VOWEL SPACE AREAS ACROSS DIFFERENT REGIONAL DIALECTS OF MALAYALAM

Rini Sarika

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Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI, MYSORE-570 006

May, 2016

CERTIFICATE

This is to certify that the dissertation entitled ***Vowel space areas across different regional dialects of Malayalam*** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Speech-Language Pathology) of the student (Registration No. 14SLP025). 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 Malayalam*** 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.

Mysuru

May, 2016.

Dr. N. Sreedevi

Guide

Reader & Head
Department of Clinical Services
All India Institute of Speech and Hearing,
Manasagangothri, Mysuru.

DECLARATION

This is to certify that this dissertation entitled ***Vowel space areas across different regional dialects of Malayalam*** is the result of my own study under the guidance of Dr. N. Sreedevi, Department of Clinical Services, 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: 14SLP025**

May , 2016

Dedicated to my Lord papa and

My Amma, Appa and Dida

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CHAPTER 1

INTRODUCTION

The universal power of human language is the sacred sounds of creation

- Frank van den Bovenkamp

Speech is a complex communication system and a principal mode used to convey human language (Redford, 2015). Each language has its own set of speech sounds. Speech sounds can be classified as vowels and consonants. Vowels are speech sounds produced by the passage of air through the vocal tract with very little constriction in the oral or pharyngeal cavities (Shriberg & Kent, 1995). Vowels can be classified based on tongue height, tongue advancement, degree of muscular effort, rounding of lips, duration, position of soft palate and tone (Kent, 2003).

The acoustic properties of vowels of different languages have always been an interesting arena of research. Ladefoged and Broadbent (1957) states that a vowel sound can convey information on three main aspects that is phonemic information, which is the identity of the vowel sound in terms of the vocal tract configuration and gender of an individual; sociolinguistic information about a person's regional background and linguistic characteristics of vowel systems for specific dialects and languages. Vowels play a major role to serve as a class of speech sounds and thereby help in determining the acoustic properties of speech. These sounds are produced by the alteration of vocal tract resonances by the articulators as explained by Fant (1960) in the acoustic theory of speech production. These vocal tract resonances are called formants. These formant frequencies help in determining the phonetic quality of vowels. The first two formant frequencies are usually used to characterize vowels across different languages (Ladefoged & Maddieson, 1999).

The formants are displayed in the spectrograms as dark bands for vowels /a/, /i/ and /u/ in figure 1.1. Later research on vowel acoustics led to the use of vowel space area.

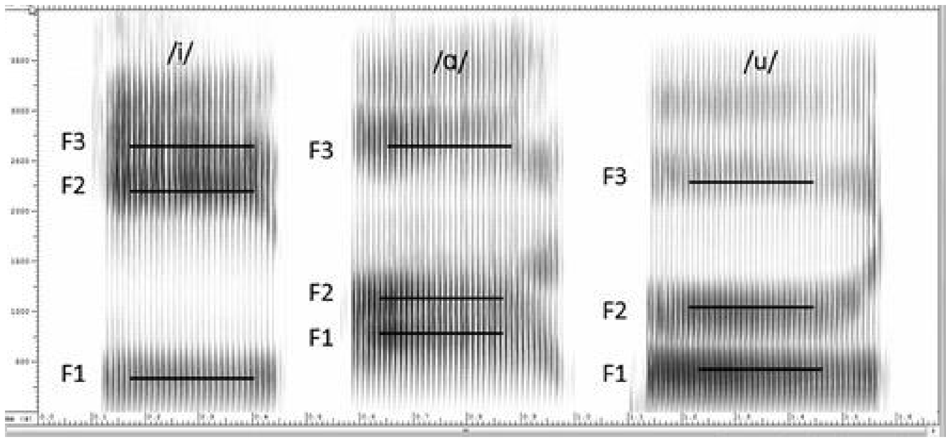

Figure1.1. Representation of formants F_1, F_2 and F_3 of vowel/a/, /i/ and /u/ in the spectrogram (Source: Neel, 2010).

Vowel space area

The vowel space area (VSA) is a graphical method to represent vowels, using the first two formant frequencies and it signifies their location in both acoustic and articulatory space. The vertical axis of the VSA plot represents the first formant frequency (F_1) and the horizontal axis, the second formant frequency (F_2). This two dimensional plot, represents the position of the tongue for vowels in terms of its height and advancement. Hence vowel space is also called vowel working space (Ziegler &Von Cramon, 1983). Vowel space areas are affected by several factors such as gender, age, phonetic context, and dialects. A regional dialect is a language variety spoken by a group of people who live in a particular place (Zsiga, 2013). The dialects of a single language are mutually intelligible, but when the speakers can no longer understand each other, the dialects become languages. Several researchers have used the vowel space area to understand the differences in dialects of languages like American

English, Persian and Dutch etc. The present study uses vowel space areas to investigate different dialects of Malayalam.

Malayalam is a Dravidian language spoken by 32 million people in the state of Kerala in India. Initially the origin of Malayalam language was questioned by many linguists. There were two rising opinion regarding the origin of Malayalam whether it is a dialect or independent shoot off proto Dravidian form of Tamil language. Zvelebil (1970) has described three distinct types of terrestrial dialects of Kerala as South Kerala, North Kerala and Central Kerala dialects. The present study considered the four dialects (Kozhikode, Ernakulam, Thrissur and Thiruvananthapuram dialects respectively) based on above terrestrial dialectal regions. Kozhikode dialect is spoken in northern part of Kerala. This dialect of Malayalam is spoken by Mappila Muslims and has greater influence of Arabic languages. Ernakulam dialect is spoken in the south central region of Kerala and natives tend to use standard Malayalam compared to other dialects. Thrissur dialect is spoken in the north central region of Kerala and has a distinct intonation pattern. Thiruvananthapuram dialect is spoken in the southern most region of Kerala. Figure 1.2 shows the map of Kerala depicting the districts considered for the study.

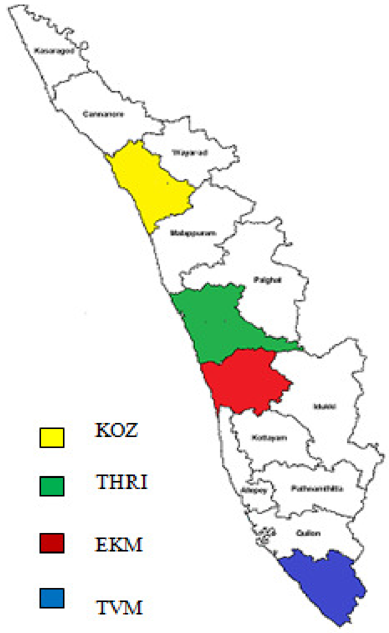

Figure 1.2. Shows the map of Kerala depicting the four districts. (Retrieved and adapted from http://www.natureknights.net/2011/06/kerala.html)

(*KOZ=Kozhikode, THRI=Thrissur, EKM=Ernakulam, TVM=Thiruvananthapuram*)

Need for the study

Several studies in the past have revealed that formant frequencies of vowels vary with respect to age, gender and languages. It has also been used widely to define the vowel systems of different dialectal varieties of a language. Nevertheless studies using VSA would provide a better estimation of both acoustic and articulatory dynamics of vowels. Also in the Indian context very few studies have explored the vowel space areas in different dialects and languages. Hence, with this prologue the present study explores vowel space areas in different dialects of Malayalam.

Aim of the study

To investigate the vowel space areas across the four dialects of Malayalam (Kozhikode, Thrissur, Ernakulam and Thiruvananthapuram dialects respectively).

