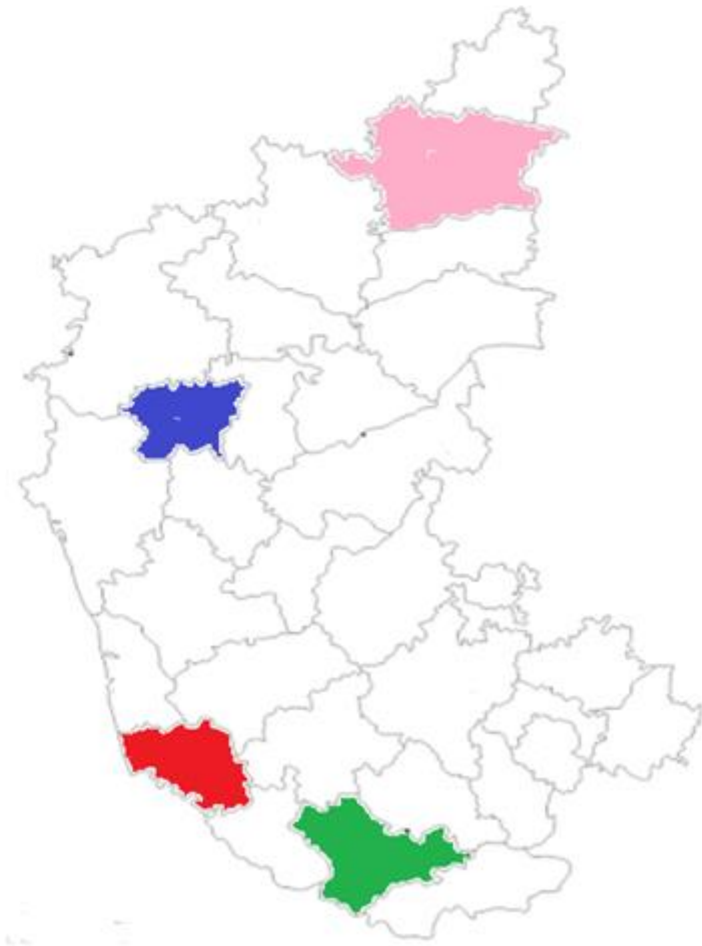

Figure1.3. Map of Karnataka depicting the four districts. *Red: Mangaluru dialect, Green: Mysuru dialect, Blue: Dharawad dialect, Pink: Kalaburagi dialect*

Need for the study

In Indian languages there is an extensive variability in the acoustic characteristics of vowels across speakers from different geographical regions.The majority of studies examining these variations have been primarily focused in the positions of the vowels in the acoustic vowel space and phonetic quality. However, there is a lack of research in the vowel space across different regional dialects. Hence the present study attempts to explore the vowel space areas across regional dialects of Kannada.

Aim of the study

To explore and compare the vowel space areas across different dialects of Kannada (Mangaluru, Mysuru, Dharawad, and Kalaburagi).

Objectives of the study

1) To obtain vowel space using first (F_1) and second (F_2) formant frequencies of the corner vowels /a/, /i/, /u/ and calculate vowel space in native Kannada speaking adults between 20-30 years of age of Mangaluru, Mysuru, Dharawad, and Kalaburagi districts respectively.
2) To compare the vowel space across the four different regional dialects.
3) To compare vowel space across the dialects in males and females

Limitations of the present study

- Samples are taken from limited regions.
- The participants considered for the study are less.

Implications of the study

- The findings of the study help to understand the variation within language.
- The present study helps to understand the articulatory and acoustical dynamics of the vocal tract.
- The information on vowel space will help the Speech Language Pathologists to evaluate the vowel appropriateness and vowel intelligibility in persons with communication disorders.

CHAPTER- 2

REVIEW OF LITERATURE

Vowel is a speech sound resulting from the unobstructed passage of the laryngeally modulated airstream, radiated through the mouth or nasal cavity without audible friction or stoppage (Nicolosi, Harryman&Kreshech, 1978).Vowels are produced by voiced excitation of the open vocal tract. Vowels can be produced in isolation without changing the position of the articulators, and uses the glottis as the primary source of sound. Vowels /a/, /i/, and /u/, are referred to as corner vowels and these vowels frequently occur in the world's languages (Maddieson, 1984).Vowels are produced by vibration of the vocal folds as the air flow moves through the mouth which is held in an open and fixed position. The shape of the tongue and lips alter the shape of oral cavity and give different vowels of their characteristic sound quality. To describe vowels, the position of tongue, duration/extent of phonation and lip shape are important. Subba Rao, 1992 described the tongue positions in terms of front, central, back, high, mid and low; the lip shape is described as either rounded or unrounded and extent of phonation is described long and short. The tongue positions for the corner vowels /a/, /i/ and /u/ are represented in figure 2.1.

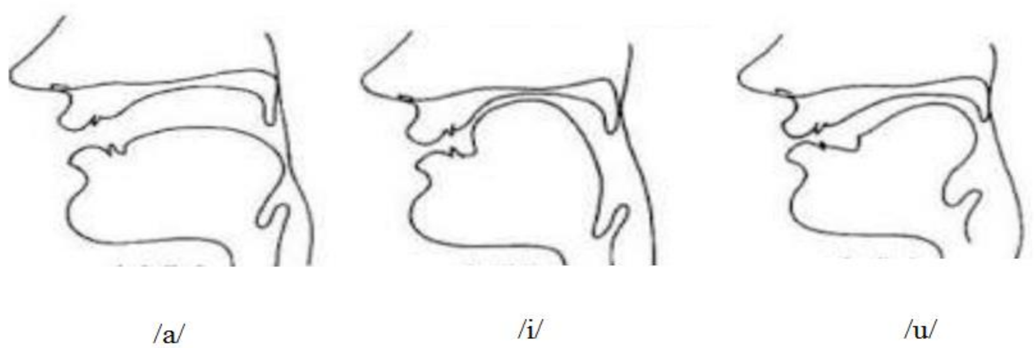

*Figure 2.1.*Tongue positions for corner vowels /a/, /i/, /u/. Source: Wikipedia.org

Vowels are mainly characterized by the first three formants (F_1, F_2, and F_3). The most important acoustic cues to the perception of vowels lie in the frequencies and the patterning of the speaker's formants. A formant is a preferred resonating frequency of an acoustical system and is characterized by its center frequency and the range of frequencies on either side that have amplitudes within 3 dB of the center frequency. The first three formant frequencies are referred to as the F-pattern (F1-F2-F3) for a vowel (Hixon, Weismer & Hoit, 2008).

Hixon et al. (2008) described that the tongue height, tongue advancement, and lip rounding contribute to change in formant frequencies. The first formant frequency (F1) varies inversely with tongue height. Therefore, the lower the tongue at the major point of constriction for the vowel, the higher is F1.The second formant (F2) increases and F1 decreases with increasing tongue advancement. Finally, all formant frequencies decrease with increased lip rounding.

Acoustic vowel space

The acoustic vowel space is a graphical method to represent the vowels, and their location in both "acoustic" and "articulatory" space. It is considered central in understanding the accuracy of vowel articulation, which signifies gross motor control ability of the tongue and jaw coordination. The vowel space is plotted using the first two formants, where the vertical axis represents the first formant frequency (F1) and the horizontal axis represents the second formant frequency with the lines connecting the points representing the gap between the first two formants (F2-F1). The corner vowels /a/, /i/, and /u/ are designated to examine the acoustic vowel space because they are perceptually and acoustically exceptional and they represent the extreme positions in a talker's articulatory vowel working space, and hence extreme formant frequency values in acoustic space (Lindblom, 1990). The ‘‘corner’’ vowels, have also been described as quantal points and are the most common in human languages (Ladefoged & Maddieson, 1996).The acoustic vowels space are affected by several factors such as age, gender, language, dialect, etc. The factors are explained in the following headings.

Acoustic vowel space across age

Studies have advocated that the vowel space changes with age. The effect of growth and development of the vocal tract on vowel production are on formant frequencies, which decrease as the vocal tract lengthens. Vorperian and Kent (2007) suggested that the ***length of the vocal tract increases from birth (approximately 6 to 8 cm) to adulthood (15 cm for women and 18 cm for men).*** Vocal tract growth has been characterized as non-uniform because its oral (anterior or horizontal) and pharyngeal (posterior or vertical) parts have different growth patterns. Predominantly in males, the vocal tract has disproportionate growth in the pharyngeal region compared with the oral region.

Vorperian and Kent (2007) studied the development of VSA in children and summarized the following results:

- First, the child establishes a language-appropriate acoustic vowel space.
- With growth of the vocal tract, there is a gradual decrease in formant frequency values and in formant frequency variability for a given vowel.
- Gender differences in the values of the formant frequencies for the same vowel emerge by age four years (especially for low vowels).
- Gender differences become more pronounced with age, with more apparent differences by eight years.

