INFLUENCE OF NATIVE MALAYALAM LANGUAGE (L1) ON ENGLISH (L2) VOWEL PRODUCTION

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Register No: 10SLP009

CERTIFICATE

This is to certify that this dissertation entitled **"Influence of Native Malayalam Language (L1) On English (L2) Vowel Production"** is a bonafide work submitted in part fulfillment for the degree of Master of Science (Speech- Language Pathology) of the student Registration No: 10SLP009. 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 diploma or degree.

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This is to certify that this dissertation entitled **"Influence of Native Malayalam Language (L1) On English (L2) Vowel Production"** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

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DECLARATION

This is to certify that this master's dissertation entitled **"Influence of Native Malayalam Language (L1) On English (L2) Vowel Production"** is the result of my own study under the guidance of Dr. S.R. Savithri, Prof. in Speech Sciences & Director, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore **Register No. 10SLP009**
May, 2012

Dedicated to Achan, Amma, Ettan,
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CHAPTER I

INTRODUCTION

Learning of a second language is the influenced by speakers' native language. Such an influence is principally noticed in the area of phonetics and phonology. According to Odlin (1989) the transfer between two languages can take place in the both phoneme and phonetic levels in L2 speech learning. The other factors which influence the level of difficulty in learning the sounds of L2 may due to typology or cross-linguistic frequencies of certain segments, common phonological rules, and syllable structure differences between the native and target languages.

Studies on the subjects have reported that individuals who speak an Asian language as their first language (L1) show phonetic inaccuracies in their production of English spoken as their second language (L2) (Tarone, 1980; Wang, 1983; Flege & Davidian, 1985; Flege, 1989; Pittam & Ingram, 1992; Yang, 1996). The extent of such phonetic inaccuracies are believed to be related to the amount of experience (or length of time) speaking English (Flege, 1995) or the age period during which L2 was acquired (Johnson & Newport, 1991). Phonetic inaccuracies are assumed to arise from the segmental and prosodic differences between the two languages, whereby L1 competes (or interferes) with production of L2 (Eady, 1982; Os, 1985; Cheng, 1987, 1993; Flege, Bohn and Jang, 1997).

Global English is today spoken in a variety of accents, and one of the major differences in such pronunciation of English is due to the differences of vowels in different varieties of English (Yan & Vaseghi, 2003; Salbrina, 2006; Mutonya, 2008; Maxwell & Fletcher, 2009). Since differences in the number of vowels and in vowel quality have been found in varieties of English as a first (L1) and second language (L2), this occurrence can be anticipated in the English vowels produced by Malayalam speakers whose L1 is Malayalam. In the elementary case of a word containing a consonant-vowel-consonant phoneme (CVC/CVCV) structure, a speaker's pronunciation of the vowel within the word will be influenced by his particular dialectal background; and his pronunciation of the vowel may differ both in phonetic quality and in measurable characteristics from that produced in the word by speakers with other backgrounds.

Perception and production of vowel sounds of languages of the world has interested researchers for many years. Vowels differ in their spectral and temporal characteristics and languages are found to use these cues to different extents to perceive the vowels. In languages like American English, vowels are differentiated mainly by their spectral cues (Hillenbrand, Clark, & Houde, 2000). For example, words like /had/ and /head/ are differentiated mainly by the relative locations of the first several resonance prominences, or formant frequencies, of the vowels. Vowel duration is used as a cue only when the formant frequencies are ambiguous (Ainsworth, 1972). On the other hand, in languages like Thai, in addition to spectral cues, vowels are differentiated on the basis of vowel duration as long or short.

Chen, Robb, Gilbert, and Lerman (2001) compared first and second vowel formants of 11 vowels produced by 40 Mandarin speakers to that of 40 American English speakers. Results of acoustic analysis showed that for both male and female speakers, overall vowel quadrilateral appeared smaller than that of American speakers'.

Hubais and Pillai (2010) studied the production of English vowels produced by 10 Omani speakers. Frequency of first and second formants, and vowel duration was measured to examine any length contrast between vowel pairs. Results revealed that Omani speakers had a similar vowel space as British English vowels although individual vowels have different qualities.

Age of acquisition of L2 is considered to be one of the factors which influences the change in perception and production of L2 in L1 speakers. There are many studies to support these findings. The ability of bilinguals to perceive vowels in a second language (L2) have been examined by Flege, 1992; Best, Faber, and Levitt, 1996; Flege, Bohn, and Jang, 1997, 1999. Other studies have examined bilinguals' productions of L2 vowels (Major, 1987; Flege, 1992; Busà, 1992, 1995; Munro, 1993; Jun and Cowie, 1994; Munro, Flege, MacKay, 1996). The results of these studies indicate that individuals who began learning their L2 in childhood (early bilinguals) are expected to produce and perceive certain L2 vowels more like L2 native speakers than are individuals who began learning their L2 in late adolescence or early adulthood (late bilinguals).

Immigration of Asians to the US has been increasing in last few decades. Apart from that English language has become the standard medium through which the communication is taking place globally. There has been an increase in the number of individuals who speak American English as L2. Thus the need for normative data regarding vowel phoneme inaccuracies during their L2 productions of English has become necessary in the clinical decision-making process (Montgomery, 1999; Mueller, Ball & Guendouzi, 2000).

India, being a multi-lingual country offers great potentials to answer the questions on cross language research. Little is known about the influence of the Dravidian Language Malayalam on the production of English vowels. The American English vowel system consists of 12 distinct vowels /i, I, e, ɛ, , æ , a , ɔ , ʊ , u, ʌ, o, ɜ / (Hillenbrand,1995) excluding the glides. Categorization of vowels according to features of tongue articulation reveals a vocal tract vowel space which consists of four distinct corners corresponding to a quadrilateral shape. Vowels identified for each corner are /i/ (high-front), /æ/ (low-front), /u/ (high-back), and /a/ (low-back). And Malayalam is a Dravidian language which is spoken in the state of Kerala in India. The vowel system of Malayalam language has six vowels, /I, e, a, o, ʊ, ə/**.** The longer counterparts are / i:, e:, a:, o:, u: / (Shyamala, 1997). The front vowels /i/ and /e/ have a /j/ onglide in the initial position and the back vowels /o/ and /ʊ/ have a /w/ onglide in the initial position (Shyamala, 1972). According to Shayamala (1972) the low front vowel /æ/ occurs in medial position in words borrowed from English. However, listening to native speakers of Malayalam, it can be observed that /æ/ is often produced as /e/. Thus it is possible that /æ/ is realized as /e/ in Malayalam.

Vowels occurring in the word of English as spoken by a native Malayalam speaker are likely to be influenced by Malayalam. It is interesting and important to know about the way in which Malayalam speaker says English vowels as it is clinically relevant with bilingual clinical population. In this context, the present study was planned. The purpose of this study was, thus, to investigate the production of vowels in English (L2) by bilingual Malayalam speakers (L1) who have learnt English as second language and were not exposed to same till 12 years of age.

CHAPTER II

REVIEW OF LITERATURE

The review will be focused on the following aspects:

1. Description of vowels
2. Factors influencing accented speech in bilinguals
3. Formant frequencies of vowels
4. Literature on influence of L1 on L2 (formant frequencies).

1. Description of Vowels

Vowels are speech sounds produced by the passage of air through the vocal tract with very little constriction in the oral or pharyngeal cavities (Jones, 1934; Olive, Greenwood & Coleman, 1993; Shriberg & Kent, 1995). Vowels are usually voiced sounds and are longer in duration than consonants. They usually carry the greatest energy in the speech signal, because during the phonation the vocal tract is most open. Because of these characteristics, vowels are the easiest speech category to recognize in a spectrogram.

Acoustic analyses of vowels can provide their spectra. A spectrum is the representation of the amplitude of all the component frequencies of the sound. Vowel spectra will show various peaks of energy, which are called formants. Formants are those frequency ranges which emerge from the mouth and nose with the greatest relative amplitude. Formants may be recognized as the resonant frequencies of the vocal tract. The first three formants are usually sufficient to be recognized as a vowel.

Those formants are labeled as F_1, F_2, and F_3. The lowest peak is the first formant (F_1), the next peak is the second formant (F_2), the third peak as third formant (F_3) and so on. Fundamental frequency or F0 is the lowest frequency of vibration of the vocal folds. Perceptual studies of vowels using synthetic continua show that vowels can be perceived on the basis of the location of first two formant frequencies (Carlson, Granstrom, & Fant, 1970).

Vowels can also be described in terms of the two phonetic parameters vowel quality and vowel quantity. Vowel quality refers to differences in the place of articulation of the vowel, including the position of the tongue in the vocal tract (front, central and back), the size of the constriction or degree of openness (open or close), tongue height (high, mid and low), shape of lips (spread, rounded and unrounded), whether the vowel is nasalized or not and depending on the tenseness of the articulators (tense and lax). Vowel quality differences are seen in the acoustic signal in different spectral patterns for different vowels (Peterson & Barney, 1952). On the other hand, vowel quantity refers to the duration of the vowel which is considered an intrinsic part of its phonemic identity. The vowels are described here are in terms of whether it is short or long vowel (Fant, 1970).

Hence articulatory features that distinguish different vowel sounds are said to determine the vowel's quality. Daniel Jones (1934) developed the cardinal vowel system to describe vowels in terms of the common features height (vertical dimension), backness (horizontal dimension) and roundedness (lip position). Cardinal vowels (Figure 1) are a set of arbitrary reference points for vowel articulation. The vowel quality of cardinal vowels is independent of any language (Denes and Pinson, 1993). Phoneticians used the cardinal vowel system to describe the vowels of different languages.

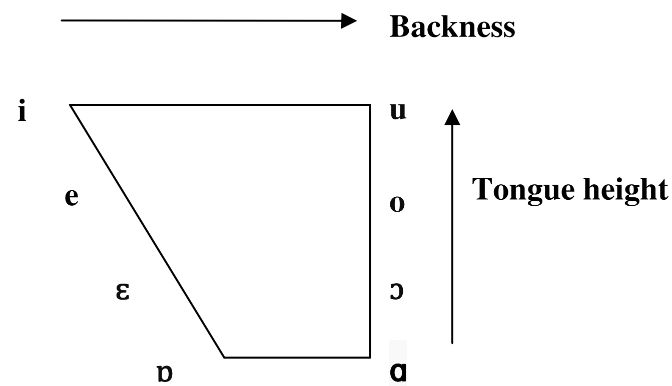

Figure 1: Cardinal Vowels (adapted from Jones, 1934)

VOWEL HEIGHT

Vowel height is named for the vertical position of the tongue relative to either the roof of the mouth or the aperture of the jaw. In high vowels, such as [i] and [u], the tongue is positioned high in the mouth, whereas in low vowels, such as [a], the tongue is positioned low in the mouth. The IPA prefers the terms close vowel and open vowel, which respectively describe the jaw as open or closed. However, vowel height is an acoustic rather than an articulatory quality and is defined not in terms of tongue height, or jaw openness, but according to the relative frequency of the first formant (F_1). The higher the F_1 value, the lower (more open) the vowel; height is thus inversely correlated to F_1.