Objectives of the study

1. To obtain vowel triangle using formant frequencies one (F_1) and two (F_2) of the corner vowels /a/, /i/, /u/ and calculate the vowel space in native typical Malayalam speaking adults of 20-30 years of age, across the four different regional dialects.
2. To compare the vowel space across the four regional dialects (Group 1: Kozhikode, Group 2: Thrissur, Group 3: Ernakulam and Group 4: Thiruvananthapuram dialects).
3. To compare vowel space areas in gender across the four regional dialectal groups.

Implications of the study

- This study can serve as a reference and normative data for understanding the acoustic properties of vowels of different dialects in Malayalam.
- It will also aid in gaining insights regarding the vowel articulatory dynamics and serve as a benchmark for evaluating and treating individuals with speech and language disorders from different dialectal regions of Kerala.

Limitations of the study

- The sample size considered was small.
- The sample was drawn from a limited region where the dialect was spoken.

CHAPTER 2

REVIEW OF LITERATURE

Vowels play an important role in our speech by forming the nucleus of a syllable. Vowels are defined as vocal sounds produced by relatively free passage of the airstream through the larynx and oral cavity (Zemlin, 1998). A vowel system can be described in terms of certain parameters. The most basic parameters of a vowel system are vowel height, tongue advancement, variations of lip rounding which help in contrasting vowels as high/low vowels, front/back vowels and rounded /unrounded vowels. Based on these parameters an eight primary cardinal vowel system was developed by Jones (1965) to describe vowels which serves as reference points for comparing of vowel qualities across different languages. The cardinal vowels /i/, /a/, /u/ and /ɑ/ forms the corner vowels, the other vowels are auditorily equidistant between these three corner vowels. The secondary cardinal system was also developed considering lip rounding features of vowels. Figure 2.1 represents the primary cardinal vowel system.

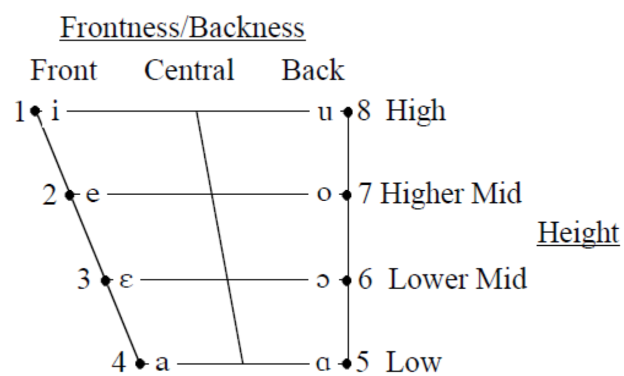

Figure 2.1. Primary cardinal vowel system *(Retrieved from linguistics.berkeley.edu/~kjohnson/ling110/.../3_Vowels/Vowels.pdf)*

The vowels can acoustically be defined in terms of its spectral and temporal characteristics. It can be spectrally defined in terms of fundamental frequency and formants. Formants are defined as the spectral peaks of the sound spectrum (Fant, 1960). The first two formants are important in distinguishing different vowels. The vowel /i/ is defined as high front vowel characterized with high F_2 because the oral cavity is short and the tongue is in front position of the oral cavity and vowel /a/ is defined as a low mid vowel with high F_1 because of the narrow size of pharynx and low position of tongue. The vowel /u/ is defined as low back vowel with low F_1 and F_2 as lips are rounded, while the pharynx is lowered. Figure1.1 represents the spectra and X ray images of vowels of /a/, /i/ and /u/.

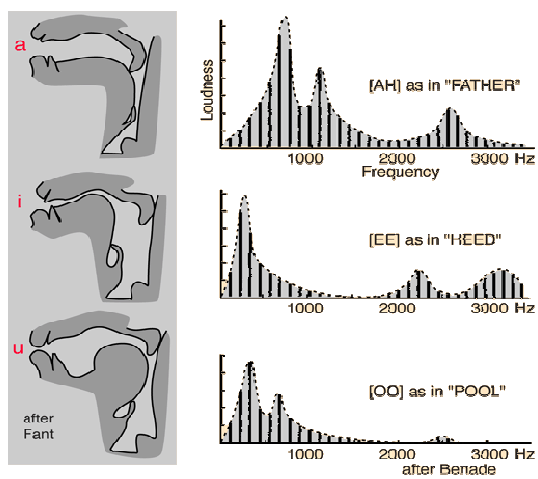

Figure 2.2. The X ray sketches and spectra of /a/, /i/, /u/

(Source: Retrieved from *hyperphysics.phyastr.gsu.edu/hbase/music/**vowel**.html*)

Acoustic vowel space

Vowel space is an acoustic measure for indexing the size of the vowel articulatory working space using F_1 and F_2 of vowels /a/, /i/ and /u/ (Krishna & Rajashekhar, 2012). This was first demonstrated by Essner (1947) and Joos (1948). Formants F_1 depends on tongue height and represents position of the tongue on a vertical axis and F_2 depends on tongue advancement and represents position of tongue on horizontal axis. Vowel space can be a triangle or quadrilateral based on the language. For most languages vowel system is triangular. Ladefoged and Maddieson (1996) have stated that to examine the vowel working spaces of individual talkers, the ‘‘corner’’ vowels that is /a/, /i/ and /u/ are frequently selected because these vowels are the most common in human languages. The vowels /a/, /i/ and /u/ are also referred to as point vowels because they represent the extreme frequencies. Many researchers have used vowel space areas to understand the type and extent of reductions in vocal tract function. The vowel space studies have revealed that vowel space is influenced by several factors like age, gender, languages, dialects, phonetic context, and rate of speech. Figure 2.3.Illustrates the vowel triangle using three corner vowels /a/, /i/ and /u/.

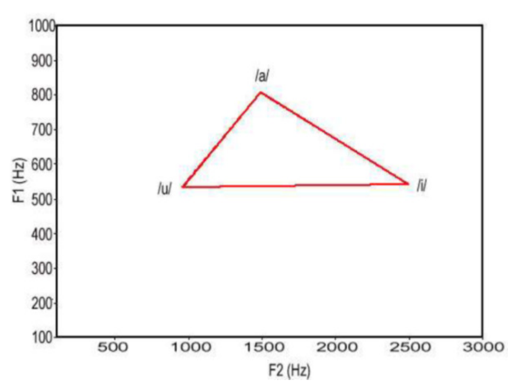

Figure 2.3. Vowel space area using three corner vowels /a/, /i/ and /u/

(source: Krishna and Rajashekar, 2012).

Vowel space area across age and gender

Peterson and Barney (1952) investigated formant patterns of vowels in men, women and children, revealing that the formant frequencies vary substantially across age and gender. Anatomically, children have smaller vocal tracts which result in higher formant values; formant values decrease throughout childhood as vocal tract size increases (Eguchi & Hirsh, 1969; Lee, Potamianos & Narayan, 1999; Perry, Ohde, & Ashmead, 2001). Meta analysis of studies on acoustic vowel space development in children by Vorperian and Kent (2007) also supports the notion that there is gradual decrease in the formant patterns with reduction in vowel space area (VSA) as age increases. They also report that gender differences in vocal tract emerge as early as 4 years of age and become much more evident by 7 years of age, with lowering of formants for males than females accompanied with concurrent changes in the VSA.

Several studies have also reported that females on average have a larger acoustic vowel space than males cross-linguistically (Hillenbrand, Getty, Clark, and Wheeler (1995) for American English; Whiteside (2001) for British English; Simpson and Ericsdotter (2007) for German language). Pettinato, Tuomainen, Granlund and Hazan (2015) investigated the development of vowel space area (VSA) in childhood and adults using conversational speech. The results revealed that children's VSA were significantly larger than adults suggesting a more extreme articulation in children.