- An abrupt lowering of frequencies in the F1-F2 space, which was apparent for all corner vowels between ages one and four years and again between ages 14 and 15 years (rel atedto lowering of the laryngeal position in infants and again in adolescence, especially in males).
- Increase in F1-F2 space that were limited to low vowels for children between five and six years and females between ages 10 and 12 years were postulated to relate to differences in certain regions of vowel acoustic space (differences in anterior-oral versus posterior-pharyngeal regions of the vocal tract).

Vorperian and Kent also observed that, across development, there was minimal variability in F_1 for high vowels but increased variability for F_2, especially for /u/. They hypothesized that this may reflect influences of dialect, articulatory variability, and non uniform growth of vocal tract, particularly in posterior pharyngeal regions.

In the Indian context, Krishna and Rajashekhar examined the acoustic vowel space in 72 typical native Telugu speakers from three different regions (Coastal, Rayalaseema and Telengana) in three different age groups (6 to 9 years; 13 – 15 years; and 20 – 30 years). The stimuli consisted of a list of 60 meaningful words consisting of all ten short and long vowels present in Telugu, in all possible preceding consonant and semivowel (CVCCV/CVCV) context was used. The participants were asked to read the sentence presented to them visually. Results (as depicted in figure 2.2) revealed that $F_1$and F_2 for all vowels (/i/, /a/ and /u/) reduced as the age increased which indicated that smaller vowel space is noted for adults as compared to children.

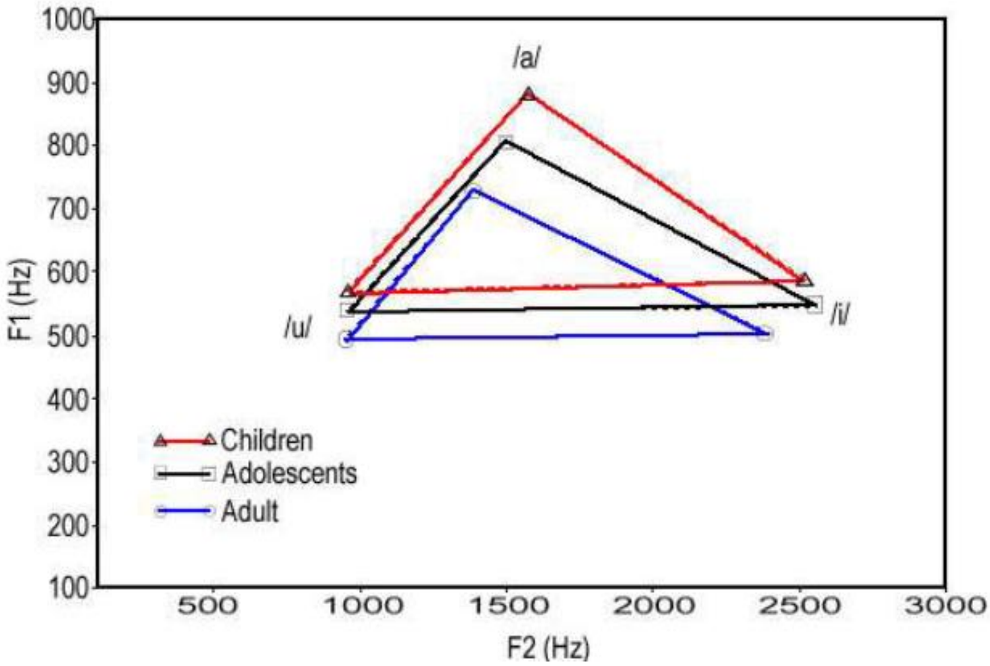

*Figure 2.2.*Vowel space across age groups. Source: Krishna and Rajashekhar, 2012

Acoustic vowel space across gender

Formant values are related to the properties of an individual's vocal tract, which is composed of two cavities (pharyngeal and oral) which can differ in overall length and in length ratio. On average, males have longer vocal tracts and particularly longer pharyngeal cavity [Chiba &Kajiyama(1941), Fant (1966)]. The cavities and the moving articulators give rise to different characteristic formant structures reflected in vowel space. These spaces vary in persons sue to sociocultural and biological factors.

Simpson (2001) studied the relationship between the articulatory and acoustic product and examined the gender-specific differences between male and female vocal tracts. Acoustic and articulatory records were collected from 22 male and 26 female speakers of Upper Midwest dialect of American English between 18 to 27 years of age. The participants were asked to perform linguistic (reading short texts, telephone numbers), and non-linguistic (swallowing) which were recorded. Articulatory data constituted the position of eight gold pellets (four lingual, two labial, two mandibular) which were extracted for each acoustic data. The acoustic data of the vowels were investigated in for the words “they”, and “all” from the sentence “they all know what I said”. The diphthongs /ai/ was considered for acoustic analysis for the word “light” from the sentence “the coat has a blend of both light and dark fibres”. Results indicated that F_1 excursion for vocalic stretch was maximum in female speakers as compared to male speakers. Secondly, it was observed that posterior male lingual pellets travelled maximum distance at higher speed than female speakers which contributed to reduced vowel space.

In the Indian context, Krishna and Rajashekhar (2012) compared the acoustic vowel space and formant frequencies across genders of typical native speakers of Telugu language. Results indicated that (as depicted in figure 2.3), female participants showed higher values compared to male participants for all formant frequencies and vowels compared. It was noted that the vowel /a/ had the highest mean F_1 followed by high front vowel /i/ and high back vowel /u/ whereas high front vowel /i/ had highest mean F_2, followed by /a/ and /u/.

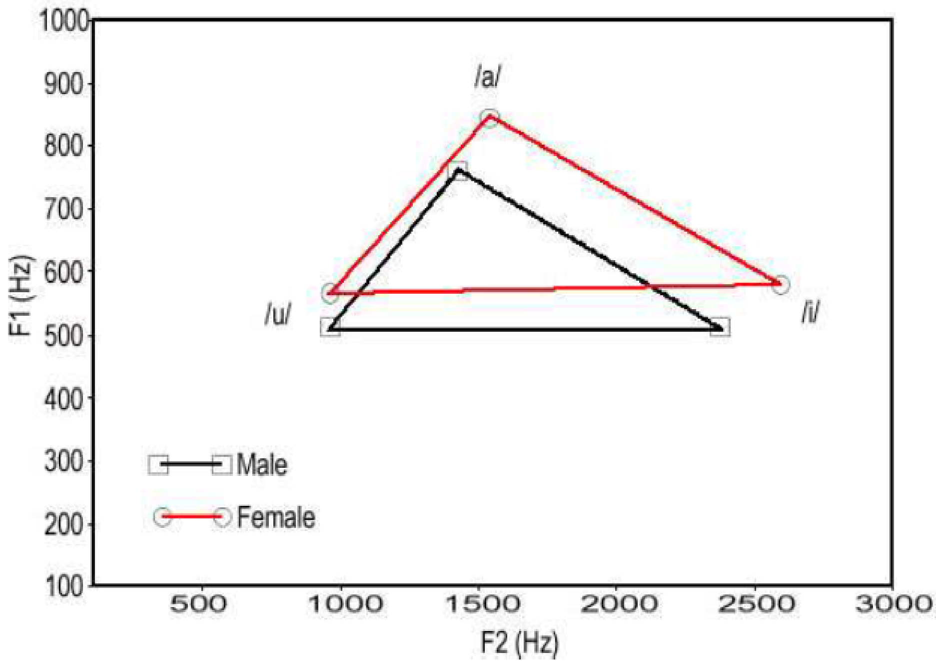

*Figure 2.2.*Vowel space across gender. Source: Krishna and Rajashekhar, 2012

Acoustic vowel space across languages

Bradlow, (1994) did a comparative study on English and Spanish vowels to explore the effect of vowel space area on phonemic vowel categories of English and Spanish. The first finding of this study is that the English and Spanish vowel spaces differ systematically in the location of their vowel categories in the acoustic space defined by F1 and F2. English vowels are all significantly higher in the F2 dimension than their Spanish counterparts, suggesting that the English vowels are all articulated with a fronted tongue position relative to the Spanish vowels. This finding is consistent with other cross-language comparisons of acoustic vowel spaces. Disnet, (1983) suggested that the vowels of one language may differ in a systematic way from similar vowels of another language.