The International Phonetic Alphabet identifies seven different vowel heights:

- Close vowel (high vowel)
- Near-close vowel
- Close-mid vowel [e ø o] are typically used for either close-mid or true-mid vowels.
- Mid vowel
- Open-mid vowel
- Near-open vowel
- Open vowel (low vowel)

VOWEL BACKNESS

Vowel backness is the position of the tongue during the articulation of a vowel relative to the back of the mouth. In front vowels, like [i], the tongue is positioned forward in the mouth, whereas in case of back vowels, such as [u], the tongue is positioned towards the back of the mouth. The higher the F_2 value, the fronter the vowel; backness is thus inversely correlated to F_2.

According to the International Phonetic Alphabet identifies five different degrees of vowel backness are as follows:

- Front vowel
- Near-front vowel
- Central vowel

- Near-back vowel
- Back Vowel

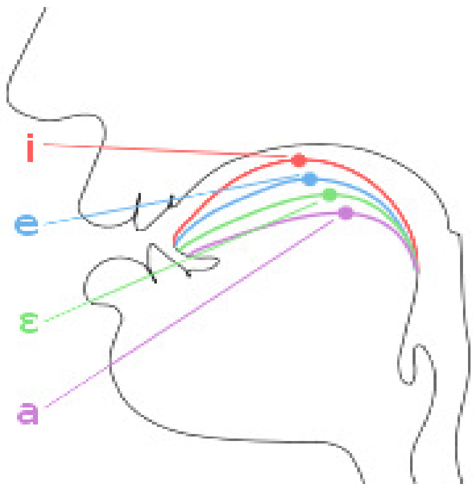

Figure 2: Tongue positions of cardinal front vowels with highest point indicated. The position of the highest point is used to determine vowel height and backness.

LIP ROUNDEDNESS

Roundedness refers to whether the lips are rounded or not. In most languages, roundedness is a reinforcing feature of mid to high back vowels, and is not distinct. Generally the higher a back vowel is, the more intense the rounding. In most languages, [o] and [u] are rounded; [a] is open and [e] are spread.

The main acoustic correlate of vowel quality is the spectra which included the fundamental frequency and formant frequencies. Formant frequencies vary when spoken by different speakers. For example, F_1 can vary from 300 Hz to 1000 Hz. The lower it is, the closer the tongue is to the roof of the mouth. The vowel /i:/ as in the word 'beet' has one of the lowest F_1 values of about 300 Hz , whereas the vowel /a/ as in the word 'bought' has the highest F_1 value of about 950 Hz (Bradlow, 1995).

The second formant frequency, F_2 can vary from 850 Hz to 2500 Hz. The F_2 value is directly proportional to the frontness of the highest part of the tongue during the production of the vowel. Apart from that, lip rounding causes a lowering of F_2 than with unrounded lips. For example, the vowel /i:/ as in the word 'beet' has a F_2 of 2200 Hz, the highest F_2 of any vowel. During the production of this vowel the tongue tip is relatively far forward and the lips are unrounded. At the other extreme, /u/ as in the word 'boot' has an F_2 of 850 Hz; in this vowel the tongue tip is very far back, and the lips are rounded (Bradlow,1995).

F_3 is also important is determining the phonemic quality of a given speech sound, and the higher formants such as F_4 and F_5 are considered to be significant in determining voice quality.

Study by Peterson and Barney (1952) provide one of the earliest evidence which shows how a listener classify different vowels according to their formant frequencies. In their study , 70 subjects had to listen to 1520 recorded words from the set heed, hid, head, had, hod, hawed, hood, who'd, hud, heard (10 vowels i, I, ɛ, æ, ɑ, ɔ, ʊ, u, ʌ, 3) as produced by 76 different adult male, adult female, and child speakers. The results of this study show that there is a relation between vowel type and frequencies of the first and second formants. The table of fundamental frequency and formant frequencies of these vowels from this study is given in table 1.

Vowels		**i**	**ɪ**	**ɛ**	**æ**	**ɑ**	**ɔ**	**ʊ**	**u**	**ʌ**	**ɜ**
Fundamental	**M**	136	135	130	127	124	129	137	141	130	133
Frequencies	**W**	235	232	223	210	212	216	232	231	221	218
(Hz)	**Ch**	272	272	260	251	256	263	276	274	261	261
F_1	**M**	270	390	530	660	730	570	440	300	640	490
(Hz)	**W**	310	430	610	860	850	590	470	370	760	500
	Ch	370	530	690	1010	1030	680	560	430	850	560
F_2	**M**	2290	1990	1840	1720	1090	840	1020	870	1190	1350
(Hz)	**W**	2790	2480	2330	2050	1220	920	1160	950	1400	1640
	Ch	3200	2730	2610	2320	1370	1060	1410	1170	1590	1820
F_3	**M**	3010	2550	2480	2410	2440	2410	2240	2240	2390	1690
(Hz)	**W**	3310	3070	2990	2850	2810	2710	2680	2670	2780	1960
	Ch	3730	3600	3570	3320	3170	3180	3310	3260	3360	2160

Table 1: Averages of fundamental frequency and formant frequencies (F_1, F_2, and F_3) of American English vowels produced by 76 speakers including men (M), Women (W) and Children (Ch).

Hillenbrand, Getty, Clark & Wheeler (1995) replicated and extended the Peterson & Barney study. They included 2 more vowels apart from the 10 vowels in Peterson & Barney study. So in total there were 12 vowels (i, I, ɛ, æ, ɑ, ɔ, ʊ, u, ʌ, ɜ, o, e) in this study. The subjects included 45 men, 48 women, and 46 children in age range of 10 to 12-year-old (27 boys, 19 girls). The F0 contour, vowel duration and formant frequencies were measured. Analysis of formant data showed differences from Peterson & Barney study, both in terms of average frequencies of F_1 and F_2, and the degree of overlap between adjacent vowels. Yet, data were comparable to Peterson and Barney regarding vowel-specific formant frequencies, and also as change in formant values according to vocal tract size and shape. The data is given in the table 2.

Vowels		i	ɪ	e	ɛ	æ	ɑ	ɔ	o	ʊ	u	ʌ	ɜ
Duration (ms)	**M**	243	192	267	189	278	267	283	265	192	237	188	263
	W	306	237	320	254	332	323	353	326	249	303	226	321
	C	297	248	314	235	322	311	319	310	247	278	234	307
F0 (Hz)	**M**	138	135	129	127	123	123	121	129	133	143	133	130
	W	227	224	219	214	215	215	210	217	230	235	218	217
	C	246	241	237	230	228	229	225	236	243	249	236	237
F_1(Hz)	**M**	342	427	476	580	588	768	652	497	469	378	623	474
	W	437	483	536	731	669	936	781	555	519	459	753	523
	C	452	511	564	749	717	1002	803	597	568	494	749	586
F_2(Hz)	**M**	2322	2034	2089	1799	1952	1333	997	910	1122	997	1200	1379
	W	2761	2365	2530	2058	2349	1551	1136	1035	1225	1105	1426	1588
	C	3089	2552	2656	2267	2501	1688	1210	1137	1490	1345	1546	1719
F_3(Hz)	**M**	3000	2684	2691	2605	2601	2522	2538	2459	2434	2343	2550	1710
	W	3372	3053	3047	2979	2972	2815	2824	2828	2827	2735	2933	1929
	C	3702	3403	3323	3310	3289	2950	2982	2987	3072	2988	3145	2143
F_4(Hz)	**M**	3657	3618	3649	3677	3624	3687	3486	3384	3400	3357	3557	3334
	W	4352	4334	4319	4294	4290	4299	3923	3927	4052	4115	4092	3914
	C	4572	4575	4422	4671	4409	4307	3919	4167	4328	4276	4320	3788

Table 2: Average duration, fundamental frequency, and formant frequencies of 12 vowels produced by 45 Men (M), 48 women (W), and 46 children(C).

Vowels as already mentioned, can also be described based on vowel quantity as short or long, on the basis of duration. One of the earliest studies on vowel duration was done by Heffner (1937) in American English. He studied the duration of 9 vowels, /i ɪ e ɛ æ u ʊ o a / in CVC context. The subject was the author himself. It was a single subject study. He found that the terms 'long' and 'short' as applied to the duration of American English vowels could be used only in a relative manner, as there was huge overlap between these two categories of vowels occurring in the language. Heffner

(1937) stated that "length alone is not the differentiating factor" for American English vowels.

However in languages like Korean (Ladefoged 1982 & Maddieson, 1984), Icelandic (Pind, 1986; 1995), Navajo (McDonough, Ladefoged & George, 1993), Thai (Abramson, 1993), Finnish, Estonian (Engstrand & Krull, 1994), Creek (Johnson and Martin, 2001), Japanese (Mugitani, Pons, Fais, Dietrich, Werker and Amano, 2009), vowel duration is used to differentiate between short and long vowels. It is also reported to differentiate the tones in languages like Cantonese (Kong, 1987) and Croatian (Mildner, 1994). Differences in duration between the long and short vowels are maintained in conversational speech in these languages (Abramson, 1993; Engstrand and Krull, 1994; Pind, 1986; 1995).

In Dravidian languages like Tamil, Malayalam, Telugu, and Thoda, and in language such as Sanskrit where there are phonemically long and short vowels, the long vowels are about twice as long as the short vowels (Jensen & Menon, 1972; Balasubramanian, 1981; Nagamma Reddy, 1988; Sasidharan, 1995; Savithri, 1989; Shalev, Ladefoged & Bhaskararao, 1993).

Relation between tongue height and duration is found in some Dravidian languages as reported by Balasubramanian, 1981 (Tamil); Nagamma Reddy, 1988 (Telugu)). As tongue height increases, vowel duration is found to decrease.

Vowels can be organized in acoustically defined space, based on the production (Peterson and Barney, 1952; Jongman, Fourakis, & Sereno, 1989; Bradlow, 1993, 1995) or perception data (Scholes, 1967; Hawks and Fourakis, 1995). Liljencrants and Lindblom (1972) gave a numerical simulation of the organization of vowels based on the principle of maximal contrast. This is also called 'adaptive dispersion' (Johnson, Ladefoged, and Mc Donough, 1993; Johnson, 2000). According to the principle of maximal contrast, vowels will be positioned so as to maximize the distance between adjacent vowel categories. However, this was found to hold true for only three, four, five, and six vowel systems. When there are more than six vowel categories, there were several errors in the system. Lindblom (1986) modified the principle of maximum contrast and established the principle of minimal contrast, according to which, the vowels are organized to provide only adequate contrast between pairs.