In Indian context vowel space area was explored Jyotsna (2015) in Malayalam speaking individuals across different age groups (3-4 years, 7-8years and 20-25 years), gender and in three different phonetic contexts (velar, bilabial, retroflex) and the results revealed that, children had larger vowel space area than adults; females had larger vowel space area than males in adults. However in children no significant differences were seen with respect to gender.

Vowel space area in different speaking rates

Vowel space areas are also used by several investigators to understand the changes in the rate of speech in different clinical populations and normal individuals. Studies in the past have reported increase in the size of acoustic vowel spaces in clear speech and in hyperarticulated speech (Picheny, Durlach & Braida, 1986; Johnson, Flemming & Wright, 1993; Bradlow, Kraus & Hayes, 2003). Turner and Weismer (1995) investigated the influence of speech rate and intelligibility on VSA in nine individuals with amyotrophic lateral sclerosis, which was compared with nine age and gender-matched controls. The presence of smaller VSA with less influence of speaking rate was reported in dysarthric speakers when compared to the controls. However variation in VSA with respect to intelligibility was significant in normal individuals compared to dysarthric speakers.

Tsao, Weismer and Iqbal (2006) explored the size of the VSA in talkers with slow and fast habitual speaking rates in both males and females. The findings indicate that there was no difference in the size of the VSA for slow vs. fast talkers. The existence of intertalker variability of the vowel spaces was reported which was significant in slow speakers across the gender.

Vowel space in different speaking conditions

Such studies have provided insights to the extent to which different speaking conditions influences vowel space areas. Tjaden, Lam and Wilding (2013) examined vowel space area (VSA) in habitual, clear, loud, and slow speech in individuals with Parkinson disease and multiple sclerosis. VSA was reported to be largest in the clear speech condition for all participants which the authors attribute to the articulatory effort associated with speaking clearly. Whitfield and Goberman (2014) compared the VSA between individuals with Parkinsonism and their healthy controls in habitual versus clear speaking condition to examine clarity related changes in articulation of individuals with Parkinson's disease. Findings of the study indicate significantly smaller VSA in individuals with Parkinson Disease and emphasizes the use of acoustic vowel space to track changes between the habitual and clear speech conditions which were also confirmed by perceptual ratings.

Vowel space areas in different dialects and languages

The acoustic characteristics of vowels of many languages vary with respect to the size and organization of their vowel inventories. A study by Clopper and Pisoni (2005) investigated the acoustic characteristics of the vowel systems in 48 individuals of six regional dialects of American English namely New England, Mid-Atlantic, North, Midland, South and West dialects. The duration, formants F_1 and F_2 of 11 different vowels of American English was measured. Results revealed an evident variation with respect to the region of origin. The Northern dialect speakers produced shifted low vowels consistent with the Northern Cities Chain Shift and the speakers of the southern dialect produced fronted back vowels consistent with the Southern Vowel

Shift. The speakers of New England, Midland, and Western dialects exhibited a low back vowel merger.

Al Tamimi and Ferragne (2005) investigated size of vocalic space and effect of the number of vowels in a language on VSA in two Arabic dialects, namely Moroccan and Jordanian Arabic and French. The results revealed that French language had a larger vowel space compared to other two Arabic dialects, which suggests that the size of vocalic space is affected by the vowel inventory of a language. The study thereby indicates a larger vowel space area can be observed for a language with larger vowel inventory size.

Jacewicz, Fox and Salmons (2007) compared the vowel spaces of three regional varieties of American English spoken in central Ohio, south-central Wisconsin, and western North Carolina for 18 speakers from each dialect by using extended VSA. The results indicated that extended vowel space area is relatively constant across the dialects as it encompasses the complete vowel system of the three dialects. Chung, Kong, Edwards, Weismer and Fourakis (2012) explored the location of shared 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) using word repetition task in which the corners vowels were embedded. The results highlighted the presence of language-specific differences in the location of shared vowels in terms of formant values and vowel space areas for both children and adults. It was also reported that VSA of 5 year olds was similar to adults.

A longitudinal study on children's vowel production was carried out by Nittrouer, McGowan, McGowan and Denny (2014) in 18 to 48 months old six children from different American English dialect regions (Northern region, Midland region & West region) using first two formants in a naturalistic context. Results revealed that interspeaker dialect differences is noticed by age of 42 months, shape of the vowel space is established early in life and remained qualitatively constant from 30 to 48 months.

Very few studies have explored the vowel space areas across different dialects in Indian languages. Krishna and Rajashekar (2012) studied F_1 and F_2 vowel space for normal individuals across age, gender and three regional dialectal groups in Telugu (Coastal, Rayalseema, Telengana) and their results revealed decreased vowel space areas for adults compared to children; increased vowel space areas in females than males; significant difference in vowel space areas across the three dialects (Coastal, Rayalseema, Telengana). The speakers of Telengana region had larger VSA followed by Coastal and Rayalseema.

Kapali (2015) investigated formants of corner vowels in two dialects of Kannada (Mangalore and Dharwad) using 60 meaningful words. The participants included 18-30 years old individuals and the results revealed F_1 of /a/ and F_2 of /i/ was higher in Mangalore dialect compared to Dharwad dialect. Anitha (2015) compared vowel space of 20 to 40 years native adult speakers of Malayalam and two tribal languages (Paniya & Kuruma) of Kerala and results revealed adult speakers of Malayalam had larger vowel space areas than tribal languages of Kerala; Vowel space area was larger in phonetic context of velars followed by bilabials and retroflex; larger vowel space areas for females than males were obtained.

Vowel space areas in different speech and language disorders

Many studies have used vowel space areas in understanding the production deficits in different speech and language disorders. Reduced vowel working space was seen in dysarthria from traumatic brain injury (Ziegler & Von Cramon, 1983) and from amyotrophic lateral sclerosis ALS (Weismer et al., 1992). Reduced VSA was also reported in tracheostomy patients (Watson, 1991). Liu, Tsao and Kuhl (2005) studied the relation between vowel space area and vowel intelligibility in Mandarin-speaking males of 17 to 22 years of age with cerebral palsy. The task of the participants was to read 18 bisyllabic words containing vowels /a/, /i/ and /u/. The vowel and word intelligibility was scored and computed. The findings of study reported the presence of smaller working space with reduced intelligibility in individuals with cerebral palsy when compared to age matched controls and thus the results of the study indicated a significant correlation between vowel space area and intelligibility.

Wieland, Burnham, Kondaurova, Bergeson and Dilley (2005) examined vowel characteristics in adult-directed (AD) and infant-directed (ID) speech to children with hearing impairment who received cochlear implants or hearing aids compared with speech to children with normal hearing, using first and second formants of vowels /i/, /ɑ/ and /u/ were measured and vowel space area and dispersion were calculated. The greater vowel space area and dispersion in ID speech was found, compared with AD speech to children with and without hearing impairment.

Hirsch, Bouarourou, Vaxelaire and Claude (2007) analyzed the formant structure of vowels produced by stutterers and treated stutterers, by comparing their data with those of control subjects. The formant structure of vowels /i/, /a/ and /u/ was similar for treated stutterers and for control subjects, but it is different for individuals with stuttering.

Dromey, Nissen and Merill (2008) investigated the articulatory changes in 111 women with muscle tension dysphonia (MTD). The pre- and post-treatment audio recordings were analyzed acoustically using two measures: vowel space area (VSA) and vowel articulation index (VAI), constructed using the first (F_1) and second (F_2) formants of 4 point vowels which were extracted from eight words within a standard passage. And results revealed significant increases in both VSA and VAI, confirming that successful treatment of MTD is associated with vowel space expansion.