Al-Tamimi and Ferragne (2005) studied the effect of the size of the vowel inventory in the production of speech from two languages, namely: Arabic dialect (Moroccan-

MA and Jordanian Arabic- JA) and French dialect (FR). A total of 15 subjects consisting of 5 subjects per each language between 20-30 years of age range were considered for the study. The participants were asked the repetitions of word lists in C1VC, C1VCV, and C1VCVC contexts which were audio recorded and subjected to acoustic analysis. C1 was one of the three phonologically common consonants between the two languages /b d k/ and each vowel. The results indicated that the FR vowel space is larger than that of JA and MA. Secondly, the point vowels appeared to have approximately the same position in the acoustic vowel spaces across the three languages in only two conditions (Syllable and in isolation).

Chung, Kong, Edwards,Weismer, and Fourakis (2012) examined cross-linguistic variation in the location of corner vowels in the vowel space across five languages (Cantonese, American English, Greek, Japanese, and Korean) and three age groups (2-year-olds, 5-year-olds, and adults).

The vowels /a/, /i/, and /u/ were elicited in familiar words using a word repetition task. This study showed that the adult vowel spaces formed by the three point vowels systematically differed from each other in terms of both size and shape. In comparing vowel spaces of children to those of adults, results showed the vowel spaces of the 5-year-olds were mostly similar to those of adults of the same language, while those of 2-year-olds were similar in shape, but were smaller in size than those of adults.

Acoustic vowel space across dialects

Hilerbrand, Getty, Clark and Wheeler (1995) examined the acoustic characteristics of 14 American English vowels in 45 Males, 48 females and 46 children in south-eastern and south- western parts of America. Participants were asked to read 16 lists of words in /hvd/ context and were audio recorded. Based on Hillerbrand et al. (1995) study, Neel (2008) studied the relation between vowel production characteristics and intelligibility. Global measures (mean f0, F1, and F2; duration; and amount of formant movement) and fine-grained measures (vowel space area; mean distance among vowels; f0, F1, and F2 ranges; duration ratio between long and short vowels) were used to predict identification scores. Results indicated that global and fine-grained measures accounted for less than one- fourth of variance in identification scores. Vowel space area accounted for 9%–12% of variance. The differences in vowel identification were largely due to poor identification of vowels /æ/, /e/, and /a/. Hence, the researchers suggested that distinctiveness among neighboring vowels is more important in determining vowel intelligibility than vowel space area.

Jacewicz, Fox and Salmons (2007) compared vowel spaces in three regional varieties of American English spoken in central Ohio, south-central Wisconsin, and western North Carolina. Participants included 18 native speakers (9 male, 9 female) for each dialect area between 20-34 years of age .Stimulus material included 14 real words and non words in /hvd/ context which contained 14 vowels and diphthongs of American English. The researchers compared sizes of vowel space namely, 4-vowel space (includes vowels /a/, /i/, /u/, and /æ/ and 5- vowel space (included /a/, /i/, /u/, /æ/, and /oi/) respectively. Results indicated that in4- vowel space, although inter-speaker variability occurred within each dialect, significant dialectical differences were observed whereas the 5- vowel space demonstrated cross dialectical differences. Hence, the researchers postulated that in spite of differences in the formant frequency values which influence the phonetic quality of particular vowels, dialectical variations are minimal in extended vowel space area encompassing a complete vowel system. The researchers also suggested that although the positions of corner vowels differed, the size of the entire vowel space area used by male or female speakers of the three distinct regional varieties of American English remained the same.

In the Indian context; numerous studies have explored the formant frequencies of vowels. A recent study in Kannada language, Kapali (2015) investigated the acoustic characteristics of vowels in two Kannada dialects. Participants included 40 typical native speakers of Mangaluru dialect, and Dharawad dialects between 18- 30 years of age which included equal number of males and females in each dialect. The participants were asked to read 60 meaningful words in C1VIC2V2 context. V1 consisted of the three target vowels /a/, /i/, and /u/. V2 consisted of one of the vowels from Kannada language. C1 and C2 consisted of one of the stops mentioned in /k,g,c,dz,t,d,p,b,m,n/ phonemes. The data was recorded and subjected to acoustic and statistical analysis. Results indicated that F1 of vowel /a/ and F2 of vowel /i/ were higher in speakers of Mangaluru dialect as compared to Dharawad dialect and female speakers had higher formant frequencies (F1 and F2) as compared to male speakers in both the dialects. Another major observation was, vowel duration was greater in speakers of Mangaluru dialect as compared to Dharwad dialect which indicated that speakers of Mangalore dialect speak at a slower rate with a clear and precise articulation and accounted for better speech clarity. Results suggested that F_1 of /a/ and F_2 of /i/ were significantly higher in speakers with Mangalore dialect compared to Dharwad dialect and females had higher F_1 and F_2 compared to males. Mangalore .Dialect had more vowel duration when compared to other regional dialects.

Krishna and Rajasekhar (2012) compared the vowel space area and formant frequencies in native speakers of dialects of Telugu (Coastal, Rayalaseema &Telengana). The results suggested that (as depicted in figure 2.4), F1 was higher for vowels vowel /i/ and /u/ in speakers of Rayalaseema followed by Telengana and

Coastal region whereas speakers from Telengana had higher F1 of vowel /a/ followed by Coastal and Rayalseema dialects. A similar pattern was observed for F2 formant among all the vowels. Front high vowel /i/ had highest mean F2, followed by vowel /a/ and high back vowel /u/. Hence, the researchers postulated that the speakers at Coastal region had larger vowel space followed by Telengana and Rayalaseema regions.

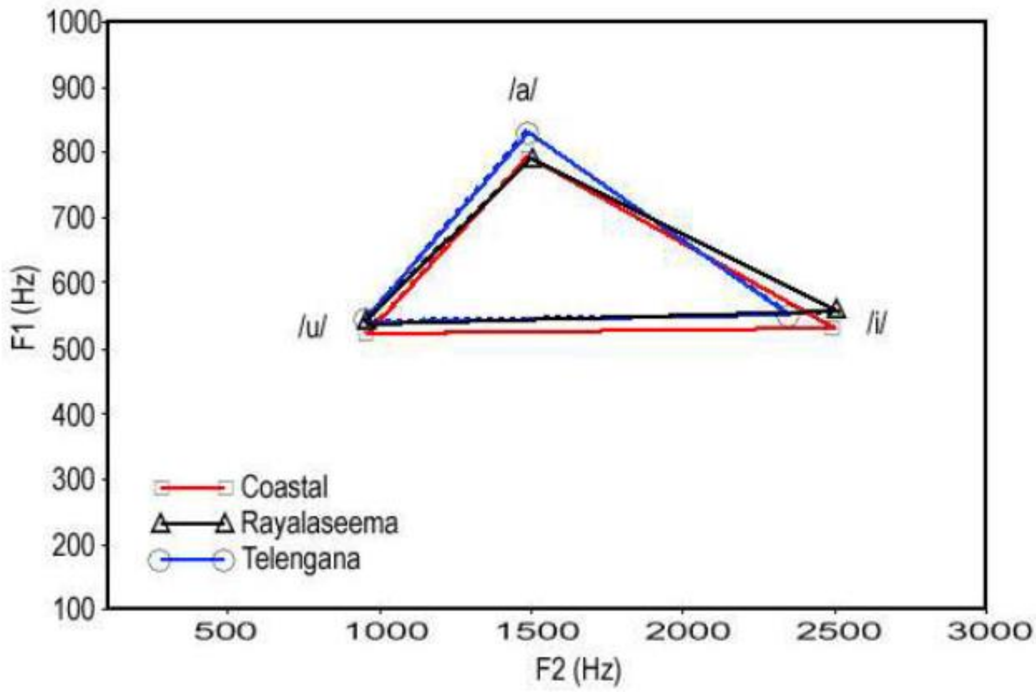

*Figure 2.5.*Vowel space area across dialects. Source: Krishna and Rajashekhar (2012)

On similar lines, another study was done in Malayalam by Anitha (2015) who compared the vowel space in 20 native speakers of Malayalam and 20 participants each in Paniya tribal community and Kuruma tribal community between 20-30 years of age respectively. The participants were asked to read nine non words in CVCV combination which included the corner vowels /a/, /i/,and /u/ respectively. The consonants included were stops with different places of articulation (bilabial /p/, retroflex /t/, and velar /k/). The data was further subjected to acoustic analysis, MATLAB analysis to compute vowel triangles and statistical analysis. Results indicated that VSA was more for Malayalam group than the two tribal languages. The researcher postulated that the difference in VSA is the effect of reduced vowel inventory in the two tribal languages. Female participants depiced larger VSA than in males and largest VSA was obtained in the velar context /k/, followed by bilabial /p/ and the least in retroflex /t/ context.