Hawks and Fourakis (1995), in their study of the perceptual vowel space of Greek and American English, found that vowels in Greek are well separated with large 'unclaimed areas' in the vowel space whereas vowels of American English are organized close to one another such that there is little unclaimed vowel space. Another interesting finding of the study was that native speakers of Greek were highly consistent in their judgment of what is not a vowel of Greek. The authors propose that languages which have fewer vowels (like Greek) organize their vowels in a maximally contrastive manner and languages with large number of vowels (like English) organize their vowels in a sufficiently contrastive manner.

Malayalam language uses vowel duration to categorize the long and short vowels. Malayalam has five spectrally distinct vowels; hence it could be expected that the vowels to be organized in a maximally contrastive manner (Sreedivya 2009).

American English vowels can be described in terms of backness (front, central, back), height (open, mid, close), lip position (spread, unrounded, rounded), length (short, long), jaw-dropping, and tenseness (tense, lax) (Ladefoged, & Maddieson, 1996).

[i] is a long close front unrounded tense vowel. It appears in words such as *see* [si], or *heat* [hit]. The tongue is as far forward as possible in the mouth. The middle part of the tongue is curved, nearly touching the roof of the mouth, whereas the tip is behind the bottom front teeth. Lips are much spread. The jaw is fairly closed, but the teeth do not touch. It is a long tense sound vowel.

[I] is a short near-close near-front unrounded lax vowel, as in *hit* [hɪt]. The tongue is curved in the middle portion, but the tip is down, just behind the bottom front teeth. In this vowel the tongue is not as close to the roof of the mouth as it is in vowel [i]. Lips are in a neutral position and the corners of the lips are still pulled back a little bit, but without tension. The jaw is completely relaxed. It is a short lax vowel.

[u] is a close back rounded long tense vowel, as in *moon* [mun], or *use*[juz]. The back part of the tongue is raised toward the soft palate, while the front part of the tongue is down, just behind the bottom front teeth. Lips take up a very rounded position, projected away from the mouth. The jaw is closed and the teeth do not touch. It is a long tense vowel.

[ʊ] is a near-close near-back rounded short lax vowel, as in the word *put*[pʊt]. Position of the tongue is very similar position to that of [u:]. The back part of the tongue is raised towards the soft palate, without really touching it, while the tip of the tongue rests down behind the bottom front teeth. The difference with [u:] is that the back part of the tongue is raised less here, and the tongue itself is not as back as before. The lips are rounded, but not as much as in [u], where they are very much projected forward. The jaw is closed and the teeth do not touch. It is a short lax vowel. Both the tongue and the lips are less stiff than in the vowel [u].

[a:] is an open back unrounded long tense vowel, as in *heart*[hɑ:t], or *palm*[pɑ:m]. The tongue is flat in the mouth. The back part of the tongue is pulled back in the mouth, but the tip is just behind the bottom front teeth. Lips are in neutral position. The jaw drops more than in any other vowel. The tongue presses down a little. It is a long tense vowel.

[ɔ] is an open-mid back rounded long tense vowel, as in *thought*[θɔ:t], or in the word *caught*[kɔ:t]. The tongue is raised more than in the case of the vowel [ɑ:] and is placed in the middle and tongue as a whole is raised, that is, both the tip and the back part. The tongue is pulled back a slightly and the tip does not touch the teeth. Lips are in rounded position. The jaw drops, not as much as in the case of [ɑ:]. It is a long tense vowel.

[ʌ] is an open-mid back unrounded short lax vowel, as in the word *hut*[h ʌ t]. The tongue is relaxed and pressed down in the back a little. It is flat in shape as opposed to other vowel sounds where the tongue is curled. As for height, it is raised a little more than in vowel [a:], where the tongue is as low as possible. Lips are in neutral position. The jaw is in neutral position, near to rest position. It is not as open as in vowel [a:].It is a short lax vowel.

[e] is an open-mid front unrounded short lax vowel, as in *bed*[bed], or as in the word red[red]. As this is a front vowel the tongue is pulled forwards. The middle part of the tongue is raised towards the roof of the mouth. The tip rests against the bottom front teeth. The tongue is somewhat widened, which is a feature not very often taken into account. Lips are not rounded and are near the rest position. The jaw is open a little. It is a short and lax vowel.

[æ] is a near-open front unrounded short tense vowel [æ], as in the words *man*[mæn], or *hat*[hæt]. The part back of the tongue is raised a little in the back; the front of the tongue stretches forward and presses behind the bottom front teeth. The production of this vowel requires stretching of the tongue. Lips are more spread than in the rest position but less than in vowel [i]. The production of this vowel requires a large opening jaw. This vowel will not sound natural unless the jaw drops as needed. It is a short and tense vowel.

[ɜ] is an open-mid central unrounded long tense vowel, as in the word *bird*[bɜ:d]. In American English, this vowel it is always followed by a retroflex approximant, the so-called rhotic accent. As central vowel, the tongue is raised towards the roof of the mouth in the middle and even touches lightly the top teeth. The tip of the tongue hangs down, but it is not close to the bottom front teeth. The lips are slightly rounded, but not as much as in [u] or [ɔ]. The jaw is in neutral position. It is a long and tense vowel.

[ə] is a mid central unrounded short lax vowel, as in words *about*[ə'baʊt], and *interesting*['ɪntrəstɪŋ]. The schwa vowel always goes on an unstressed syllable. Partly due to vowel reduction, this is the commonest vowel in American English language. The tongue is relaxed and flat, and is placed at mid height in the mouth. The back part of the tongue is lightly pulled back and the tip is just behind the bottom front teeth. The lips are very relaxed and in neutral position. The jaw is in a rest position without the teeth fairly touching. It is a short and lax vowel.

2. Factors influencing accented speech in bilinguals

Age is considered to be a factor influencing second language learning based on the observation that learning a second language during childhood results in better proficiency than when it is learned after puberty. This has led to the Critical Period (CP) hypothesis, which posits a maturational account of decreased L2 proficiency after a certain age due to neurological and/or biological changes (Penfield & Roberts, 1959; Lenneberg, 1967; Selinker, 1972; Johnson & Newport, 1989).

There has been no consensus among the authors regarding what is the exact age of learning a second language at which a speaker's accent will be detected. According to the study by Tahta, Wood and Loewenthal (1981) on bilinguals' accented English, found that subjects who began learning English at the age of eight or earlier had less foreign accent. Whereas, those who began learning English between the age of 9 and

1l were not accent free. Flege (1988) found that native Mandarin speakers whose age of arriva1 in the U.S. at the age of 7.6 years were judged to be significantly less accented in pronunciation than a group of native English speakers. According to Patkowski (1990), age of 15 is the turning point at which Learners' accents become noticeable. In Long's (1990) review study on effect of age on second language phonological learning, he concluded that a native-like pronunciation is not possible for many people if their first language exposure is not before the age of six and for the remainder by about the age of 12.

In a study by Thompson (1991), he found out those Russian immigrants who had arrived in the U.S. before 10 years of age were perceived to have an accent. In a recent study by Mack (2003), he proposed a critical period for L2 learning which ranges from birth to the age of 4 followed by a 'sensitive' period that extends until early adolescence.

There have been many debates over the exact cut off point for a critical period. But researchers believe that after the termination of critical period, it is difficult in for a language learner to achieve a native-like pronunciation. But critical period hypothesis applied to L2 learning has been questioned because of (1) the variability in age for the termination of the critical period (Birdsong, 2006), (2) the possibility of different critical periods for different language abilities (Marinova-Todd, Marshall, & Snow, 2000; Birdsong, 2006), and (3) other factors that are often confounded with age (Moyer, 1999; Marinova-Todd et al., 2000). These factors include motivation of the language learner (Moyer, 1999), the socio-linguistic identity of the learner (Piller, 2002; Gatbonton, Trofimovich & Magid, 2005), the learner's attitude towards the L2 community (Gardner, Tremblay, & Masgoret, 1997; Moyer, 1999), the verbal aptitude of the learner (Cummins, 1991), and the similarity of the two languages being learned (Birdsong & Mollis, 2001).

A different approach to the maturational account proposed by the CP hypothesis is a perception based hypothesis for speech production proposed by Flege (1992, 1995). Flege's Speech Learning Model (SLM) is based on Wode's (1994) observation that adults usually use a categorical mode of perception resulting in perception of speech in terms of the existing L1 categories. According to Flege, the basic reason for the accented speech is that older learners perceive L2 phonemes in terms of the L1 phonemic categories, especially when the L2 and the L1 phoneme share a number of phonetic cues and as a result the perception of L2 phonemes in terms of L1 phonemes hinders, but does not block, the establishment of the new L2 phonemic categories.

Another factor that would influence the accent in second language is the believed to be due of the extent of use of the first language. In two studies done by Flege and colleagues on L2 learners of English, they found that late learners and especially those who used their L1 frequently had detectable accents in English (Flege, Yeni-Komshian, & Liu, 1999; Flege, MacKay, & Piske, 2002).

In summary, researches suggests that age is a main contributing factor which affects the accuracy of pronunciation in the bilingual's second language, nevertheless no consensus has been reached on whether the critical period is, in fact, "critical."However, the influence of age can be mitigated by internal factors such as self-confidence, motivation, verbal aptitude, and attitude towards the second language community. In addition, external factors such as the linguistic relationships between the languages being acquired and the social context of language acquisition must be considered.

3. Formant frequencies of vowels in various languages

The earliest study on fundamental frequency and formant frequencies of vowels was done by Peterson and Barney (1952) in American English speakers. In their study , 70 subjects had to 1520 recorded words from the set heed, hid, head, had, hod, hawed, hood, who'd, hud, heard(10 vowels i, I, ɛ, æ, ɑ, ɔ, ʊ, u, ʌ, ɜ) as produced by 76 different adult male, adult female, and child speakers (age not mentioned). A table of fundamental frequency and formant frequencies of these vowels from this study is given below in table 3.

Vowels		i	ɪ	ɛ	æ	ɑ	ɔ	ʊ	u	ʌ	ɜ
Fundamental Frequencies (Hz)	M	136	135	130	127	124	129	137	141	130	133
	W	235	232	223	210	212	216	232	231	221	218
	Ch	272	272	260	251	256	263	276	274	261	261
F_1(Hz)	M	270	390	530	660	730	570	440	300	640	490
	W	310	430	610	860	850	590	470	370	760	500
	Ch	370	530	690	1010	1030	680	560	430	850	560
F_2(Hz)	M	2290	1990	1840	1720	1090	840	1020	870	1190	1350
	W	2790	2480	2330	2050	1220	920	1160	950	1400	1640
	Ch	3200	2730	2610	2320	1370	1060	1410	1170	1590	1820
F_3(Hz)	M	3010	2550	2480	2410	2440	2410	2240	2240	2390	1690
	W	3310	3070	2990	2850	2810	2710	2680	2670	2780	1960
	Ch	3730	3600	3570	3320	3170	3180	3310	3260	3360	2160

Table 3: Averages of fundamental frequency and formant frequencies (F_1, F_2, and F_3) of American English vowels produced by 76 speakers including men (M), Women (W) and Children (Ch).