Neumeyer, Harrington, and Draxler (2010) compared acoustically the vowel spaces of young aged (15 to 25 years) and old aged (55 to 70 years) groups of cochlear implantees (CI) with two age-matched normal hearing group using five German vowels embedded in alveolar and bilabial contexts and the results revealed the presence of compressed vowel space areas in cochlear implantees which authors attribute to the reduced auditory feedback in such individuals.

Bunton and Leddy (2010) examined the articulatory working space area in vowel production of adults with Down syndrome and results revealed a reduced vowel space areas due to the intelligibility deficits reported clinically for adults with Down syndrome. Jacks, Mathes and Marquardt (2010) investigated whether the vowel production is more variable in apraxia of speech (AOS) by examining the vowel acoustic measures in seven adults AOS and Brocas aphasia who were compared to the control subjects. The stimuli used included six vowels of American English embedded in the medial context of the word /hVC/. The results revealed that there were no significant differences in measures of vowel acoustics that is absolute bark formant values, vowel space area, Intervowel distance between individuals, Individual trial to trial formant variability with AOS and normal subjects. Thereby the authors conclude that vowel production is relatively intact in word level for the current individuals with AOS. Pestian, Gratch, Morency and Scherer (2015) examined the relationship between depression and vowel space in conversational speech by comparing vowel space measures of subjects with and without psychological conditions associated with psychological distress, namely depression, post-traumatic stress disorder (PTSD), and suicidality. Results of the study suggest reduced vowel space indeed characterizes conversational speech of individuals with depression suggesting that motor control and speech production are influenced by depression due to psychomotor retardation.

Clinical applications of vowel space areas

Vowel space area studies across different gender groups gives us insights towards understanding the developmental differences between the gender groups in terms of acoustic and articulatory characteristics. It is an acoustic metric which helps us infer the developmental patterns across children and adults. The study of this acoustic metric of vowels in children can be used to study developmental patterns of speech and help in devising better assessment and interventions tools for speech disorders, and development of speech recognition systems and speech synthesis systems suitable for children's voices. Vowel space areas across different dialects and languages give us information about vowel inventory size and acoustic characteristics of vowels of different languages and dialects. It can be viewed as an index of the accuracy of vowel articulation, which signifies gross motor control ability of the tongue and jaw coordination (Liu, et al., 2005). Many past investigations have revealed that larger vowel space areas indicate greater excursions of the articulators in terms of tongue height (F_1 dimension) or tongue advancement (F_2 dimension). Studies done by

Turner et al., 1995; Weismer et al., 2000 have also reported a positive relationship between speech intelligibility and the area of vowel working space formed by the corner vowels for English-speaking adults with dysarthric speech. Thereby larger VSA can be used to indicate better intelligibility.

Vowel space area clinically can be used in detecting dysarthria as demonstrated in a study by Lansford and Liss (2014). The researchers determined the extent to which vowel metrics are capable of distinguishing normal subjects from dysarthric speech. The results suggest the use of acoustic metrics in the detection of dysarthria nevertheless it may not be considered as a reliable indicator of dysarthria subtypes. Vowel space area can be used as an acoustic measure for comparing the differences between pre and post therapy measures and thereby documenting efficacy of treatment outcome. Therefore the wide range of clinical applications of vowel space areas highlights the importance of vowel space area as a valuable acoustic metric measure.

CHAPTER 3

METHOD

Participants

A total of 92 native speakers of Malayalam, between 20-30 years of age were considered from the four dialectal groups: Group 1: Kozhikode, Group 2: Thrissur, Group 3: Ernakulam, Group 4: Thiruvananthapuram dialects which included 20, 22, 26 and 24 participants respectively. All the four dialectal groups included 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 deficits on oro-motor examination.
- Native speakers from respective geographical regions with no major influence of other dialects were included.

Stimuli

A 100 word standard passage (Appendix I) in Malayalam was preferred as a stimulus which was used in the study of Speech rhythm in Indian languages by Savithri, Deepa, Maharani and Sanjay (2007). The frequency of occurrence of vowels was controlled by using this stimulus across dialects. It includes the three corner vowels, mid central vowel **/a/,** high front vowel **/i/** and high back vowel **/u/.** Only short vowels were considered for further analysis.

Instrumentation

Olympus multi track linear PCM recorder (LS 100) was used for recording the speech samples.

Procedure

The samples were collected from the respective geographical regions. All the participants were seated comfortably in a quiet room and informed consent was obtained prior to the audio recording and the sample was recorded individually. The participants were asked to silently read the stimulus to familiarize and then to narrate the passage in their own dialect naturally. The recorder was kept approximately 10 cm away from the mouth of the participant.

Data Analysis

The data analysis included acoustic analysis using Praat version 5.3.23 (Boersma & Weenink, 2012) to obtain the formant frequencies (F_1 & F_2) and MATLAB based program (developed by Department of Electronics, AIISH, Mysore) was used to obtain vowel space areas (VSA).

a) Acoustic analysis

Initially the recorded data was transferred to a personal computer and the short vowels /a/, /i/, /u/ were located in the medial position for different words in the context of both voiced and unvoiced stop consonants (/p/, /b/, /ʈ/, /ɖ/, /k/, /g/). For each target vowel the first formant and second formant frequencies were measured at the midpoint of vowel at a sampling frequency of 22000 Hz. Average of each formant for three occurrences of each vowel were considered for further analysis. For example, three occurrences of vowel /a/ were identified and formant frequencies (F_1 & F_2) were obtained for each of the occurrences. These three values were averaged to obtain the average values of formants. Illustrations of first two formant frequencies are depicted in the figure 3.1.

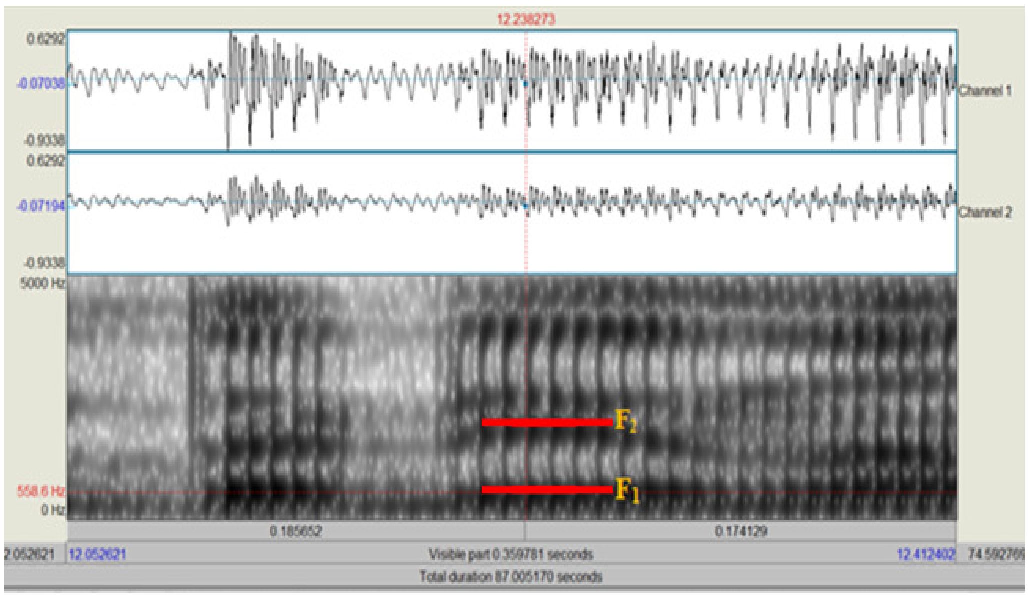

*Figure 3.1.*Illustration of measurement of formant frequencies F_1 and F_2 of vowel /i/ on a spectrogram.

b). MATLAB analysis

The MATLAB (7.9.0.529) based program computed the area of vowel triangle using an algorithm based on the Herons formula that is $A = \sqrt{s(s-a)(s-b)(s-c)},\ s = \frac{a+b+c}{2}$ where a, b, c represents the length of triangles on the three sides. The vowel triangle is displayed on a F_1 and F_2 plot where F_2 is plotted on X axis and F_1 on Y axis. In the present study a custom made MATLAB program was used which can compute the area of four triangles across the four dialectal groups.

b) .1. VSA across dialect groups

Initially the formant frequencies (F_1 & F_2) of target vowels (/a/, /i/, /u/) of all individuals in each dialect was averaged to obtain the overall vowel space area of each dialect. To obtain four triangles a total of 24 formant frequencies (6 formants for one triangle that is F_1 and F_2 of /a/, F_1 and F_2 of /i/, F_1 and F_2 of /u/ *4) were fed into MATLAB program. Four triangles were color coded differently for each dialect as seen in figure 3.2.