Jyotsna (2015) compared the acoustic vowel space across age groups in 72 native Malayalam speaking speakers from Kannur district of Kerala. The participants were divided into three groups of age range 3-4 years, 7-8 years, and 20-25 years respectively. The participants were asked to read nine non words in CVCV combination which included the corner vowels /a/, /i/,and /u/ respectively. The consonants included were stops with different places of articulation (bilabial /p/, palatal /t/, and velar /k/). The data was further subjected to acoustic analysis, MATLAB analysis to compute vowel triangles and statistical analysis. Results indicated that VSA decline with increasing age. Findings revealed that vowel space was larger in Malayalam speakers compared to the Tribal languages. The researcher has postulated that the larger VSA during early development period can be attributed to the increased variabilityof vowel production that corresponds to immature motor control.Second major observation was no gender specific differences were observed across the groups, and female speakers demonstrated larger VSA in adult group which can be attributed to the morphological differences across gender. It was also observed that context played a role in VSA across all the age groups. VSA was highest in bilabial context /p/ followed by /k/ and least in the context of /t/.

Acoustic vowel space across disordered population

Vowel space area studies have been carried out in several disordered population and most of the studies indicated a significant smaller vowel space in them: Populations with cerebral palsy (Kuhl, 2005); severe to profound hearing impairment (Palethorpe& Watson, 2003); Down syndrome (Bunton & Leddy, 2013); and glossectomy (Whitehill, Ciocca, Chan, &Samman, 2006).

Kuhl, 2005 studied the association between the area of the vowel space (F1/F2 space) and speech intelligibility in a group of 20 Mandarin-Chinese-speaking young adults with cerebral palsy. Subjects read aloud 18 bisyllabic words containing the vowels /i/, /a/, and /u/ using their habitual speaking rate. The target words were grouped into to three minimal-phonemic word pairs for each vowel contrast, (i-a, u-a, i-u). The corner vowels, /a/, /i/, or /u/ in the first syllable of each word was considered as the target vowel for acoustic analysis. These 18 vowel-contrast wordswere adapted from a Mandarin word intelligibility test (Liu et al.,2000). Talkers were asked to read each word aloud using a normal speaking rate and speech intelligibility scores were computed. Results revealed that in speakers with cerebral palsy, intelligibility varied greatly across individuals. Speakers with cerebral palsy showed smaller vowel space areas when compared to controls. The participants with cerebral palsy demonstrated vowel centralized dispersions as compared to aged matched controls.Thus, vowel space area can serve as an important component of overall estimates of speech intelligibility.

Palethorpe and Watson (2003) investigated the effects of diminished auditory feedback in 3 male and 9 female Australian adult speakers with severe to profound hearing loss (postlingually). The speakers were compared with 11 aged matched normal hearing controls. The task included 5 repetitions of /hvd/ words containing 18 vowels. Acoustic analysis was administered to measure F1 and F2, and vowel duration. Results indicated increased vowel duration in speakers with hearing impairment and demonstrated differential vowel space betweenmale and female speakers. Hence, the results supported the view that postlingually deafened speakers maintain reasonably good speech intelligibility, by employing production strategies designed to strengthen auditory feedback.

Whitehillet. al. (2006) studied the vowel space area in indiividuald with partial glossectomy. Results indicated that speakers with partial glossectomyshowed significantly lower mean F2 values for the vowel /i/, and limited F2 ranges, when compared with the control speakers. The researchers suggested that the lingual movement was limited along the anterior-posterior dimension for vowel production. The significantly smaller vowel space areas for the speakers with glossectomy supported the hypothesis of vowel formant centralization.

Clinical applications

Vowel space measures have been extensively used in the study of speech to evaluate the impact on speech of various disorders such as stuttering, dysarthria, cerebral palsy, hearing impairment, and articulation disorders to study the effects of vowel perception, vowel articulationand to assess speech intelligibility.The researchers have proposed that development of the acoustic vowel space is considered central to define the capacity for intelligible speech. The reference normative data on vowel space area from infancy to adulthood help in acoustic interpretation of unintelligible speech. The first application of the vowel space is the need to examine specific vowel errors made by listeners, attempt to relate the perceptual confusions to the acoustic characteristics of the vowels involved. For disordered speech, vowel space measure helps in understanding the type and number of perceptual confusions and the difference in the acoustic characteristics with the nature and severity of the disorders.

The second application is vowels space helps in understanding the process in which the speakers make distinctions among the similar vowels and formant movement characteristics (variability of F_1 and F_2).

The third application of the vowel space areas are the studies of rate of speech variability among the speakers. Gay (1977) have extensively done research on the variability of acoustic vowel space across slow talkers and fast talkers. The researchers have related rate of speech with vowel reduction and vowel centralization. The authors have postulated that fast rate of speech is an indicator of undershoot of formant frequencies and contributes to reduced vowel space.

CHAPTER- 3

METHOD

Participants

A total of 80 native Kannada speaking typical participants between 20-30 years of age was considered from Mysuru, Mangaluru, Dharwad and Kalaburagi districts respectively. The participants were divided into four groups and each dialectal group comprised an equal number of males and females.

Inclusion criteria

- Individuals with no history of any speech, language, hearing or any neurological/ cognitive impairments.
- No structural or functional deficit on oro-motor examination.
- Native speakers from respective geographical regions with no major influence of other dialects

Stimuli

A 38 word standard Kannada passage (Appendix 1) which was developed at All India Institute of Speech and Hearing was used as a stimulus and presented to the participants. The three corner vowels, namely, the low central vowel /a/, high front vowel /i/ and high back vowel /u/ were extracted from the passage. The corner vowels considered for the stimulus were only short vowels.

Instrumentation

The Olympus multi track linear PCM recorder LS 100 was used for recording the samples.

Procedure

The researcher collected the samples from the respective geographical regions. Each participant was seated comfortably in a quiet room and informed consent was obtained prior to the recording and the samples were recorded individually. Initially the participants were asked to silently read a passage in Kannada to familiarize with the same and then to narrate the passage in their own dialect in a natural manner. The samples were recorded with the recorder which was kept approximately 10 cm away from the mouth of the participant.

Data Analysis

The data analysis included the acoustic analysis of extracting the F_1 and F_2 formants from the target vowel using the PRAAT (5.3.23) software. Plotting of vowel triangles and calculation of acoustical vowel space (VSA) was done using a MATLAB based program(developed by Department of Electronics, AIISH, Mysore).

a) Acoustic analysis

Firstly, the recorded data was transferred to a personal computer. The short corner vowels /a/, /i/, and /u/ were extracted in the medial position of different words in the context of both voiced and voiceless plosives (/p/, /b/,/ʈ/, /ɖ/, /k/, /g/). The acoustic analysis software Praat version 5.3.23 (Boersma &Weenink, 2012) was used to analyze the samples. The first formant (F_1) and second formant (F_2) for each target vowel was measured at the mid point of vowel at a sampling frequency of 22050 Hz. The first and second formants of the corner vowels were measured at three different contexts from the passage. For example, vowel /a/ was identified in three occurrences from the passage and formant frequencies (F_1& F_2) were measured for each of the occurrences. Thus, a total of 18 formants for each individual participant were measured. For example, combination of three contexts of F_1 and F_2 of vowel /a/, followed by three contexts of vowel /i/, and followed by three contexts of vowel /u/.

Hence, the three values of the corner vowels were averaged to obtain the values of formant frequencies (F_1 and F_2) and subjected to further analysis. The illustration of the formant frequencies are represented in figure 3.1.