Majewski and Hollien (1967) studied in detail the first and second formant frequencies of vowels in Polish. The subjects were native speakers of polish; there were 7 men and 7 women in the age range of 32-40 years. The vowels were produced in two ways: (a) as sustained vowels of approximately 1 sec duration and (b) in CVC utterances created by speaking each vowel within the consonants b and t. The mean values are given table 4.

Mean	**Bit**	**i**	**b ɨt**	**ɨ**	**bet**	**e**	**bat**	**a**	**bot**	**o**	**But**	**u**
F_1 Mean	261	230	389	371	537	548	726	732	544	525	360	303
F_2 Mean	2280	2291	1984	2001	1862	1882	1346	1216	1052	946	787	662
Women	**Bit**	**i**	**b ɨt**	**ɨ**	**bet**	**e**	**bat**	**a**	**bot**	**o**	**But**	**u**
F_1 Mean	341	293	450	430	602	637	921	909	619	576	454	396
F_2 Mean	2543	2661	2254	2287	2084	2143	1567	1434	1140	991	834	720

Table 4: Mean values of F_1 and F_2 for the Polish vowels in isolation and word level uttered by male and female speakers.

Jensen and Menon (1972) measured the formant frequencies of the five long and short vowels of Malayalam. They were included in the phonemic frame/k__ti/. This procedure, therefore, resulted in ten CVCV stimulus words. These vowels were produced by six speakers (male) of Malayalam in the age range of 26 to 41 years. Each word was spoken in a standard carrier phrase, /i:wa:k___ ena:na/ (translated as "This word is . ."). Fundamental frequency, Formant frequency, duration, and intensity were measured. The average measures are given in the table 5.

Vowel pairs	Formant frequency(Hz) F_1	F_2	F_3	F0	Intensity (dB)	Duration (msec)
/i/	192	1960	2279	118.1	26.8	99
/i:/	192	2007	2369	122.4	27.0	196
/e/	318	1760	2192	114.8	28.3	115
/e:/	307	1167	2247	119.2	27.4	210
/a/	557	1167	2046	113.6	29.6	117
/a:/	609	1083	2166	228.0	30.4	236
/o/	318	729	2172	114.5	29.3	128
/o:/	302	698	2208	119.0	28.6	210
/u/	214	698	2153	113.7	27.8	89
/u:/	229	625	2161	119.5	29.0	201

Table 5: Average values of F_1, F_2, F_3 frequencies (in Hz), fundamental frequency, intensity, and duration of five short and long vowels in Malayalam.
Jensen & Menon (1972)

The F_1 frequency of /i/ -/iː/ and F_2 frequency of /e/-/eː/ did not differ from each other. The F1 frequency of /e/ versus /eː/, /o/ versus /oː/ and /u/ versus /uː/ differed by less than 20 Hz and the F_2 frequency of /o/ versus /oː/ differed by 31Hz. However, the F_1 frequency of /a/ versus /aː/ showed a difference of 52 Hz and the F_2 frequency of /a/ - /aː/ and /u/ - /uː/ showed differences of 84 Hz and 73 Hz respectively. Thus the long and short vowels except /a/ - /aː/ and /u/ versus /uː/ showed no large differences in formant frequencies.

Khan, Gupta and Rizvi (1994) extracted formant frequencies of Hindi vowels in/ hVd/ and C1VC2 contexts for words spoken in isolation which was produced by for two male and one female adult speakers. The vowels included 10 monophthongs /ʌ, a, I, i, U, u, e, ɛ, o, ɔ/. Each speaker was instructed to read the lists of words. F0, F_1, F_2, F_3, and F_4 were extracted from the data. The average value for F0, F_1, F_2, F_3 are summarized in table 6.

	F0(Hz)			F_1(Hz)		
Stimulus	**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 1**	**Speaker 2**	**Speaker 3**
/hʌd/	160	150	200	600	600	720
/dʌs/	150	150	200	580	590	720
/had/	150	150	210	660	670	800
/pas/	160	160	220	670	660	790
/hid/	160	150	240	420	440	590
/dʒis/	170	160	230	380	390	550
/hUd/	170	170	220	380	400	400
/kUʃ /	170	170	230	490	520	610
/hud/	180	170	250	560	590	660
/putʃ/	170	160	270	580	580	670
/hed/	150	140	210	520	570	620
/deʃ/	160	150	220	510	550	650
/hɛd/	170	160	250	600	620	680
/gɛs/	170	160	260	610	610	700
/hod/	150	140	200	510	460	580
/dosh/	160	160	200	510	460	590
/hɔ̱d/	170	160	210	590	600	670
/pɔ̱dʒ/	170	160	210	600	590	600
	F_2(Hz)			**F_3(Hz)**		
Stimulus	**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 1**	**Speaker 2**	**Speaker 3**
/hʌd/	1250	1240	1640	2090	2030	2620
/dʌs/	1290	1290	1700	2050	1960	2520
/had/	1150	1140	1900	2170	2140	2720
/pas/	1160	1150	1930	2180	2100	2760
/hid/	2260	2070	2670	3050	2710	3380
/dʒis/	2210	2040	2500	2960	2760	3340
/hUd/	1210	1320	1820	1970	1980	2300
/kUʃ /	1210	1300	1980	1990	2010	2410
/hud/	1270	1430	1700	2160	2190	2530
/putʃ/	1290	1390	1820	2230	2200	2650
/hed/	2150	2000	2620	2960	3280	3400
/deʃ/	2290	2170	2540	2970	3420	3400
/hɛd/	2420	2170	2820	3250	3390	3900
/gɛs/	2480	2400	2800	3380	3520	3570
/hod/	1120	1120	1870	1990	2010	2800
/dosh/	1230	1150	1870	2040	2010	2750
/hɔ̱d/	1230	1190	2000	2200	2140	2940
/pɔ̱dʒ/	1330	1190	1980	2200	2110	2930

Table 6: The mean F0, F_1, F_2, F_3 of 10 Hindi vowels (Khan, Gupta and Rizvi (1994)).

Bradlow (1995) in his study, compared vowel production of Spanish speakers and English speakers. He used 11 vowels vowel and the target vowels occurred between either /p/ or /b/, and /t/. The English vowels were monosyllabic (beat, bit, bait, bet, bat, pot, bought, boat, put, boot, but), and in accordance with Spanish phonotactics. The Spanish words were disyllabic (bita, beta, bata, bota, puta). The words were embedded in frame sentences that were similar in length, syntactic structure, and position of the target word across the two languages. The English and Spanish frame sentences were "say___again" and "Escribe___bien" ("write__again") respectively. A list of these sentences was constructed in each language such that the subjects read the sentence list from their respective languages. Four male speakers of American English and four male speakers of Madrid Spanish were the subjects in this study. The first and second formant frequencies of the vowels were measured. The mean values of $F_1$and F_2 for Spanish vowels are given are given in the table 7 and for the English vowels are given in Table 8.

Vowel	F_1	F_2
i	288	2147
e	458	1814
a	638	1353
o	460	1019
u	322	992

Table7: Spanish CVCV mean vowel formants in hertz. Bradlow (1995)

	English CVC		English CVCV	
	F_1	**F_2**	**F_1**	**F_2**
i	268	2393	264	2268
I	463	1995	429	1831
e	430	2200	424	2020
ɛ	635	1796	615	1665
æ	777	1738	773	1640
ʌ	640	1354	655	1216
ɑ	780	1244	783	1182
ɔ	620	1033	614	945
o	482	1160	473	1094
ʊ	481	1331	411	1361
u	326	1238	316	1183

Table 8: Mean F_1 and F_2 of English vowels in CVC and CVCV context. (Bradlow, 1995)

Hillenbrand, Getty, Clark & Wheeler (1995) replicated and extended the Peterson & Barney study. They included 2 more vowels apart from the 10 vowels in Peterson and Barney study. So in total there were 12 vowels (i, I, ɛ, æ, ɑ, ɔ, ʊ, u, ʌ, ɜ, o, e) in this study. The subjects included 45 men, 48 women, and 46 children in age range of 10- to 12-year-old (27 boys, 19 girls).

The F0 contour, vowel duration and formant frequencies were measured. Analysis of formant data showed differences from Peterson and Barney study, both in terms of average frequencies of F_1 and F_2, and the degree of overlap between adjacent vowels. Yet, data were similar to Peterson and Barney regarding vowel-specific formant frequencies, as well as change in formant values according to vocal tract size and shape. The data is given in the table 9.

Vowels		i	ɪ	e	ɛ	æ	ɑ	ɔ	o	ʊ	u	ʌ	ɜ
Duration (ms)	**M**	243	192	267	189	278	267	283	265	192	237	188	263
	W	306	237	320	254	332	323	353	326	249	303	226	321
	C	297	248	314	235	322	311	319	310	247	278	234	307
F0	**M**	138	135	129	127	123	123	121	129	133	143	133	130
	W	227	224	219	214	215	215	210	217	230	235	218	217
	C	246	241	237	230	228	229	225	236	243	249	236	237
F_1	**M**	342	427	476	580	588	768	652	497	469	378	623	474
	W	437	483	536	731	669	936	781	555	519	459	753	523
	C	452	511	564	749	717	1002	803	597	568	494	749	586
F_2	**M**	2322	2034	2089	1799	1952	1333	997	910	1122	997	1200	1379
	W	2761	2365	2530	2058	2349	1551	1136	1035	1225	1105	1426	1588
	C	3089	2552	2656	2267	2501	1688	1210	1137	1490	1345	1546	1719
	M	3000	2684	2691	2605	2601	2522	2538	2459	2434	2343	2550	1710
F_3	**W**	3372	3053	3047	2979	2972	2815	2824	2828	2827	2735	2933	1929
	C	3702	3403	3323	3310	3289	2950	2982	2987	3072	2988	3145	2143
	M	3657	3618	3649	3677	3624	3687	3486	3384	3400	3357	3557	3334
F_4	**W**	4352	4334	4319	4294	4290	4299	3923	3927	4052	4115	4092	3914
	C	4572	4575	4422	4671	4409	4307	3919	4167	4328	4276	4320	3788

Table 9: Average duration, fundamental frequency, and formant frequencies (F_1, F_2, F_3, and F_4) in Hz, of 12 American English vowels produced by 45 Men (M), 48 women (W), and 46 children(C).

Yang (1996) compared the fundamental frequency and first three formant frequencies of 10 Korean vowels and 13 American English vowels produced by 10 males and 10 female speakers (18 to 27 years) in the respective language. The stimuli consisted of 67 American English words and 52 Korean words with these vowels. The American English vowel occurred in /hVd/ context. And the 13 vowels were / (æ, a, ɔ, e, ɛ, i, ɚ, I, ɑ, o, ʊ, ʌ, u) as in *had , hard , hawed , hayed , head , heed , herd ,hid , hod , hoed , who ' d , Hudd ,* and *hood.* Each Korean vowels occurred in /hVda/ context as this was pattern was found typically in Korean language. The 10 Korean vowels used in this study were /a, ɛ, e, i, o, ø̞, u, y, ʌ, ɨ/ as in *hada , hɛda , heda , hida , hoda , hø̞da , huda ,hyda , h ʌ da ,* and *h ɨ da.* The subjects had to read out the vowels from a reading list in random order. The average values of F0, F_1-F_3 of the vowels were compared within and across the groups. Results of statistical analysis revealed significant difference in vocal tract length between male and female speakers and between Korean and American English speakers. There was also significant difference in the formant frequencies values of across the languages. The average values are given in the table 10, table 11, table 12 and table 13.