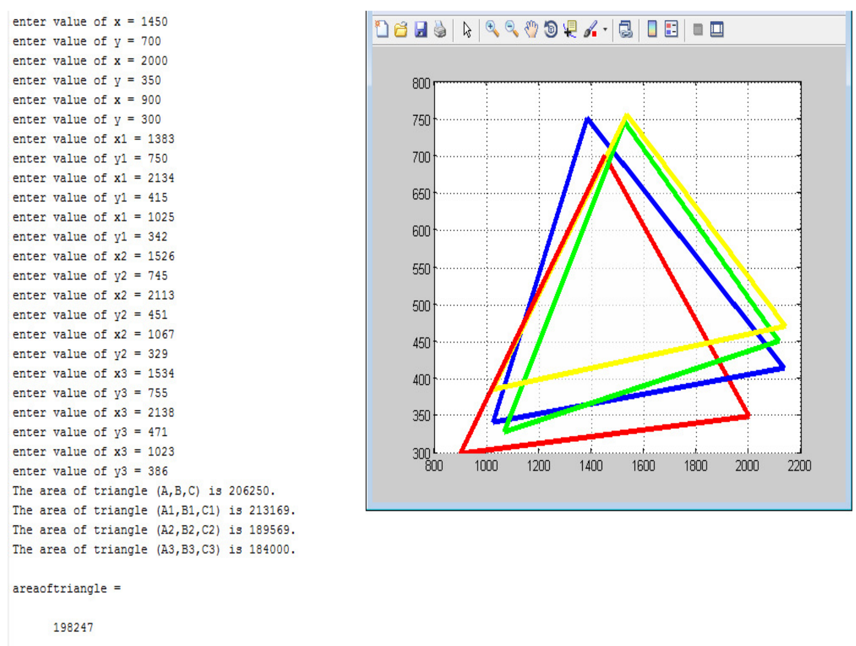

Figure 3.2. Illustration of computation of the area of four vowel triangles in MATLAB program

Vowel triangle was also plotted for males and females in four dialects separately. The formant frequencies (F_1 & F_2) of males in each dialect was averaged to obtain four vowel triangle of males across dialects and a total of 24 formant frequencies (6 formants for one triangle that is F_1 and F_2 of /a/, F_1 and F_2 of /i/, F_1 and F_2 of /u/ *4) were fed for the same. Similarly, averaged formant frequencies (F_1 & F_2) of females were considered to analyze the pattern of vowel triangle across the dialects.

Statistical analysis

SPSS (version 21) software was used for statistical analysis. Shapiro Wilk test of normality was administered to test the normality of the data. Further appropriate parametric tests were applied.

CHAPTER 4

RESULTS

The present study aims to explore and compare the vowel space areas (VSA) of four regional dialects of Malayalam, a Dravidian language spoken in the state of Kerala. The study also focused on the variation of VSA with respect to gender in the four dialects.

The data was obtained from 92 native typical adult speakers of Malayalam in the age range of 20-30 years of age from four dialectal regions. The task of the participants was to narrate a standard passage in Malayalam. The passage included three corner vowels, mid central vowel **/a/,** high front vowel **/i/** and high back vowel **/u/**. The formants F_1 and F_2 of the corner vowels were extracted using PRAAT software (5.3.23) and VSA plots were obtained using a MATLAB (7.9.0.529) based program. The data was further subjected to statistical analysis using SPSS software.

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

1. Test of normality
2. Vowel space area across four dialects

    2.1 Ernakulam dialect

    2.2 Kozhikode dialect

    2.3 Thiruvananthapuram dialect

    2.4 Thrissur dialect

3 Vowel space area across the four dialects in males

4. Vowel space area across the four dialects in females

1. **Test of Normality**

Shapiro Wilk normality test was performed to check for normality. The data obtained in all the groups were found to have normal distribution ($p > 0.05$) except for males in Thrissur dialect. Normality was satisfied for this dialect, when two outliers were removed from the data. Hence, further parametric tests were carried out to compare the independent variables.

2. **Vowel space area across the four dialects**

The mean and standard deviation values were computed using the descriptive statistical analysis. It was observed that mean VSA and standard deviation was largest in Ernakulam dialect followed by Kozhikode and Thiruvananthapuram dialects respectively. The mean VSA and quantity of dispersion was smallest in Thrissur dialect. The mean vowel space area for males was smaller compared to females in all the four dialects. Table 4.1 shows mean in KHz^2 and standard deviation (S.D) of the vowel space area (VSA) for males and females in each dialect.

Table.4.1

Mean in KHz^2 and Standard Deviation (S.D) of the Vowel Space Area for Males and Females in Each Dialect.

Dialects	**Males**	**Females**
	Mean(S.D) (KHz^2)	**Mean(S.D) (KHz^2)**
Ernakulam	142.16 (50.66)	254.63 (57.51)
Kozhikode	127.68 (24.46)	252.08 (25.81)
Thiruvananthapuram	113.63 (18.38)	240.15 (46.81)
Thrissur	99.94 (17.43)	223.78 (33.27)

Two way ANOVA was carried out to study the effect of gender and dialect on vowel space area. The results revealed that there was a significant main effect of gender [F (1, 84) = 229.301, p<0.05] and dialect [F (3, 84) = 4.020, p<0.05] on the vowel space area. There was no interaction effect observed for dialects and gender. Tukey Post hoc test was used for pair wise comparison of dialects and the results revealed that there was significantly higher VSA for Ernakulam dialect than Thrissur dialect with p<0.05. Each of these four dialects is discussed below.

2.1 Ernakulam dialect

Ernakulam dialect which is spoken in the south central region of Kerala had the **largest mean VSA among all the four dialects**. Female participants had larger mean VSA and standard deviation compared to males. Among all the four dialectal groups, differences between mean VSA of males and females were least in this group.

2.2 Kozhikode dialect

Kozhikode dialect spoken in the northern region of Kerala had the second largest VSA among the four dialects. Larger mean VSA and standard deviation was observed for female participants than males as seen in Ernakulam dialect. The standard deviation of Kozhikode dialect was higher compared to Thrissur and Thiruvananthapuram dialects and less compared to Ernakulam dialect.

2.3. Thiruvananthapuram dialect

Thiruvananthapuram dialect which is spoken in the southern region of Kerala has third largest mean VSA compared to other dialects. Similar to the findings in previous dialects, larger mean VSA and standard deviation was observed in females. The amount of variation of Thiruvananthapuram dialect was less compared to Ernakulam and Kozhikode dialects and higher compared to Thrissur dialect. Also the difference of mean VSA between males and female participants was largest compared to the other dialects.

2.4 Thrissur dialect

The dialect spoken in north central region of Kerala had the **smallest VSA among all the four dialects**. Mean VSA and quantity of dispersion was higher in females as in other dialects. Thrissur dialect had the least standard deviation compared to the other dialects. Figure 4.2 represents comparison of VSA across the four dialects.