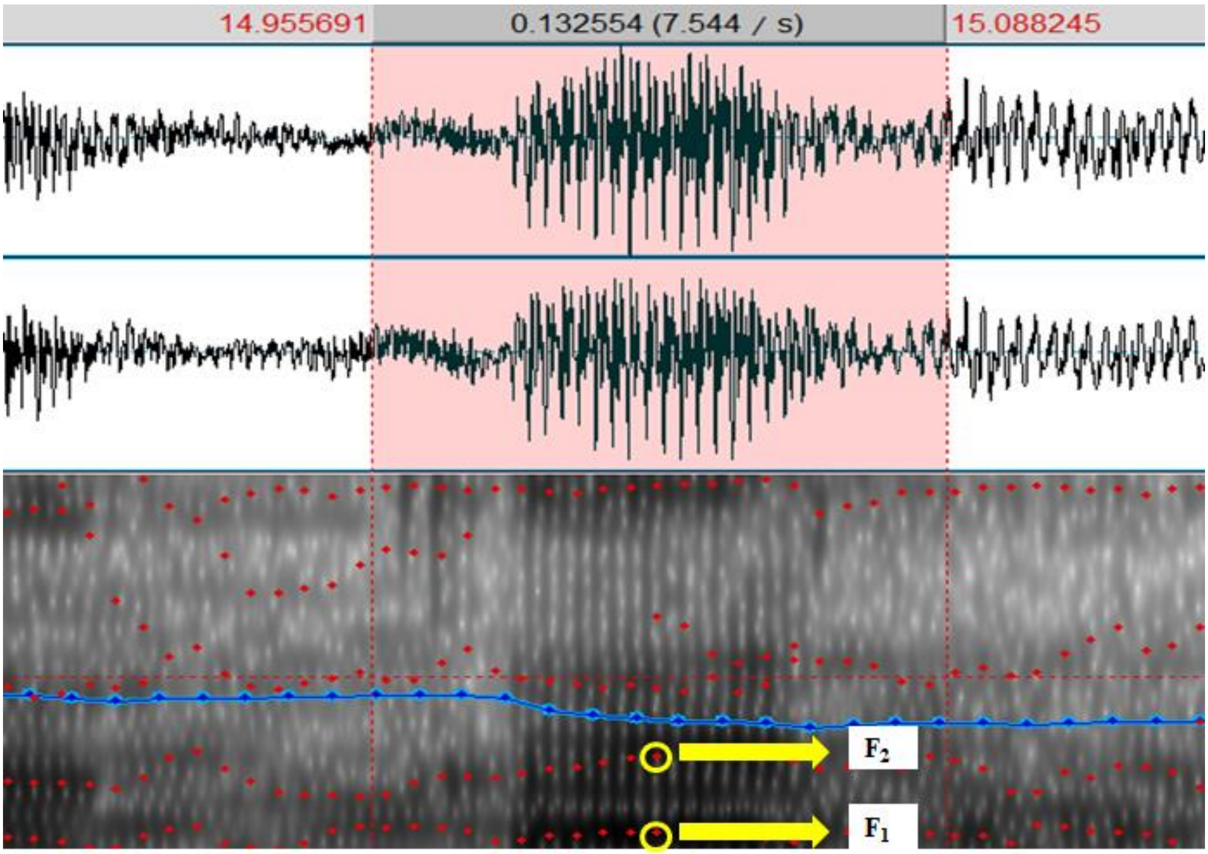

*Figure 3.1.*An illustration of measurement of formant frequencies ($F_1$and F_2) for the vowel /a/ on a spectrogram.

b) MATLAB analysis

The averaged formant frequency values (F_1 and F_2) were entered in MATLAB (7.9.0.529) based program. Heron's formula was computed to formulate an algorithm to calculate the vowel space of individual vowel triangles. The Heron's formula is designated as follows:

$$S = \sqrt{s(s-a) + s(s-b) + s(s-c)} \qquad s = \frac{a+b+c}{2}$$

Vowel triangles and acoustic vowel space were obtained which was displayed on a F_1 and F_2 plot. F_2 was plotted on X- axis and F_1 on Y- axis. In the present study, the vowel space areas of the four triangles were computed across the dialect groups. Initially, the formant frequency values (F1 and F2) of the target vowels /a/, /i/, and /u/ of the individual participants were tabulated in the command window of the MATLAB based program and mean VSA across dialect groups were calculated.

VSA across dialectical groups

An individual vowel triangle comprises of a total of 6 formant frequencies that were fed to MATLAB based program. To obtain four triangles a total of 24 formant frequencies were fed into MATLAB program. Four triangles were colour coded differently for each dialect as depicted in figure 3.2. Secondly, the formant frequencies (F1 and F2) of 20 participants in each dialect was averaged and the VSA in each dialect was measured. The VSA across the four dialects in males and females were measured separately

Thirdly, the formant frequencies were averaged to obtain the overall vowel space area of each dialect. For example, overall vowel space area of Kalaburagi dialect+ Dharawad dialect+Mysuru dialect+ Dharawad dialect were computed. The mean VSA values of the four dialects were tabulated subjected to further statistical analysis.

```
enter value of x = 1678.34
enter value of y = 636.07
enter value of x = 2235.54
enter value of y = 432.78
enter value of x = 1209.17
enter value of y = 436.59
enter value of x1 = 1598.5
enter value of y1 = 712.34
enter value of x1 = 2133.32
enter value of y1 = 447.52
enter value of x1 = 1184.99
enter value of y1 = 390.01
enter value of x2 = 1849.56
enter value of y2 = 711.03
enter value of x2 = 2272.86
enter value of y2 = 485.57
enter value of x2 = 1226.21
enter value of y2 = 357
enter value of x3 = 1732.08
enter value of y3 = 624.6
enter value of x3 = 2290.13
enter value of y3 = 432.25
enter value of x3 = 1286.76
enter value of y3 = 357.27
The area of triangle (A,B,C) is 103263.9127.
The area of triangle (A1,B1,C1) is 140947.1244.
The area of triangle (A2,B2,C2) is 145200.695.
The area of triangle (A3,B3,C3) is 117420.4043.

areaoftriangle =
```

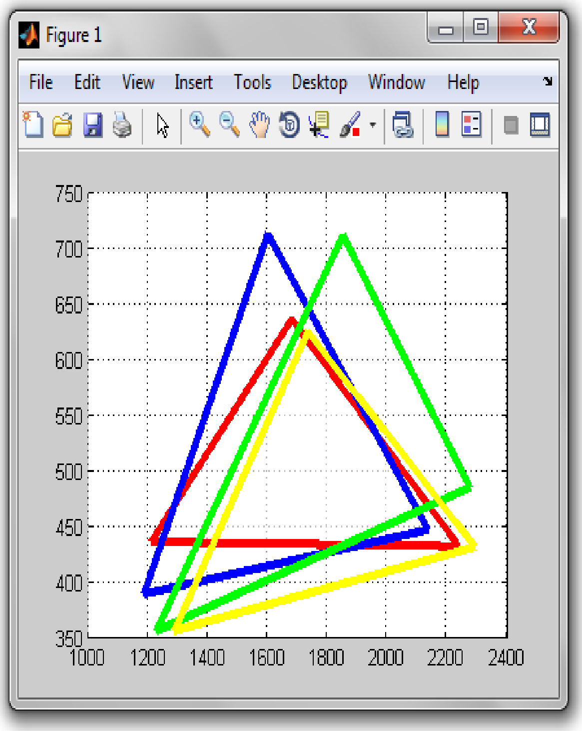

Figure 3.2. An illustration of vowel triangles obtained across the four dialects in females using MATLAB based program. Red: Kalaburagi, Blue: Dharawad, Green: Mangaluru Yellow: Mysuru

c) Statistical analysis

Statistical analysis was administered using SPSS (version 21) software. The normality of the distribution was tested using Shapiro Wilk test of normality. Further non parametric tests were administered when the variables were not following all the assumptions of parametric test.

Chapter- 4

RESULTS

The present study aimed to explore and compare the vowel space areas across different dialects of Kannada (Mangaluru, Mysuru, Dharawad, and Kalaburagi).A total of 80 typical native speakers of Kannada between 20-30 years of age were considered from Mangaluru,Mysuru, Dharawad, and Kalaburagi districts respectively.

The participants were divided into four groups (Group 1: Mangaluru dialect, Group 2: Mysuru dialect, Group 3: Dharawad dialect, Group 4: Kalaburagi dialect) with 20 participants in each dialectal group and comprised an equal number of males and females. The participants were asked to narrate a standard Kannada passage, which were audio recorded. The passage included the three corner short vowels namely; low central vowel /a/, high front vowel /i/ and high back vowel /u/. The corner vowels were selected from the passage in the context of plosives in the medial position of the word. The formants F_1 and $F_2$of the corner vowels were extracted using the PRAAT (5.3.23) software. The vowel space area was calculated using a MATLAB (7.9.0.529)based program. The data was further subjected to statistical analysis using SPSS software (version 21).

The results of the study are presented under the following headings:

1. Tests of normality
2. Vowel space area across the four dialects

    2.1 Mangaluru dialect

    2.2 Mysuru dialect

    2.3 Dharawad dialect

    2.4 Kalaburagi dialect

3. Vowel space area across the dialects in males
4. Vowel space area across the dialects in females

1. Tests of normality

Shapiro- Wilk test was performed to check the normality of the data. The data obtained in all the groups were found to have normal distribution ($p > 0.05$). Hence, parametric tests were carried out to test the behavior of the variables across the dialect groups.

2. Vowel space area across the four dialects

The formants F_1 and F_2 of three corner vowels of each participants were tabulated and descriptive statistical analysis was performed to obtain the mean and standard deviation values. Table 4.1 shows mean (in KHz^2) and standard deviation (SD) of the vowel space area of the four dialects. **It was observed that VSA was largest in Mangaluru dialect and smallest in Kalaburagi dialect.** As expected, the VSA for males were smaller as compared to females across the four dialects.

Table 4.1

Mean in KHz^2 and standard deviation (S.D) of the Vowel space area for males and females of each dialect.