Vowel	F0(Hz)	F_1(Hz)	F_2((Hz)	F_3(Hz)
æ	126	687	1743	2497
a	125	638	1051	2318
ɔ	128	663	1026	2527
e	128	469	2082	2636
ɛ	132	531	1900	2561
i	136	286	2317	3033
ɚ	130	490	1363	1787
I	130	409	2012	2671
ɑ	127	694	1121	2548
o	129	498	1127	2375
ʊ	135	446	1331	2380
ʌ	127	592	1331	2494
u	135	333	1393	2282

Table: 10.Average values of F0, F_1, F_2, and F3 for the American male speakers' vowels.

Vowel	F0(Hz)	F_1 (Hz)	F_2(Hz)	F_3(Hz)
æ	209	825	2059	2928
a	205	782	1287	2563
ɔ	206	777	1140	2895
e	209	521	2536	2991
ɛ	211	631	2244	2968
i	221	390	2826	3416
ɚ	218	523	1550	1927
I	216	466	2373	3014
ɑ	205	857	1255	2877
o	207	528	1206	2824
ʊ	214	491	1486	2836
ʌ	206	701	1641	2901
u	228	417	1511	2796

Table 11: Average values of F0, the first three formants (F_1, F_2, F_3) for the American female speakers' vowels.

Vowel	F0(Hz)	F_1(Hz)	F_2(Hz)	F_3(Hz)
a	162	738	1372	2573
ɛ	165	591	1849	2597
e	167	490	1968	2644
i	172	341	2219	3047
o	170	453	945	2674
ø̞	166	459	1817	2468
u	174	369	981	2565
Y	174	338	2114	2729
ʌ	165	608	1121	2683
ɨ	174	405	1488	2497

Table 12: Average values of F0, the first three formants (F_1, F_2, F_3) for the Korean male speakers' vowels.

Vowel	F0(Hz)	F_1(Hz)	F_2(Hz)	F_3(Hz)
a	264	986	1794	2957
ɛ	263	677	2285	3063
e	263	650	2377	3068
i	271	344	2814	3471
o	269	499	1029	3068
ø̞	265	602	2195	3013
u	278	422	1021	3024
Y	272	373	2704	3222
ʌ	263	765	1371	3009
ɨ	279	447	1703	2997

Table 13: Average values of F0, the first three formants (F_1, F_2, F_3) for the Korean female speakers' vowels.

Hagiwara (1997) studied on vowel production of southern California English speakers. The subjects included 9 women and 6 men in the age range of 18-26 years. He extracted the first three formant frequencies of the 11 vowels [i, I, ɛ, æ, e, u, ʊ, o, ɑ, ʌ, ɹ̩] .These vowels were produced in a CVC context. The results are given in the table 14.

	F_1 (Hz)		F_2(Hz)		F_3(Hz)	
	W	**M**	**W**	**M**	**W**	**M**
I	362	291	2897	2338	3495	2920
i	467	418	2400	1807	3187	2589
e	440	403	2655	2059	3252	2690
ɛ	808	529	2163	1670	3065	2528
æ	1017	685	1810	1601	2826	2524
u	395	323	1700	1417	2866	2399
ʊ	486	441	1665	1366	2926	2446
o	516	437	1391	1188	2904	2430
ɑ	997	710	1390	1221	2743	2405
ʌ	847	574	1753	1415	2889	2496
ɹ̩	477	429	1558	1362	1995	1679

Table 14: Formant frequency averages of vowels for 15 southern Californian speakers of English

Cox (2004) examined formant frequency and durational characteristics of 18 vowels and diphthongs of Australian English produced by 60 male and 60 female subjects. The vowels were embedded in hVd context. The average age of the speakers was 15 years and 10 months at the time of recording. The vowels were /i, ɪ, ɛ, æ, a, ʌ, ɒ, ɔ, ʊ, u, ɜ/. The subjects were instructed to read out the words written on a flash card. Stimuli were recorded and analyzed. The diphthongs were segmented at target 1 onset, target 1, target 1 offset, target 2 onset, target 2, and target 2 offset. The durations of the onglide, target and offglide for vowels and the onglide, target 1, transition, target 2, and offglide for diphthongs were established. The figure showing average F_1/F_2 vowel space plot for the vowels is shown in figure 3.

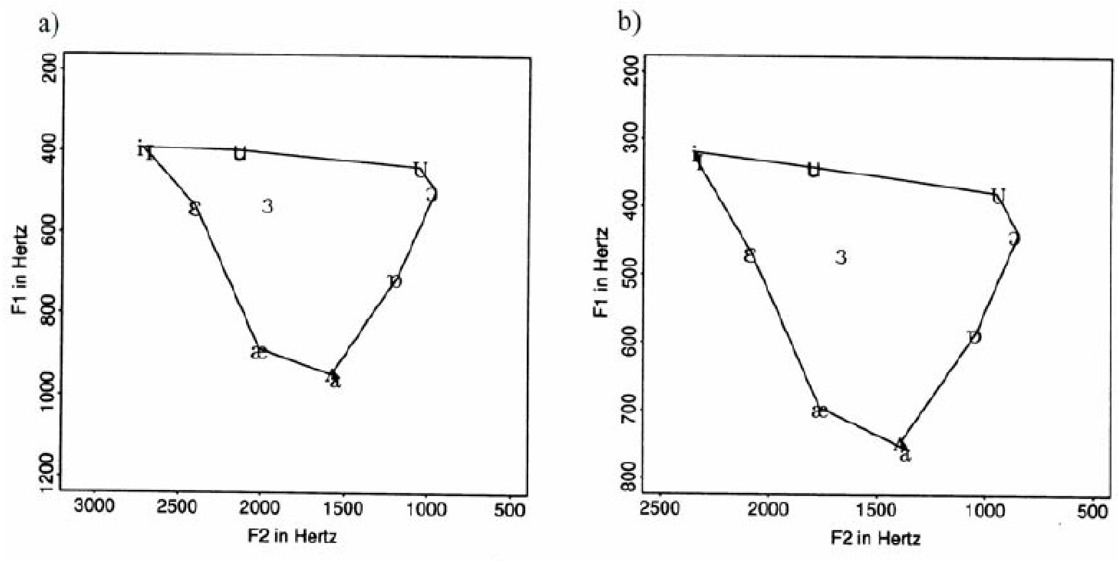

Figure 3: The average F_1/F_2 monophthong vowel space diagram for a) females and b) males.

Savithri and Jayaram (2004) investigated base of articulation in thirteen Indian languages namely Assamese, Bengali, Hindi, Kannada, Kashmiri, Kodava, Malayalam, Marathi, Oriya, Punjabi, Rajasthani, Tamil and Telugu that have phonemically unequal inventories. Ten normal native speakers each (5males and 5 females) in the age range of 18 to 35 years speaking these languages participated in the study. Non sense V1CV2 words with these vowels in the initial position (V1) were considered for the study. The final vowel (V2) was always /a/. These nonsense words were embedded in a phrase, “say the word____now” and a total of 819 phrases, each written in their respective language on a card, formed the material. Frequencies of the first two formants were plotted on a F_1-F_2 plane and compared across languages. The mean of F_1 and F_2 in each language was calculated. The results were compared across languages on the basis of five common vowels /a, I, u, e, o/. The results indicated that Oriya had the lowest F and Kannada had the highest F2 compared to other languages.

Vowel /i/ had the lowest F_1 and vowel /a/ had the highest F_1. Also, vowel /u/ had the lowest F_2 and vowel /i/ had the highest F_2 compared to other vowels. Females had higher F_1 and F_2 values compared to males in all languages. Table 15 shows mean F_1 and F_2 of common vowels /a/, /i/, /u/ and /e/ in 13 languages.

Languages	**F_1 (in Hz)**		**Average (F_1)**	**F_2 (in Hz)**		**Average (F_2)**
	Male	**Female**		**Male**	**Female**	
Kannada	467	527	497	1480	1712	1596
Tamil	445	469	457	1488	1663	1576
Telugu	461	489	475	1487	1732	1609
Malayalam	482	486	484	1453	1755	1604
Hindi	397	482	440	1482	1753	1617
Rajasthani	450	516	483	1580	1730	1655
Marathi	406	432	419	1495	1695	1595
Bengali	445	528	486	1595	1784	1689
Kodava	431	507	469	1446	1700	1573
Oriya	367	460	413	1442	1667	1555
Assamese	458	502	480	1524	1613	1569
Punjabi	442	540	491	1471	1712	1591
Kashmiri	452	497	475	1434	1579	1507

Table 15: Mean F1 and F2 of common vowel in thirteen languages.
Savithri and Jayaram (2004)

Grepla, Furstb and Josef Pesaka (2007) investigated vowel production of Czech speakers. 35 subjects (21 male, 14 female, aged 21−28 years, and average age 23.15) participated in the study where they had to produce the 5 vowels a, e, i, o, u. The frequency of the first formant was plotted against the frequency of the second one and pure vocal formant regions were identified as shown in figure 4.

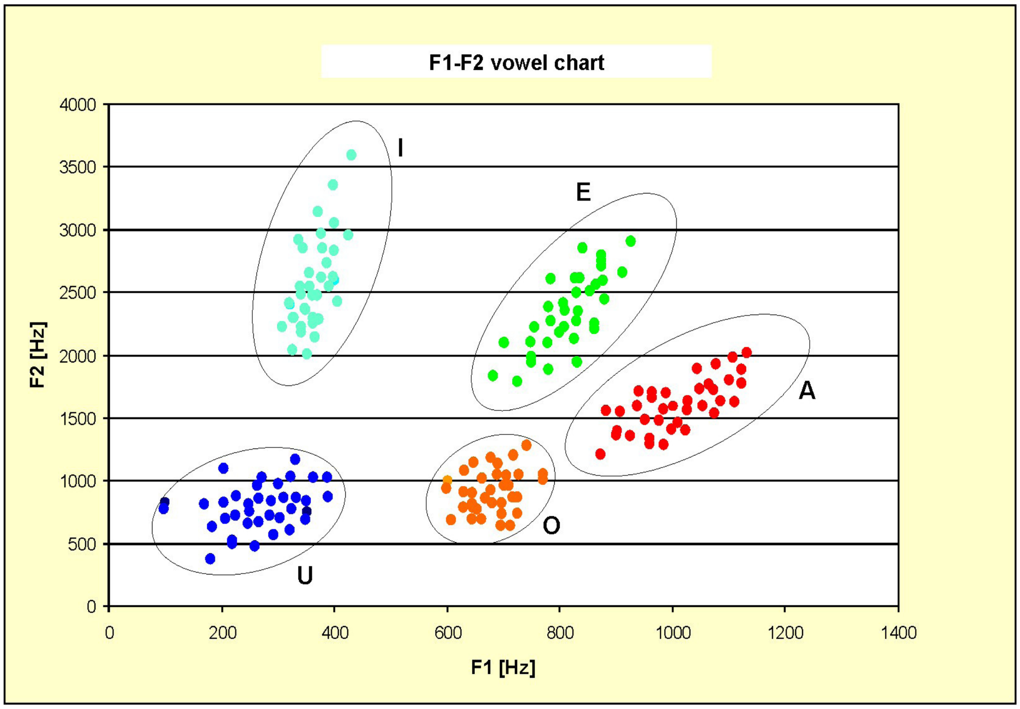

Figure 4: Vowel chart showing frequency of first and second formants Czech speakers.