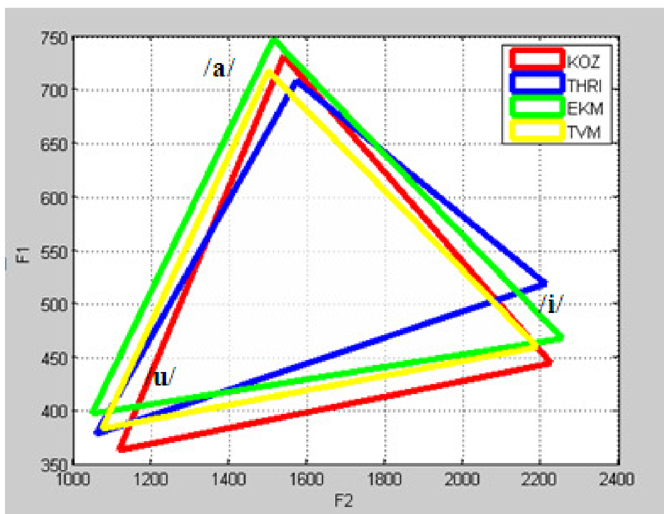

Figure 4.2. Comparison of Vowel space areas across the four dialects

3. Vowel space area across the four dialects in males

One way ANOVA was applied for comparison of VSA in males across the four dialects. The VSA for males was largest for Ernakulam followed by Kozhikode, Thiruvananthapuram and Thrissur dialects. The results revealed there was significant main effect of dialects [$F(3, 45) = 3.843$, $p<0.05$] on VSA for males. Hence, Tukey Post Hoc analysis was run and there was significant difference between Thrissur and Ernakulam dialects ($p<0.05$), with Ernakulam on the higher side. The formants of males and females across the four dialects is mentioned in Appendix II

The F_1 and F_2 of corner vowels of males across the four dialects can be inferred from the VSA plots in Figure 4.4. In male speakers of **Ernakulam dialect,** the F_1 of vowel /a/ and F_2 of vowel /i/ were higher compared to other dialects. F_1 of vowel /i/ was low in male speakers of **Kozhikode dialect**.

It was observed that F_1 and F_2 of vowel /a/ were lower in **Thiruvananthapuram dialect** for male speakers. In **Thrissur dialect**, male speakers had low F_2 for vowel /i/. Vowel /u/ had high F_1 and low F_2. Figure 4.3.Depicts vowel space areas across the dialects in males.

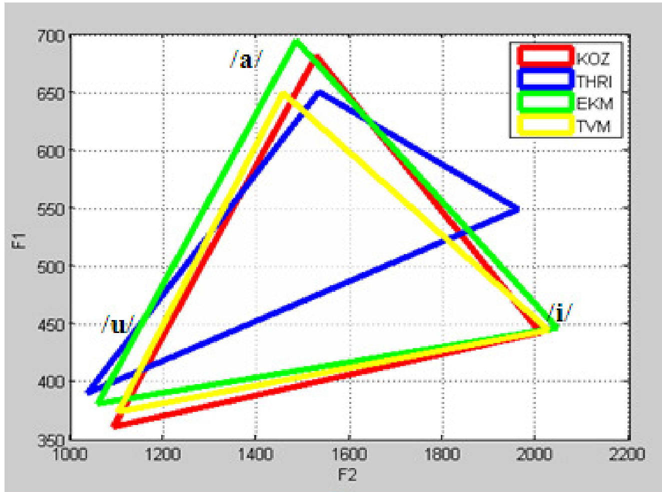

Figure 4.3. Vowel space areas across the four dialects in males

4. Vowel space area across the four dialects in females

One way ANOVA was used for comparison of VSA in females across the four dialects. There was no significant main effect of dialects [$F(3, 45) = 1.167$, $p > 0.05$] on VSA in females. Nevertheless, VSA for females also followed a similar trend as in males. The VSA was largest for Ernakulam followed by Kozhikode, Thiruvananthapuram and Thrissur dialects. From the VSA plots, the F_1 and F_2 of corner vowels of females across the four dialects can be inferred from Figure 4.4. Vowel /a/ had high F_1 and low F_2. The F_1 and F_2 of vowel /i/ were higher compared to other dialects. Vowel /u/ had high F_1 and low F_2 in female speakers of **Ernakulam dialect**, compared to other dialectal groups.

In female speakers of **Kozhikode dialect**, the F_1 and F_2 of vowel /i/ were lower when compared to other dialects. Vowel /u/ had low F_1 and high F_2 in contrary with the Ernakulam dialect. In **Thiruvananthapuram dialect** female speakers, only F_2 of vowel /i/ was higher than other dialects. In female speakers of **Thrissur dialect,** vowel /a/ had low F_1 and high F_2 than other dialects. Figure 4.4. shows vowel space areas across the dialects in females.

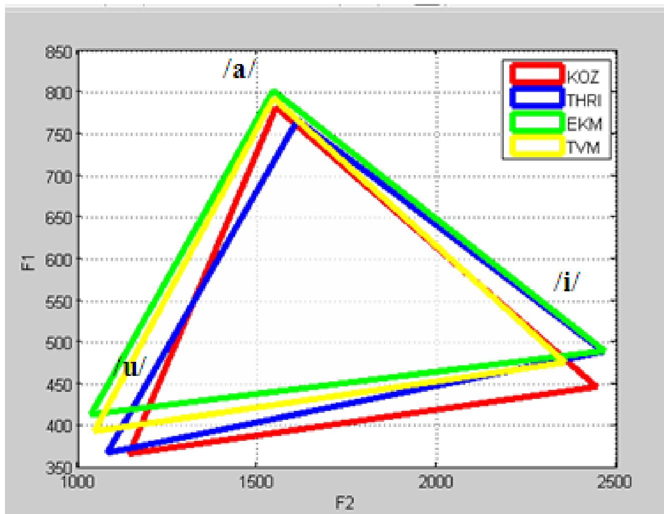

Figure 4.4. Vowel space areas across four the dialects in females

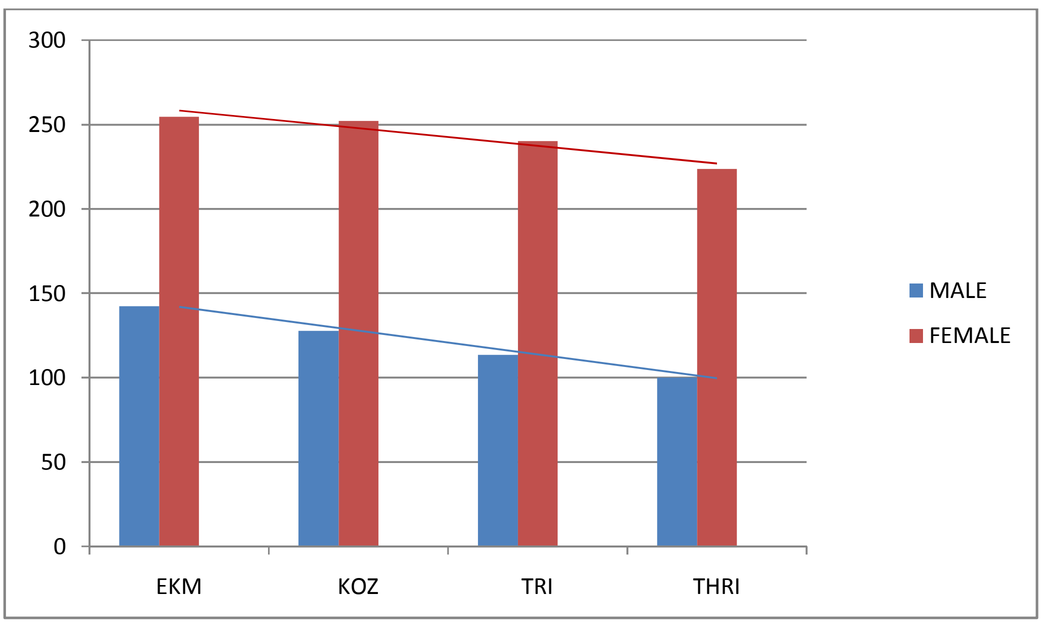

Figure 4.5. Represents comparisons of vowel space in males and females across the dialects

Note: EKM= Ernakulam dialect, KOZ= Kozhikode dialect, TVM=Thiruvananthapuram dialect, THRI=Thrissur dialect.