Dialect	**Males**	**Females**
	Mean(S.D) (KHz^2)	**Mean(S.D) (KHz^2)**
Mangaluru	125.55 (14.28)	155.39 (12.66)
Mysuru	115.76 (2.37)	130.69 (10.73)
Dharawad	97.79 (8.96)	149.75 (6.04)
Kalaburagi	59.98 (9.81)	108.56 (9.30)

Two way ANOVA was carried out to study the main effects and interaction effects of dialect and gender. It was observed that there was significant main effect of dialect [F (3, 72) =136.64] and gender [F (1, 72) =275.81] and significant interaction effects between dialects and gender [F (3, 72) =16.86] at $p<0.05$. Further Duncan post hoc test was performed to get the homogeneous subtests. It was observed that Mangaluru dialect was significantly different from Kalaburagi dialect at $p<0.05$.

2.1 Mangaluru dialect

Mangaluru dialect had the **largest mean VSA** with the highest standard deviation and high F1-F2 difference among all the four dialects. It was observed that male speakers had maximum variability than female speakers as compared to other dialects.

2.2 Mysuru dialect

Mysuru dialect had the second largest mean VSA as compared to other dialects. Contradicting to the speakers of Mangaluru dialect, female speakers of Mysuru dialect had more standard deviation than male speakers, and in males, Mysuru dialect had the smallest standard deviation as compared to other dialects.

2.3 Dharawad dialect

Dharawad dialect had the third largest mean VSA as compared to other dialects. In accordance to the previous findings, larger mean VSA was observed in females. It was observed that the female participants had the smallest standard deviation than other dialects.

2.4 Kalaburagi dialect

Kalaburagi dialect of Kannada had the **smallest mean VSA and least F1-F2 difference among all the four dialects**. Similarly, females had larger mean VSA as compared to males. The standard deviation in females was more as compared to males. Figure 4.1represents comparison of VSA across the four dialects. The vowel triangles were computed using MATLAB based on formant frequencies as depicted in figure 4.1.

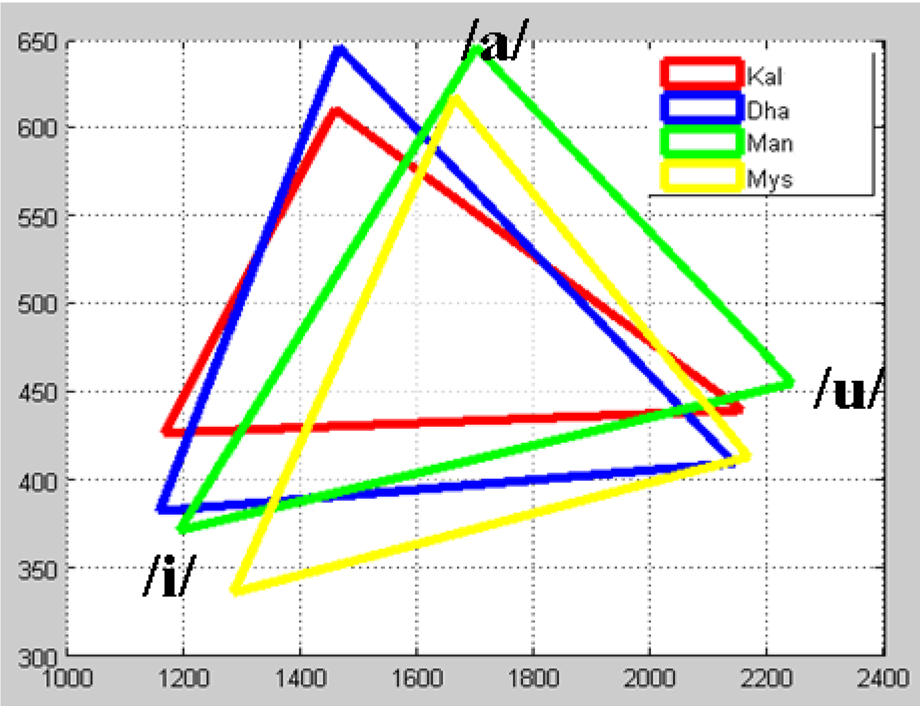

Figure4.1. Comparison of Vowel space areas across four dialects

3. Vowel space area across dialects in males

One way ANOVA was carried out to study the effects of dialects in males. As explained previously, male speakers followed the trend of overall Mean VSA in the order of Mangaluru>Mysuru>Dharawad>Kalaburagi respectively. Results indicated that significant main effect of mean VSA was observed in males [F (3, 39) = 86.49, p< 0.05] in all the four dialects. The F_1 and F_2 of corner vowels of males across the four dialects were represented from the VSA plots as shown in Figure 4.2. Duncan Post Hoc test was performed and it was observed there was significant difference between Kalaburagi and Mangaluru dialects at with p<0.05. In male speakers of **Mangalurudialect,** the F_1 of vowel /a/ and F_2 of vowel /i/were higher as compared to other dialects. Conversely, male speakers of **Kalaburagidialect**had least F_1 for vowel /a/ and F_2 for vowel /i/ respectively. F1 and F2 for vowel /u/ was relatively stable across the four Kannada dialects.

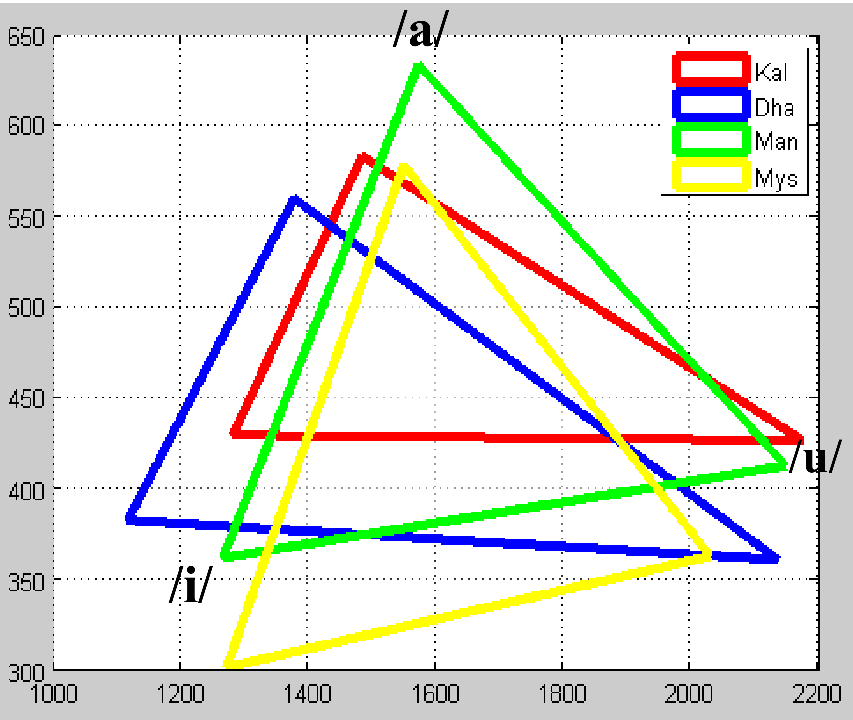

Figure 4.2. Vowel space areas across dialects in males

4. Vowel space area across dialects in females

In females though Mangaluru speakers had largest mean VSA, different trend was observed than males in the order of: Mangaluru>Dharawad>Mysuru>Kalaburagi respectively. The significant main effect of dialect on mean VSA was also observed in females [F (3,39) = 64.08, p< 0.05] across the four dialects of

Kannada.DuncanPost Hoc test revealed that there was significant difference between Kalaburagi and Mangaluru dialects and Kalaburagi and Dharawad dialects at $p<0.05$. Vowel triangles were computed across the four dialects in females as shown in figure 4.3.In female speakers of **Mangalurudialect,** the F_1 of vowel /a/ and F_2 for vowels /a/ and /i/ were higher as compared to other dialects. as stated earlier, F_1 and F_2 of vowel /u/ was relatively stable across the four dialects.