Frequency bands for the Czech vowel "a" were circumscribed between 850 and 1150 Hz for first formant (F_1) and between 1200 and 2000 Hz for second formant (F_2). Similarly, borders of frequency band for vowel "e" they were 700 and 950 Hz for F_1 and 1700 and 3000 Hz for F_2. For vowel "i" 300 and 450 Hz for F_1 and 2000 and 3600 Hz for F_2, for vowel "o" 600 and 800 Hz for F_1 and 600 and 1400 Hz for F_2, for vowel "u" 100 and 400 Hz for F_1 and 400 and 1200 Hz for F_2.

Chen et. al. (2008) investigated vowel formants of 22 children (11 boys and 11 girls) speaking Mandarin language. The age range was from 5-12 years. The speech material consisted of 6 high frequency disyllabic words in Mandarin. The dissyllabic words were arranged as consonants-vowel-consonant-vowel (CVCV) and the target vowel was placed in first syllable. The subjects read out the stimuli written on a card and the data was recorded and analyzed. F_1 –F_2 measurements and vowel space area was determined. The differences between boys and girls were found. The F_1 values of the three vowels were different among these children, with the highest values for the vowel /a/, then the vowel /u/, and the lowest for the vowel /i/. There were similar F_2 values for the three vowels in boys and girls. The F_1 value of the vowel /i/ showed a significant difference between boys and girls in the Wilcoxon Rank-sum test. The F_1 value of the vowel /i/ was significantly higher in girls than in boys.

There was no significant difference of the F_1 values of the vowels /u/ and /a/ between boys and girls. The F_2 values of all three vowels (/i/, /u/, and /a/) did not show significant differences between boys and girls. The F_2-F_1 values of the three vowels also showed no significant differences between boys and girls. The vowel space areas varied a lot among these normal children. There were no significant differences between boys and girls. Vowel spaces were not correlated with age, gender, and body height or body weight. Table 16 shows the mean value of F_1, F_2 and F_2-F_1.

		BOYS		**GIRLS**	
		Median	**Range**	**Median**	**Range**
F_1	/i/	360	320-506	458	358-548
	/u/	497	386-563	531	460-642
	/a/	845	670-955	815	666-1058
F_2	/i/	1335	1128-2014	1357	1048-2342
	/u/	1326	1099-1538	1337	1053-1544
	/a/	1338	1251-1472	1278	1227-1411
F_2-F_1	/i/	954	793-1654	895	644-1841
	/u/	816	581-986	780	670-990
	/a/	503	270-627	481	257-731

Table 16: Mean F_1, F_2 and F_2-F_1 (Hz) values of Boys and Girls of vowels /a/, /i/, /u/. Chen et. al. (2008)

Escudero, Boersma, Rauber, and Bion (2009) investigated four acoustic correlates of vowel identity in Brazilian Portugese (BP) and in European Portugese (EP). They were first formant, second formant, duration and fundamental frequency. The subjects included 20 BP and 20 EP speaking individuals (equal number of male and females in both the groups) with mean age of 23.3 years for female BP and mean age of 22.5 years for male BP subjects. For EP speakers, the females' mean age was 19.8 years and the males' mean age was 18.7 years.

The target vowels /i, e, ɛ, a, ɔ, o, u/ were orthographically presented to the speakers embedded in a sentence written on a computer screen. Each vowel was produced in a context CVCV sequence, where two consonants were two identical voiceless stops or fricatives. The averages of F0, F_1, F_2, F_3, for female and male speakers of BP and EP are given in table 17.

			/i/	/e/	/ɛ/	/a/	/ɔ/	/o/	/u/
BP	**F0(Hz)**	**F**	242	219	210	209	211	225	252
		M	137	131	124	122	122	132	140
	F_1	**F**	307	425	646	910	681	442	337
		M	285	357	518	683	532	372	310
	F_2	**F**	2676	2468	2271	1627	1054	893	812
		M	2198	2028	1831	1329	927	804	761
	F_3	**F**	3296	3074	2897	2625	2653	2627	2691
		M	2952	2719	2572	2324	2335	2380	2309
EP	**F0**	**F**	216	211	204	201	204	211	222
		M	126	122	117	115	117	123	127
	F_1	**F**	313	402	511	781	592	422	335
		M	284	355	455	661	491	363	303
	F_2	**F**	2760	2508	2360	1662	1118	921	862
		M	2161	1987	1836	1365	934	843	814
	F_3	**F**	3283	3007	2943	2535	2729	2636	2458
		M	2774	2559	2475	2333	2414	2429	2315

Table 17: The averages of F0, F_1, F_2, F_3, for female and male speakers of British Portugese (BP) and European Portugese (EP).

Natour, Marie, Saleem, and. Tadros (2011) examined acoustic characteristics of the normal Arabic voice. . The subjects included 300 normal Arabic speakers (100 adult males, 100 adult females in the age range of 18-24 years, and 100 children in the age range of 5-10 years). The subjects produced a sustained phonation of the six steady state Arabic vowels (/i:/, /e:/, /a:/, /ɑ:/, /o:/, and /u:/). F0, F_1, F_2, and F_3 of the six Arabic vowels were analyzed using Frequency Analysis Software (TF32). The mean values of all the measurements for the three groups are summarized in table 18.

Vowels (Male)	**F0 (Hz)**	**F_1 (Hz)**	**F_2(Hz)**	**F_3(Hz)**
/i:/	132.36	329.36	2166.50	2869.26
/e:/	128.92	451.89	1873.15	2610.22
/a:/	127.71	616.27	1427.34	2643.97
/ɑ:/	128.01	593.37	1102.32	2720.27
/o:/	130.39	470.29	1007.20	2562.36
/u:/	134.12	369.41	952.51	2502.25
Vowels (Female)	**F0 (Hz)**	**F_1(Hz)**	**F_2 (Hz)**	**F_3(Hz)**
/i:/	236.84	394.52	1969.85	3025.25
/e:/	226.94	543.91	1878.51	2834.97
/a:/	225.69	782.20	1696.81	1878.68
/ɑ:/	224.42	747.30	1471.58	2809.72
/o:/	225.20	567.57	1311.07	2598.47
/u:/	233.44	450.72	1261.85	2560.75
Vowels (children)	**F0(Hz)**	**F_1(Hz)**	**F_2(Hz)**	**F_3(Hz)**
/i:/	258.36	381.51	1537.16	2760.37
/e:/	249.17	610.07	1917.74	2992.85
/a:/	248.60	888.31	1947.00	3088.79
/ɑ:/	247.31	806.90	1523.86	2808.03
/o:/	248.62	624.45	1483.65	2673.19
/u:/	257.00	487.02	1402.30	2585.51

Table 18: Mean F0, F_1, F_2 and F_3 of the 6 Arabic vowels produced by 100 male, 100 females and 100 children.

Krishna and Rajashekhar (2012) study was first of its kind on vowel space in Telugu (one of the Dravidian languages) population across the age, gender and region groups. The vowel studied was /i/, /a/ and /u/. The stimuli consisted of 60 target word in CVCV/CVCCV context with varying preceding consonants. The target word was embedded in the final position of a frame /i: padamu _____/" (This word is____). Subjects included 72 Telugu speaking normal individuals in age group of (Group I: 6 to 9 years; Group II: 13 – 15 years; Group III: 20 – 30 years) from three different regions (Coastal, Rayalaseema and Telengana). All the participants were born in Andhra Pradesh and were native Telugu speakers.

A qualified Speech-Language Pathologist and Audiologist evaluated and certified their speech, language, and hearing, as being normal at the time of data collection. The participants were asked to read the sentence presented to them visually. The analysis of the recorded speech was done using CSL 4500. Formant frequencies F_1 and F_2 were measured to draw the vowel triangle and to calculate the vowel space. The results of the analysis reveal that with increase in age, the vowel space decreased. Females had larger vowel space than males and samples of Coastal region speaker have larger vowel space followed by Telengana and Rayalaseema regions. Table 19 represents the mean F_1 and F_2 values obtained for vowels /i/, /a/ and /u/.

Vowel	Formants	Children	Adolescent	Adult
/i/	F_1	586.82	546.66	502.77
	F_2	2529.8	2563.53	2390.78
/a/	F_1	885.76	811.44	730.67
	F_2	1569.16	1490.76	1378.64
/u/	F_1	572.45	538.15	495.7
	F_2	951.12	947.29	942.88

Table 19: Mean F1 & F2 (Hz) of /i/, /a/ and /u/ vowels in Telugu speakers across different age groups.

F_1 for all vowels (/i/, /a/ and /u/) reduced as the age increased. Except for vowel /i/, F_2 decreased as the age progressed. For vowel /i/, F_2 had maximum of 2563.53 Hz and reduced in adults. Among all age groups, central low mid vowel /a/ had the highest mean F_1 followed by /i/ and back high vowel /u/. Front high vowel /i/ had highest mean F_2, followed by central low mid vowel /a/ and high back vowel /u/. Table 20 shows the mean F_1 & F_2 (Hz) of /i/, /a/ and /u/ vowels in Telugu speakers across the genders.

Vowel	Formants	Female	Male
/i/	F_1	580.56	509.57
	F_2	2598.3	2388.82
/a/	F_1	851.47	766.83
	F_2	1541.05	1418.79
/u/	F	564.08	506.6
	F_2	947.74	946.44

Table 20: Mean F_1 & F_2 (Hz) and SD of /i/, /a/ and /u/ vowels in Telugu speakers across the genders.

Gender differences do exist for both formant frequencies across the vowels. Females showed higher values compared to males for all formant frequencies and for all vowels compared. Here too, central low mid vowel /a/ had the highest mean F_1 followed by /i/

and back high vowel /u/. Front high vowel /i/ had highest mean F_2, followed by central low mid vowel /a/ and high back vowel /u/. F_1 and F_2 values were compared for the three vowels /i/, /a/ and /u/ across the three dialects which is summarized in table 21.