To summarize, figure 4.5 represents the VSA in males and females across the four dialects with VSA plotted on the Y axis and the dialects on the X axis. The figure illustrates the trend in change of VSA across the dialects. The vowel space area is largest in Ernakulam followed by Kozhikode, Thiruvananthapuram and Thrissur dialects respectively in both in males and females. VSA was larger for females than males in all the four dialectal groups.

CHAPTER 5

DISCUSSION

The main aim of the study was to gain insights regarding the vowel space area and its variation with respect to four dialects of Malayalam. The results of the study have revealed several points of interest. ***The first finding was that, vowel space areas vary across dialects of Malayalam.*** In the past, researchers have used formant frequencies of vowels and vowel space area to compare dialects of different languages. One such study explored vowel space area across age, gender and three regional dialectal groups (Coastal, Rayalseema, Telengana) of Telugu language (Rajashekhar & Krishna, 2012). The findings of the study reveal significant differences in vowel space areas across the three dialects of Telugu which is in consensus with the findings of the current study.

However contrary to this finding, Jacewicz .et.al (2007) investigated vowels space area of three regional varieties of American English spoken in central Ohio, south-central Wisconsin, and Western North Carolina and the results reveal that there were no significant differences of VSA across the three dialects of American English. The authors reason out this stating that there was no difference across dialects due to the use of an extended VSA encompassing the complete vowel system in all the three dialects. However in the current study, only the three corner vowels /a/, /i/, /u/ was used to represent a vowel triangle in consensus with the previous studies carried out in Indian languages which have demonstrated significant differences in VSA across dialects. (Rajashekhar & Krishna, 2012 ; Anitha, 2015).

The present finding of variation in mean VSA can be explained using two theories. The first theory, which is the quantal theory, suggests that across languages the corner vowels have same location in the acoustic vowel space. On the contrary, dispersion theory states that vowels of languages are organized rather in a perceptually distinct way. In the current study, the corner vowels varied in their locations even across dialects of the same language and thereby the result does not support the quantal theory and is in support of the dispersion theory. A similar finding was reported by Anitha (2015) on vowel space in tribal languages prevalent in Sultan Battery in Kerala and the Malayalam spoken in the same district.

In the present study among all the four dialects, it was observed that the mean vowel space area and standard deviation was **largest in Ernakulam dialect** followed by Kozhikode and Thiruvananthapuram dialects. **Thrissur dialect had the smallest mean VSA and standard deviation**. Perceptually it was noticed that Ernakulam dialect speakers had more stressed syllables with longer duration of vowels. Also the speakers of Ernakulam dialect demonstrated high F_1 for vowel /a/ and F_2 for vowel /i/ respectively. This observation is in consensus with the findings of Qiu and Liang (2015) who investigated the effect of stress on vowel space in Daxi Hakka Chinese language and the results suggested that stress had an effect on formant frequencies by raising F_2 for front vowel /i/ and low F_1 vowel /a/. Therefore, it can be inferred that vowel space areas in the stressed condition are significantly greater than unstressed conditions. The acoustic correlates of emphatic stress in Malayalam was also investigated by Irfana, Rofina and Sreedevi, (2015) using stressed and unstressed phrases in 10 males and 10 female subjects. The results also revealed that duration was significantly different in males and females across both stressed and unstressed conditions. However the fundamental frequency did not have any significant difference between the two conditions, except for small differences.

Picheny et al. (1986) suggested that increased vowel space results in intelligible speech in normal speakers. In the current study, speakers of Ernakulam dialect had larger vowel space area, which implies they have more clear speech compared to other dialects of Malayalam.

The next finding was significant main effect of gender on VSA. Among all the four dialectal groups, males had demonstrated lower VSA compared to female participants. The differences between mean VSA of males and females was least in Ernakulam dialect and was maximum in **Thiruvananthapuram dialect**. The reduced **VSA in males** suggests that they tend to have less clear speech than females in consensus with previous studies (Bradlow et al, 1996; Ferguson & Kewley-Port, 2007). Several studies in the past describe the reasons for differences in vowel space area of male and females. Henton (1995) states that females produce more open mouthed variants of vowels than males which means females are more phonetically explicit. It was also suggested that females have greater articulatory distinctions than males. Simpson (2001) supported this view by stating that males have greater articulatory dimensions and have to travel greater articulatory distances at higher speeds to reach the same vowel targets than females.

The third finding is that there was significant main effect of dialects on VSA of males. Mean vowel space and standard deviation showed the same trend as in the overall comparison of dialects. However, ***in females there was no significant main effect of dialect on mean VSA***. But females also followed a similar trend as in males. Individual vocal tract properties determine the formant frequencies of vowels. That is

F_1 is inversely related to tongue height and volume of back cavity and F_2 is directly related to tongue advancement and volume of front cavity (Fant, 1960).

In male speakers of **Ernakulam dialect,** the **F_1 of vowel /a/ was high** which implies they use low tongue position and lesser back cavity and use greater degree of mouth opening. **F_2 of vowel /i/ was higher** compared to other dialects suggesting greater tongue fronting for production of /i/. A similar finding was reported by Kapali (2015) who stated that F_1 of vowel /a/ and F_2 of vowel /i/ were higher in Mangaluru dialect which had the larger VSA than Dharwad dialect. However in male speakers of **Kozhikode dialect** the F_1 of vowel /i/ was low suggesting these speakers tend to produce /i/ with high tongue position and have more back cavity.

In **Thiruvananthapuram dialect,** male speakers showed F_1 and F_2 of vowel /a/ were low. It can be inferred thereby that these speakers tend to produce vowel /a/ with high tongue position and less tongue advancement which results in production of /a/ to be centralized. In **Thrissur dialect**, it was observed that male speakers had low F_2 for vowel /i/ suggesting the production of vowel /i/ with less tongue advancement. Vowel /u/ had high F_1 and low $F_{2.}$ Thus vowel /u/ is produced with low tongue position and less tongue advancement thereby producing the vowel further back compared to other dialects.

In female speakers of **Ernakulam dialect**, Vowel /a/ had high F_1 and low F_2 suggesting the production of /a/ to be comparatively with low tongue position and less tongue advancement as observed in males The F_1 and F_2 of vowel /i/ were higher compared to other dialects suggesting low tongue position and more tongue advancement towards front cavity. Vowel /u/ had high F_1 and low F_2 compared to other dialects suggesting a low tongue position and less tongue advancement.