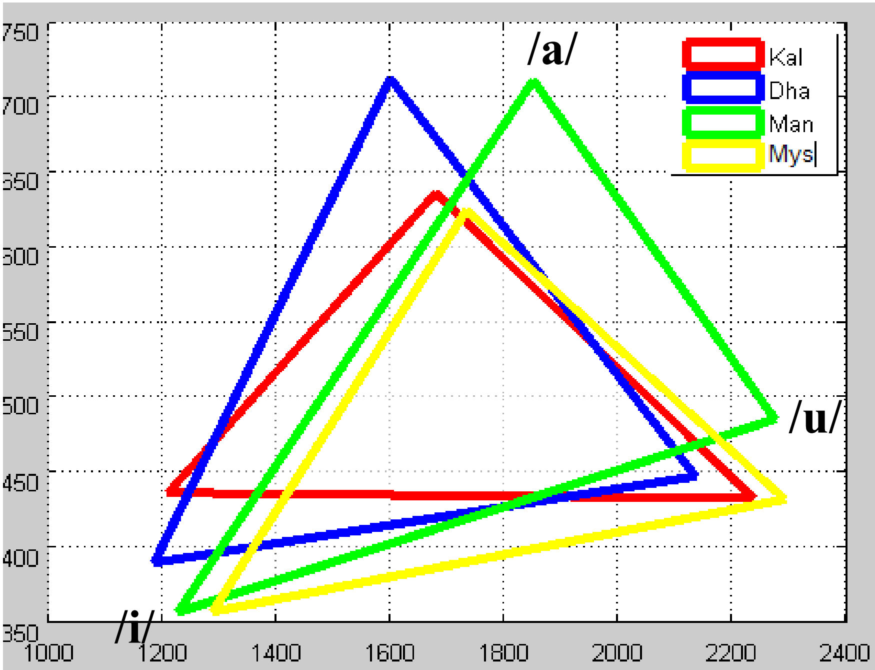

Figure 4.3. Vowel space areas across dialects in females

For better understanding, absolute formants are represented in figure 4.4 which depicts the mean VSA of males and female across the four dialects of Kannada studied. The X- axis represents the dialects and the Y- axis represents the mean VSA. It can be inferred that, in both males and females, speakers of Mangaluru dialect has the largest mean VSA and speakers of Kalaburagi dialect has the smallest mean VSA among all the four dialects investigated. The mean VSA for females were larger as compared to males. Despite, the mean VSA was largest in Mangalurudialect, it followed a different trend in both males and females. In males, the mean VSA was larger in Mangaluru>Mysuru>Dharawad>Kalaburagi and in females, the VSA was larger in Mangaluru>Dharawad>Mysuru>Kalaburagi respectively.

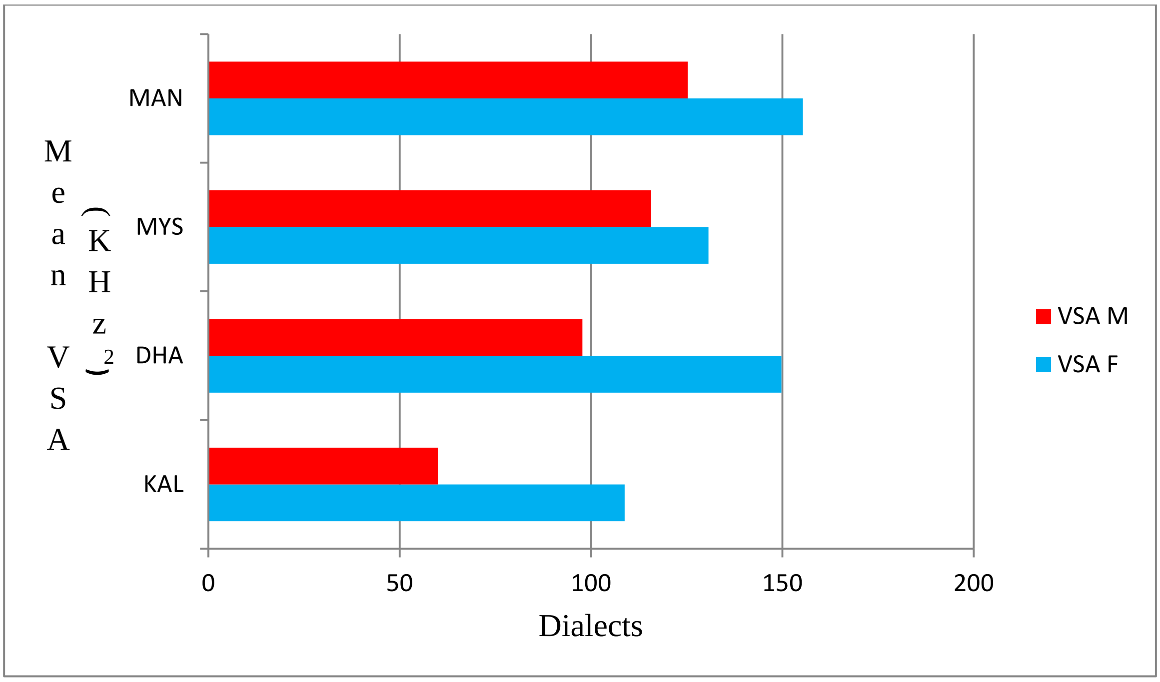

Figure 4.4. Overall VSA across the four dialects in males and females

MAN:*Mangaluru,* ***MYS:****Mysuru,* ***DHA:****Dharawad,* ***KAL:****Kalaburagi*

CHAPTER- 5

DISCUSSION

The present study aimed to explore the vowel space areas and its variations with respect to the regional dialects of Kannada (Group 1: Kalaburagi Kannada, Group 2: Dharawad Kannada, Group 3: Mangaluru Kannada, and Group 4: Mysuru Kannada). The results of the present study stipulated several points of interest.

Firstly, it was observed that, there was significant main effect of dialects on mean VSA. On examining the results from the statistical analysis, it was found that vowel space area and standard deviation was highest in Mangaluru dialect as compared to other dialects. This is because of the fact that perceptually, Mangaluru Kannada is spoken with clear diction and clearer articulation as compared to other dialects. This finding can also be supported by observations of Kapali (2015) who stated that F_1 of vowel /a/ and F_2 of vowel /i/ were significantly higher in Mangaluru Dialect. Neel (2008) stated that vowel space is the strong prediction of speech intelligibility.In the present study, F_1 of vowel /a/ was higher and F2-F1 vowel space was maximum in Mangaluru dialect as compared to other dialects. Hence, speakers of Mangalore tend to speak with better clarity in speech and with their tongue placed anteriorly in the oral cavity. This finding is in support of Krishna and Rajashekhar (2012) who stated that speakers at coastal region havemore clearer speech.

Mysuru dialect had the second largest mean VSA as compared to other dialects. In the present study, Mysuru dialect provided contrasting evidence that F_1 of vowel /a/ and F_2 of vowel /i/ in both males and females were lower as compared to Mangalore dialect.

The participants of Dharawad dialect had a relatively lower mean VSA as compared to Mangaluru and Mysuru Dialects. Kapali (2015) carried out acoustic analysis of vowels in speakers of Mangaluru and Dharawad dialects. Findings indicated that F_1 of vowel /a/ and F_2 of vowel /i/ were significantly lower in speakers of Dharawad dialect as compared to Mangaluru dialect. In the present study, speakers of Dharawad dialect substituted schwa vowel /ə/ in their speaking contexts. This centralilization of the vowels contributed to reduced vowel space area as compared to Mangaluru and Mysuru dialects.

In the present study, the speakers of Kalaburagi dialect demonstrated least mean VSA as compared to other dialects. F_1 of vowel /a/ and F_2 of vowel /i/ were significantly lower in Kalaburagi dialect. A major observation here was that the speakers of Kalaburagi dialect demonstrated least F2-F1 vowel space which contributed to reduced clarity in speech as compared to other dialects. Second interesting observation noted was perceptually the speakers of Kalaburagi dialect demonstrated faster rate of speech. The current study is in consensus to the findings of Lindblom (1963) and Gay (1968) who stated that increasing rate of speech may result in an undershoot of vowel target formant frequencies. Hence, the increased rate of speech in speakers of Kalaburagi dialect resulted in vowel reduction and thus attributed to the reduction of acoustic vowel space.

The second major observation in the present study was,therewere significant interaction effects of dialect and gender on VSA. As mentioned earlier, male speakers of Mangaluru dialect, demonstrated larger mean VSA followed by Mysuru, Dharawad and Kalaburagi dialects respectively. Despite the fact that larger mean VSA was observed in female speakers, larger mean VSA was observed in the order of

Dharawad, Mysuru, and Kalaburagi dialects respectively. In the present study it was observed that, in both males and females, F_1 of vowel /a/ and F_2 of vowel /i/ were higher and mean VSA was larger in females than in males across all the four dialects studied.

The current study is in consonance with findings from Traunmiller (1984) who stated that speakers differ from each other in vocal tract anatomy and supported the differences between male and female formant frequencies. On average, males have longer vocal tracts and particularly longer pharyngeal cavity (Chiba &Kajiyama, 1941; Fant, 1966). The cavities and the moving articulators give rise to different characteristic formant structures reflected in vowel space.

Inter-speaker variability has been investigated in terms of static targets and stable acoustic regions. McDougall (2006) found that dynamic movements and acoustic transitions between the targets can be speaker-specific and are also influenced by individual physiological differences. In support to McDougall's study, Simpson (2001) studied the relationship between the articulatory and acoustic product and examined the gender-specific differences between male and female vocal tracts.