Vowel	Formants	Coastal	Rayalseema	Telengana
/i/	**F_1**	530.87	552.71	552.2
	F_2	2501.67	2522.93	2457.85
/a/	**F_1**	797.83	795.29	834.84
	F_2	1477.67	1482.04	1479.42
/u/	**F_1**	525.92	542.56	537.59
	F_2	947.61	942.92	950.66

Table 21: Mean F_1 & F_2 (Hz) of /i/, /a/ and /u/ vowels in Telugu speakers across the three dialects.

Formant frequencies F_1 and F_2 varied between vowels studied across the regions. Vowel /i/ and /u/ had higher F_1 in speakers of Rayalaseema followed by Telengana and Coastal region while for vowel /a/, speakers from Telengana had higher F_1 followed by Coastal and Rayalseema.

A similar pattern was observed for F_2 formant among all the vowels. Central low mid vowel /a/ had the highest mean F_1 followed by /i/ and back high vowel /u/ among the regions. Front high vowel /i/ had highest mean F_2, followed by central low mid vowel /a/ and high back vowel /u/. Vowel space area was calculated by using the model of Blomgren et.al., (1998), for the different groups and is given in table 22.

	AGE				GENDER		DIALECT		
	Overall	**C**	**Adolescents**	**A**	**F**	**M**	**Coastal**	**Rayalseema**	**Telengana**
Area (Mz 2)	**209279**	**242631**	**218412**	**168614**	**232167**	**186752**	**210019**	**197170**	**219822**

Table22: Vowel space area for the three groups for the three vowels in Telugu.

The larger vowel space and area could be indicators of clear speech and could be used for judging the intelligibility of speech (Carrell, 1984; Blomgren, Robb & Chen, 1998; Ferguson & Kewley-Port, 2007). In this study individuals in Telegana region had larger vowel space which could be interpreted as speakers from Telengana have more clear speech. This is not true as per literature, which reports that speakers from Coastal region have more clear speech. Female having higher vowels space as compared to males indicates females having clearer speech than males.

4. Literature on influence of L1 on L2 (Formant frequency)

This section will discuss the studies in literature on the influence of vowel production in first language on the second language. Since the focus of this study is on fundamental frequency and formant frequencies of the vowels, the review will be restricted to the same**.**

Wang (1982) studied the productions of the 10 English vowels by both the native Mandarin and English speakers. The English vowels [i I eI ɛ æ u ʊ oʊ ɒ ʌ] were produced by 15 Mandarin and English speakers and the production of Mandarin vowels [i eI ʊ o ʊ a] by 15 Mandarin speakers were also analyzed. The vowels were produced in isolation except for the vowel [eI], which was produced in /peI/ due to the lack of occurrence of isolated /eI/in Mandarin. The measurement was made for the duration and first and second formants frequencies for the vowels. Results of the analysis were discussed in two sections. (a) Mandarin vowels [i eI ʊ o ʊ a] and their English counterparts**:** For duration measures, English vowels were found to be longer than their Mandarin counterparts. To test the vowel duration differences between the Mandarin [i eI ʊ o ʊ a] and English [i eI ʊ o ʊ a] two-way mixed design ANOVA was carried out with language (Mandarin or English) as a between group factor and vowel (5 levels) as a within group factor.

The results of statistical analysis indicated the effect of language was significant, because the English vowels tended to be longer overall than the Mandarin. The effect of vowel and interaction of language and vowel were not significant, suggesting that the patterns of duration differences among the five vowels in the two language groups were not significantly different. For the spectral measurement, series of two-tailed t-tests were then carried out on the log mean transformed F_1 and F_2 values of both English and Mandarin vowels to determine the differences between them. No significant differences were found between the Mandarin and English vowel [il. For [eI], the results showed that the Mandarin [eI] was significantly lower and more posterior than the English but the difference was not significant. The Mandarin [ou] was significantly lower at both measurement but more posterior than the English counterpart. For [u], no significant differences were found in F_1 across languages. However, there was a huge difference in F_2 values suggesting that Mandarin [u] was produced significantly more posterior than the English counterpart. Results also showed significant differences in F_1 between the English [ʌ] and Mandarin [ɑ].

(b) Comparison of native English and Mandarin-accented vowels [i I eI ɛ æ u ʊ oʊ ɒ ʌ]: Spoken by 15 native English speakers and 15 Mandarin speakers. A two-way ANOVA test revealed no effect of first language. There was an effect of vowel and an interaction of first language and vowel. However, tests of simple main effects showed that only the Mandarin-accented [il was significantly longer than the native English [il. For the remaining nine vowels, duration differences were not significant. To test for within group differences in vowel duration, a one-way repeated measure ANOVA was carried out for both groups.

The results revealed an effect of vowel for both the native English speakers and for the Mandarin speakers. Post-hoc Tukey HSD tests revealed the native English group's productions [eI i u oʊ æ ɒ] were significantly longer than their [ʊ ɛ ʌ I]. The results indicated that the native English speakers showed a tendency to produce longer tense vowels than lax vowels. For spectral measures, significant differences were revealed in F_1 for for [i], [el] , [ʊ], [ʌ] and [oʊ]. In general, more differences were revealed in F_2 than in F_1. Differences in F_2 were found for [I], [æ], [u] and [ʊ]. Less but still significant differences in F_2 between the two groups were also found for [ʌ] and for [ɒ]. Only [il and [ɛ] were found to have no significant differences in both vowel height and advancement. The analysis of acoustic data indicated that the majority of the Mandarin-accented vowels were significantly different from the native English ones in absolute mean F_1 or F_2 values. In general, the Mandarin speakers in this study had not learned to produce most of the English vowels in a native-like manner. The acoustic differences between the Mandarin-accented and native English vowels are explainable in terms of similarities and differences between the Mandarin and English vowel systems. The majority of the Mandarin speakers did not seem to have established separate categories for the English vowels in their productions.

Rather, the results suggested that some speakers substituted similar Mandarin vowels such as [il and [u] for the English counterparts in their productions. Mandarin-accented vowels tended to be "pulled" toward the Mandarin vowels spectrally. However, most accented vowels, especially the ones that lack Mandarin counterparts, showed some degree of approximation towards the native English vowel targets in terms of acoustic properties. Therefore, not every Mandarin speaker substituted the new English vowels with the closest vowels in the native stock.

Wang et al. (1997) studied the acquisition of English vowels by mandarin learners. Fifteen native Mandarin speakers from Beijing who had been living in Canada between 0.5 and 6 years participated as speakers and listeners, and 15 native speakers of Canadian English participated as a comparison group for the production test. The isolated English vowels [I, I, ei, ɛ, æ, u, U, ou, ɐ ʌ], produced in a carrier sentence by both groups, were identified by four native English listeners. The results showed that, in general, the Mandarin speakers' productions of the vowels that have Mandarin counterparts were as intelligible as the native English speakers' productions and were significantly more intelligible than the vowels lacking obvious Mandarin counterparts.

Flege et al. (1997) did acoustic study to examine the influence of L1 Mandarin on vowel production of L2 American English. They measured F0 and F_1- F_2 frequencies for four vowels /i, I, ɛ, æ / (of which only /i/ is found in both languages) produced by a group of native Mandarin speakers. As a means of normalizing acoustic values to account for differences in vocal tract length, F0, F_1 and F_2Hz values were converted to the Bark scale. The mean B0, B1 and B2 values were then calculated for each subject's vowel productions. Acoustic correlates of vowel height were estimated by subtracting the mean B0 from the mean B1 values (B1- B0). Estimates of tongue advancement were made by subtracting B1 from B2 (B2-B1). Flege et al. found that Mandarin subjects who were the least proficient in speaking American English showed the least accuracy (according to vowel height and tongue advancement) producing vowels not found in L1, specifically, /i, I, ɛ, æ /.

Chen, Robb, Gilbert, and Lerman (2001) compared first and second vowel formants of 11 vowels (/i, I, e, ɛ, æ , ʌ, u, ʊ, o, ɔ, ɑ/) produced by 40 Mandarin speakers to that of 40 American English speakers. The first and second formant frequencies (F_1 and F_2) of 11 vowels produced at syllable level was measured. Subjects included two groups of individuals. First group consisted of 40 adults (20 males, and 20 females) with native Mandarin as L1 and American English as L2. The mean age of the Mandarin male speakers was 33 years and that of female speakers was 28 years. Selection criteria for inclusion in the Mandarin group consisted of: (1) a college education, (2) formal instruction in English (3) the ability to speak standard Mandarin as judged by the first author who is a native speaker of Mandarin, (4) residing in the US for a minimum of 2 years and speaking English a minimum of 30% of their daily conversation, and (5) the ability to orally read English fluently. The second group consisted of 40 adults (20 males and 20 females) who spoke American English as L1. The mean ages of the American male and female speakers were 33 and 27 years respectively. The stimuli consisted of 11 vowels which were placed in /hVd/ context. And each /hVd/ word was embedded in the carrier sentence: " say____again". The subjects had to read the sentence from a card containing the words "heed', "hid", "hayed", "head", "had", "hud", "who'd", "hood", "hoed', "hawed", "hod".

To evaluate whether significant differences existed between the two language groups according to gender, acoustic features of each vowel were individually assessed. Two-tailed *t*-tests were performed to compare the F_1 and F_2 values of each vowel for each language/gender group. Results for the familiar vowels showed higher F_1 frequency in the production of /i/ and /u/ by Mandarin males compared to American males. Mandarin female speakers showed a significantly lower F_1 frequency for /ɑ/ than the American females. Results of *t*-tests for F_2 revealed a significantly lower F_2 for production of /i/ by the Mandarin males compared to the American males. Mandarin female speakers produced /i/, /u/, and /ɑ/ with significantly lower F_2 frequencies compared to American females. For unfamiliar sounds, alpha-adjusted *t*-tests were performed to compare the F_1 and F_2 values of each vowel produced by the Mandarin speakers to those produced by the American speakers for each gender group. Results of *t*-tests indicated a significantly lower F_1 for production of /æ/ and /ʊ/ for Mandarin males compared to American males, and also a significantly higher F_1 for production of /ʌ/ by the Mandarin males. Mandarin females produced the vowels /I/, /æ /, /ʊ/, and

/ɔ/ with significantly lower F_1 frequencies compared to American females. Results of *t*-tests for F_2 identified significantly higher F_2 frequencies for production of /I/ and /æ/ for Mandarin males compared to American males, as well as a significantly lower F_2 for /ʊ/ among the Mandarin males. Mandarin females produced the vowels /ʌ/, /ʊ/, and /ɔ/ with significantly lower F_2 frequencies compared to American females. In Summary, results of acoustic analysis showed that for both male and female speakers of Mandarin group, overall vowel quadrilateral appeared smaller than that of American speakers'.