Female speakers of **Kozhikode dialect** revealed that, vowel /i/ had low F_1 and F_2 when compared to other dialects which imply a higher tongue position and less tongue advancement. It is also stated in the literature that Kozhikode dialect is majorly spoken by the Muslim community which has influences of Arabic language with more back sounds resulting in high and less advanced tongue positions. Vowel /u/ had low F_1 and high $F_{2,}$ contrary to Ernakulam speakers revealing a high tongue position and more tongue advancement. In **Thiruvananthapuram dialect** of female speakers, only F_2 of vowel /i/ was higher than other dialects suggesting much more frontal production of /i/. Female speakers of **Thrissur dialect** revealed that**,** vowel /a/ had low F_1 and high F_2 compared to other dialects suggesting high tongue position and more tongue advancement. With these differences in the formant frequencies we can account for the variation in VSA across the dialects and gender.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Vowels are central to understanding the acoustic properties of speech. Research on acoustic properties of vowels has undergone a drastic arena of change. Formant frequencies were mainly used for the study of vowels earlier. Later with emerging research these formant frequencies were further used to plot a vowel space which depicts an individual's vocal tract properties and vowel system of his or her language. The articulatory working space is described by the formant frequencies of corner vowels or point vowels. In all most, all the world languages the corner vowels are found to be /a/, /i/ and /u/. Thus vowel space has been used to characterize the cross linguistic and cross dialectal differences in several studies. With this prologue the current study was used to investigate the vowel space area in different dialects of Malayalam.

In the present study, 92 participants of 20-30 years were considered across the four dialects of Malayalam with equal gender ratio. Participants were divided into four groups (Group 1: Kozhikode, Group 2: Thrissur, Group 3: Ernakulam, Group 4: Thiruvananthapuram dialects). A standard passage in Malayalam which included three corner vowels, mid central vowel **/a/,** high front vowel **/i/** and high back vowel **/u/** was used as the stimulus. The participants had to narrate the passage after familiarization, which was recorded using an Olympus digital voice recorder. The formants F_1 and F_2 of the corner vowels were extracted using PRAAT software. VSA plots were obtained from F_1 and F_2 of the corner vowels using a MATLAB based program (developed by Department of Electronics, AIISH, Mysore). The VSA obtained in the four dialects were subjected to statistical analysis using SPSS software.

The statistical results revealed significant difference in VSA across the four dialects. Mean VSA and standard deviation was largest in Ernakulam dialect followed by Kozhikode and Thiruvananthapuram, Thrissur dialects. The present finding correlates with view of dispersion theory that point vowels are represented in a perceptually distinct way. **The mean VSA and quantity of dispersion was largest in Ernakulam** dialect which can be attributed to the fact that use of emphatic stress was perceptually evident in this dialect which results in clear speech compared to other dialects.

Another finding is the distinct difference in mean VSA of males and females across the four dialects reflecting the effect of gender on VSA. It was noticed females had larger VSA than males. This can be reasoned out with respect to anatomical differences between males and females. Also several studies have got similar findings in different languages supporting the view in a stronger way that differences in mean VSA in males and females do exist.

The next finding was that there was a main effect of dialects seen in VSA for males but not in females. Mean VSA showed the same trend for males and females as seen in the overall dialects. Mean vowel space and standard deviation was maximum in Ernakulam followed by Kozhikode, Thiruvananthapuram, and Thrissur dialects.

To conclude, the outcome of the current study enhances our understanding concerning the variation of VSA across dialects of Malayalam. It can also serve as a reference to describe vowel articulation while evaluating and treating individuals with speech and language disorders from different regional dialectal groups of Malayalam.

Future directions

- The study can be improvised with more number of participants for enhanced generalization of results.
- The study could be replicated to understand the variation of VSA across the four dialects of Malayalam with respect to different age groups.
- The other regional dialects of Malayalam can be further explored to get a holistic view of the variations of VSA.

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APPENDIX I

ഒരിടത്ത് ഒരു ബ്രാഹ്മണൻ ഉണ്ടായിരുന്നു. അന്ധവിശ്വാസങ്ങൾക്ക് അടിമയായ അയാൾക്ക് ജീവിതത്തിൽ ഒരുപാടു പ്രശ്നങ്ങൾ നേരിടേണ്ടിവന്നു. മടിയനായിരുന്നതിനാൽ ജനങ്ങൾ അവനെ 'പൊണ്ണത്തടിയാ' എന്ന് വിളിച്ചു. ആര്, എന്ത് വിശേഷാവസരത്തിനു ക്ഷണിച്ചാലും മുൻപേ ഇവൻ ഹാജരാകുമായിരുന്നു.

ഒരു ദിവസം ധനപതിയെന്ന ബാല്യകാലസുഹൃത്ത് ബ്രാഹ്മണനെ തന്റെ മകളുടെ കല്യാണത്തിനായി ക്ഷണിച്ചു. എന്നാൽ, സ്നേഹിതന്റെ വീട് ബ്രാഹ്മണന്റെ വീട്ടിൽ നിന്നും ആറു കിലോമീറ്റർ അകലെ ആയിരുന്നു. നടന്നു പോയാൽ ആരോഗ്യത്തിനു നല്ലത്. കൂടാതെ, കൂടുതൽ വിശന്നാൽ ഭക്ഷണം കൂടുതലും കഴിക്കാം, ബ്രാഹ്മണൻ തീരുമാനിച്ചു.

കല്യാണദിവസം എത്തി. ഒരുക്കങ്ങളെല്ലാം വേഗത്തിൽ നടത്തി വീടിനു പുറത്തേക്കിറങ്ങിയപ്പോൾ ഒരു കുഷ്ഠരോഗി മുൻപിൽ പ്രത്യക്ഷപ്പെട്ടു. ശകുനം ശരിയല്ലെന്നു പറഞ്ഞ് വീടിനുള്ളിലേയ്ക്കുതന്നെ കയറിപ്പോയി. ഇതുപോലെ മൂന്നു പ്രാവശ്യം കൂടി സംഭവിച്ചു. പിന്നീട് അയാൾ വേഗത്തിൽ നടന്ന് സ്നേഹിതന്റെ വീട്ടിലെത്തി. അപ്പോൾ അവിടെ എല്ലാവരും ഭക്ഷണം കഴിച്ച്, താംബൂലം ചവച്ച് വിശ്രമിക്കുകയായിരുന്നു.

വൈകിവന്ന ബ്രാഹ്മണനെ കണ്ട് ധനപതി "എന്തേ ഇത്ര വൈകിയത്? ഭക്ഷണത്തിനുള്ള സമയം കഴിഞ്ഞുപോയല്ലോ", എന്നു പറഞ്ഞുകൊണ്ട് രണ്ടു വാഴപ്പഴവും പാലും വരുത്തി കൊടുത്തു.

APPENDIX II

Dialects	Gender	/a/		/i/		/u/	
		Mean in Hz (S.D)		Mean in Hz (S.D)		Mean Hz (S.D)	
		F_1	F_2	F_1	F_2	F_1	F_2
EKM	**Males**	694	1507	447	2043	382	1060
		(32.46)	(123.50)	(61.10)	(127.98)	(37.11)	(78.69)
	Females	801	1543	490	2456	414	1073
		(38.999)	(95.60)	(48.05)	(102.45)	(38.60)	(78.02)
KOZ	**Males**	681	1527	443	2007	362	1093
		(33.34)	(55.11)	(29.04)	(113.19)	(23.90)	(82.03)
	Females	781	1551.90	447	2442	367	1143
		(52.00)	(82.53)	(23.13)	(145.07)	(39.77)	(62.70)
TVM	**Males**	649	1456	445	2025	375	1103
		(20.30)	(49.16)	(27.16)	(98.97)	(21.74)	(92.08)
	Females	792	1544	476	2354	394	1046
		(45.42)	(37.49)	(14.06)	(220.68)	(18.13)	(78.92)
THRI	**Males**	650	1533	474	1960	391	1037
		(23.74)	(87.71)	(26.3)	(70.37)	(31.4)	(63.95)
	Females	766	1611	489	2457	409	1082
		(39.15)	(69.10)	(19.06)	(111.21)	(34.37)	(82.24)