Simpson (2002)examined the differences in the dimensions of the vocal tract and suggested that male speakers have greater articulatory dimensions. Simpson also hypothesized that F_1 excursion for vocalic stretch was maximum in female speakers as compared to male speakers. Secondly, it was observed that posterior male lingual pellets travelled maximum distance at higher speed than female speakers which contributed to reduced vowel space. Hence, researchers concluded that the articulators have to travel longer distances to reach the same vowel targets and hence, male speakers have smaller acoustic vowel space than female speakers.

Fant (1960) stated that male and female acoustic vowel systems have been found to differ non-uniformly. In other words, different factors are needed to scale between the individual male and female formants of each vowel category. In support to Fant's study, Henton (1995) stated that although sex-related differences in vowel spaces exist, these vary between languages. Hence,this learned behavior reflects the intercultural differences and sociolinguistic factors that are expressed in speech of males and females.

The present study is in agreement to findings of Hillerbrand (1995) and Whiteside (2001) who stated that largest gender differences appear in F_2 of vowel /i/ and F_1 of vowel /a/. In general terms, the higher the formant value the greater the difference between male and female values. Therefore, greater female vowel space is a correlate of heightened clarity attributed to the speech of female speakers.

The existing study also supported the evidence by Krishna and Rajashekhar (2012) in Telugu language, who stated that in females, F_1 of vowel /a/ and F_2 of vowel /i/ were high as compared to males across all the dialects. In the present study also, in each of the four dialects, females had high F_1 for vowel /a/ and F_2 of vowel /i/. The heightened acoustic vowel space in female speakers is attributed to better speech intelligibility.

Contrary to the present study, Jacewicz et al. (2007) used extended vowel system in three regional varieties of American English spoken in central Ohio, south-central Wisconsin, and western North Carolina. The researchers indicated no significant differences across dialects of American English.However, in the current study, the three corner vowels /a/, /i/, and /u/ were used to represent the vowel triangleand results indicated that there were significant differences across the dialects.

CHAPTER – 6

SUMMARY AND CONCLUSIONS

The vowel spaceareais a graphical representation that define the vowels and their location in both "acoustic" and "articulatory" space.It is an acoustic method which is considered as an indicator of the accuracy of vowel articulation. The corner vowels /a/, /i/, and /u/ are usually selected to plot the vowel triangles as these vowels frequently occur in all world's languages. The formant frequencies (F_1 and F_2) are used to plot the vowel space, where the vertical axis represents the first formant frequency (F_1) and the horizontal axis represents the frequency gap between the first two formants (F2-F1). Thus, the vowel space representation indicates the gross motor ability of the tongue and jaw coordination.

The present study examined the vowel space areas across different dialects of Kannada (Mangaluru,Mysuru, Dharawad, and Kalaburagi).A total of 80 native Kannada speaking typical participants between 20-30 years of age participated in the study.The participants were divided into four groups (Group 1: Mangaluru dialect, Group 2: Mysuru dialect, Group 3: Dharawad dialect, Group 4: Kalaburagi dialect) with 20 participants in each group and each dialectal group comprised an equal number of males and females. The task of the participants was to familiarize and narrate a standard Kannada passage, which were audio recorded. Three short corner vowels (/a/- low central vowel, /i/- high front unrounded vowel, and /u/- high back rounded vowel) were selected from the passage in the context of plosives in the medial position of the word.

PRAAT (5.3.23) software was used to extract the formant frequencies F1 and F2 and a MATLAB based program (Developed by the Department of Electronics, AIISH, Mysore) was used to plot the vowel triangles and to calculate the vowel space areas for individual speakers of each of the four dialects. The mean VSA values of the four dialects were further subjected to statistical analysis using SPSS software (version 21).

The results from statistical analysis indicated several points of interest. Firstly, speakers of Mangaluru dialect had maximum mean VSA, high F1 of vowel /a/ and F2 of vowel /i/ and larger F2-F1 space as compared to other dialects. Perceptually, speakers of Mangaluru dialect speak with clear diction and clearer.Contrastingly, speakers of Kalaburagi dialect demonstrated smallest mean VSA, low F1 of vowel /a/ and F2 of vowel /i/ and least F2-F1 space than otherdialects.interestingly, speakers of Dharawad dialect demonstrated vowel centralization in their speaking contexts and speakers of Kalaburagi dialect expressed fast rate of speech which contributed to less speech clarity. With the exception of Mangaluru dialect, different trends in mean VSA was followed in the order of Mysuru, Dharawad, and Kalaburagi in males, while Dharawad, Mysuru, and Kalaburagi order was followed in females.

To conclude, the increased acoustic vowel space in female speakers attributes to better speech clarity. Inter-speaker variability exists in terms of specific vowel targets and physiological differences in the acoustic vowel system. Male speakers have smaller acoustic vowel space because they have greater articulatory dimensions of the vocal tract and hence have to travel longer distances to reach the same vowel targets. Thus, the non-uniformity of the male and female acoustic systems occur and despite the sex-related differences in vowel spaces exist, these differences vary between languages. Hence, these factors are influenced by intercultural differences and sociolinguistic factors that are expressed in speech of males and females.

Future directions

- The present study can be used as a point of reference for future research.
- The current study can be replicated on other age groups.
- Similar research on other studies of Kannada can be carried out.
- Future studies of vowel identification and speech intelligibility should include measures beyond static F1 and F2 frequencies in order to adequately investigate the vowel articulation.

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APPENDIX- I

Mean (Hz) and standard deviation values of formants (F_1 and F_2) of corner vowels /a/, /i/, and /u/ in both males and females

Vowels	Formants	Mangaluru		Mysuru		Dharawad		Kalaburagi	
		Mean (SD)		Mean (SD)		Mean (SD)		Mean (SD)	
		M	F	M	F	M	F	M	F
/a/	F1	638.89	716.78	583.23	652.2	570.57	721.71	561.18	655.92
		(22.32)	(9.28)	(6.76)	(29.72)	(13.94)	(7.21)	(19.63)	(34.21)
	F2	1567.75	1830.08	1566.39	1755.04	1371.83	1554.54	1368.80	1654.38
		(22.01)	(18.43)	(17.42)	(21.59)	(13.99)	(21.62)	(47.41)	(45.45)
/i/	F1	433.93	476.6	380.36	446.69	375.49	444.11	438.66	443.49
		(15.14)	(14.74)	(9.73)	(29.06)	(14.18)	(13.61)	(21.56)	(17.73)
	F2	2230.04	2246.45	2088.33	2241.21	2129.96	2249.93	2095.60	2212.22
		(43.05)	(25.51)	(57.63)	(36.50)	(18.40)	(31.24)	(41.32)	(88.41)
/u/	F1	369.86	373.67	318.09	441.17	375.01	390.32	422.48	429.69
		(15.47)	(14.49)	(10.94)	(26.18)	(11.86)	(10.28)	(11.20)	(18.26)
	F2	1218.52	1164.93	1152.18	1168.73	1129.79	1174.47	1200.49	1230.16
		(41.04)	(34.17)	(91.30)	(81.20)	(18.85)	(15.99)	(42.22)	(98.78)

APPENDIX-II

Standard Kannada Passage

ಕೃಷ್ಣಾ ನದಿಯು ಸಹ್ಯಾದ್ರಿ ಪರ್ವತಗಳಲ್ಲಿ ಮಹಾಬಲೇಶ್ವರದ ಹತ್ತಿರ ಹುಟ್ಟುತ್ತದೆ.ಇದು ಹುಟ್ಟುವ ಪ್ರದೇಶವುರಮಣೀಯ ಸ್ಥಾನ. ಇದು ಮಹಾರಾಷ್ಟ್ರ, ಕರ್ನಾಟಕ ಮತ್ತು ಆಂಧ್ರಪ್ರದೇಷಗಳಲ್ಲಿ ಹರಿದು ಬಂಗಾಳ ಕೊಲ್ಲಿಯನ್ನು ಸೇರುತ್ತದೆ.ಇದಕ್ಕೆ ಉಪನದಿಗಳು ಹಲವು.ಕೊಯಿನಾ, ತುಂಗಭದ್ರಾ, ಘಟಪ್ರಭಾ, ಭೀಮಾ, ಮಲಪ್ರಭಾ ಅವುಗಳಲ್ಲಿ ಕೆಲವು.ಕೊಯಿನಾ ನದಿಗೆ ಆಣೇಕಟ್ಟನ್ನುಕಟ್ಟಿ ವಿದ್ಯುತ್ತನ್ನುಉತ್ಪಾದನೆ ಮಾಡುತ್ತಾರೆ.