Savithri, Jayaram, Rajasudhakar and Venugopal (2005) did a cross-linguistic study to compare the base-of-articulation in Dravidian language Malayalam and Indo-Aryan language namely Hindi that have different vowel inventories. 10 normal adults (5 males and 5 females) in the age range of 18 to 35 years, each speaking Malayalam and Hindi participated in the study. 10 vowels in Malayalam and eight vowels in Hindi were selected. These vowels as occurring in V1CV2 non sense words were considered for the study. A total of 50 nonsense V1CV2 words in Malayalam and 40 non-sense V1CV2 words in Hindi were used. Each non sense word was embedded in a phrase, "say the word___now" and was written on a card. Frequencies of the first two formants were plotted on a F_1-F_2 plane and compared across languages. The mean of F_1 and F_2 of two languages was calculated which is given in the table. Results indicated low F_1 and F_2 in long vowels compared to short vowels in both languages. Also, females had higher F_1 and F_2 value than males. A comparison of the common vowels across the two languages revealed significantly higher mean F_1 in Malayalam compared to that in Hindi. F_2 of vowels in Malayalam was lower than in Hindi. The mean F_1 and F_2 in Malayalam and Hindi is shown in the table 23.

Formants	**F_1(Hz)**				**F_2(Hz)**			
Languages	**Malayalam**		**Hindi**		**Malayalam**		**Hindi**	
Vowels/Gender	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
a	766	827	643	767	1359	1595	1365	1608
a:	757	874	711	885	1274	1467	1247	1477
i	406	332	289	342	2022	2709	2241	2707
i:	296	299	278	285	2283	2771	2335	2905
u	318	347	229	385	878	980	827	909
u:	305	328	293	312	800	950	786	717
e	464	489	380	459	1995	2431	2095	2612
e:	464	446	-	-	2106	2602	-	-
o	460	438	378	454	1012	1064	883	944
o:	432	423	-	-	909	1033	-	-
Average	461	481	400	486	1464	1760	1472	1735

Table 23: Mean F_1 and F_2 of Malayalam and Hindi vowels.
(Savithri, Jayaram, Rajasudhakar and Venugopal (2005))

MacLeod, Stoel-Gammon (2009) investigated bilinguals' ability to produce language-specific acoustic values for consonants and vowels that are highly similar across the two languages. To investigate this ability, they targeted early bilinguals who had acquired two languages before the age of 12 and continued to use both languages on a daily basis. These adult bilinguals were separated into two groups: simultaneous bilinguals (or nearly so) who acquired both languages by their third year, and sequential bilinguals who acquired their second language between the ages of 8 and 12 years. Their speech production was studied through an acoustic analysis of stop consonants (voice onset time) and vowels (formant structure). Despite the differences in age of acquisition, these bilinguals used both languages on a regular basis at work and at home and were very proficient in both languages. In contrast to other early bilinguals who undergo a change in language dominance from their first language to their second, the participants in this study maintained relatively balanced abilities in both languages. This study revealed that childhood bilinguals can maintain contrasts across their two languages, even for very similar phonemes.

Vaishna and Deepshika(2010) studied on acoustic vowel space of two Indian Languages Hindi and Panjabi to show how the acoustic vowel space gets redefined in language contact situations. The case is Hindi and Punjabi coexisting in the state of Delhi for a number of years, and the subjects who claim to be monolinguals in Hindi and Punjabi show a clear influence of the presence of the other language in environment, which is indicated by overlapping acoustic space.

The research aimed at finding the differences between acoustic spaces as indicated by seven peripheral vowels of Hindi and Punjabi as spoken in Delhi. These peripheral vowels are /i/, /e/, /ɔ/, /a/, / ɛ/, /o/ and /u/. Five male native speakers of Hindi and five male native speakers of Punjabi, all residents of Delhi, and five subjects from Lucknow, predominantly monolingual region in Uttar Pradash, participated in the study.

All the subjects were aged between 15-20 years. The stimuli consisted of two separate lists of words.. The first list consisted of Hindi words with the vowels /i/, /e/, /ɔ/, /a/, / ɛ/, /o/ and /u/ in the three word positions. And the second list consisted of Punjabi words with the vowels /i/, /e/, /ɛ /, /a/, /ɔ/, /o/ and /u/ in the three word positions. Data was recorded and analyzed using PRAAT software. F0, F_1, F_2 and F_3 was then measured for each vowel in all the languages. Thus formant values for every vowel particularly F_1 and F_2 and the difference between the two formants (F_2-F_1) were calculated for all the seven vowels. They used the plots of –(F_1) against –(F_2-F_1) for the representation of acoustic vowel space to resemble it to the cardinal vowel chart. Results indicated that F_1 values for Punjabi are consistently higher than those of Hindi indicating relatively more open articulation of vowels in Punjabi.

The same study also showed that F_2 values are also relatively higher than those of Hindi indicating that the vowels of Punjabi are more fronted. The acoustic space a showed a similarity pattern of the vowels of Hindi and Punjabi as spoken by monolingual speakers of Hindi and Punjabi residing in Delhi, although there are some differences between F_1 and F_2 values of Hindi and Punjabi. In both the groups the acoustic space is redefined.

All subjects selected for the present study claimed to be monolinguals, but their acoustic vowel space is very different from that of Hindi speakers in Lucknow which is the control group because of the language contact situation. Table 24 shows the average F_1 and F_2 values for Hindi, Punjabi and control group.

Vowel	F_1 H	F_2 H	F_1 P	F_2 P	F_1 C	F_2 C
/i/	267.45	2488.63	247.39	2396.91	299.51	1856.29
/e/	378.09	2399.11	388.29	1368.42	384.56	1653.94
/ɛ/	645.67	1820.56	635.84	1780.81	578.77	983.77
/a/	676.86	1148.86	690.68	1143.26	708.02	402.11
/ɔ/	593.14	970.01	594.95	964.33	555.05	411.67
/o/	383.50	978.04	367.61	911.01	377.66	427.13
/u/	265.21	755.65	265.00	728.87	349.45	408.37

Table 24: The average F_1 and F_2 values in Hz, for Hindi (H), Punjabi (P) and control group(C). (Vaishna and Deepshika, 2010)

To summarize, results of previous studies indicate that the first language influences the production of vowels of second language. Vowels occurring in the word of English as spoken by a native Malayalam speaker are likely to be influenced by Malayalam. It is interesting and important to know about the way in which Malayalam speaker says English vowels as it is clinically relevant with bilingual clinical population. In this context, the present study was planned. The aim of this study was thus, to investigate the production of vowels in English (L2) by bilingual Malayalam speakers (L1) who have learnt English as second language and were not exposed to same till 12 years of age. Specifically, the formant frequencies and durations of English vowels spoken by native Malayalam speakers were analyzed.

CHAPTER III

METHOD

Participants: Thirty native female Malayalam speakers (L1) with the Calicut Malayalam dialect in the age range of 20-25years (mean age of 22.5 years) who were not exposed to English speaking environment after 12 years of age participated in the study. None of them had speech, language, hearing, neurological or organic problems. They were native Malayalam speakers and residents of Kerala. They had similar educational qualifications. Subjects residing in the areas of Calicut city were considered for the study in order to control the dialectal variations.

Material: The test stimuli consisted of 10 monosyllabic words each beginning with [h] and ending with [d] and differing only in the vowel. The words used were heed, hid, head, had, hod, hawed, hood, who'd, hud, and heard (Peterson & Barney, 1952).

Procedure: Subjects were tested individually. Prior written consent from the subjects was obtained. Each word was visually presented in the phrase "the word is ____". This phrase was selected to maintain the natural prosody in a continuous speech stream. Each word/phrase was included three times in random order in a single recording script. Subjects were instructed to read the phrases in comfortable pitch and loudness. Each speaker was recorded reading from the script in a quiet place using a digital audio recorder held at 10 cm from the mouth. The samples were audio recorded and digitized at 11100 Hz sampling frequency and stored onto the computer memory. Out of three utterances, the best articulated word was selected for the acoustic analysis.

Analysis

Acoustic analysis: A total of 300 tokens were analyzed in this study. Using Praat software (Boersma & Weenink, 2011), waveform and Wide Band bar type of Spectrograms of target words were displayed. Fundamental frequency and frequency of the first three formants of the vowels in the steady state were extracted from the pitch curve and spectrogram. The steady-state portion of the vowel was determined by first placing two vertical cursors in the spectrogram: the first cursor marked the end of the formant transitions coming out of the initial consonant, and the second cursor marked the beginning of the formant transitions into the final consonant.

The period between the two cursors thus indicated the portion of the vowel which showed no or very little formant movement. A 25 ms Hanning window was placed approximately in the middle of this steady state period. The formant values were then read from the LPC spectrum and checked with readings from the spectrogram. Figure 5 illustrates the pitch curve and frequencies of the first three formants.

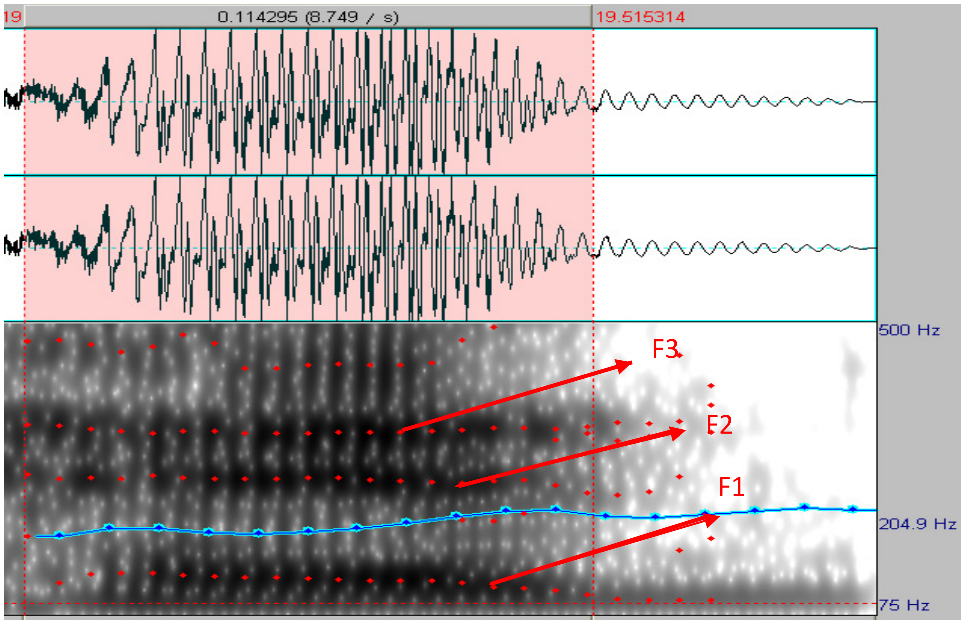

Figure 5: Pitch curve and first three formants

Statistical analysis: All statistical analysis was done using commercially available SPSS (17.0 version) software. The data from Peterson and Barney (1952) was considered for comparison. Single sample t- test was used to find the significant difference between American English and Malayalam English on fundamental frequency, F_1, F_2, and F_3.

CHAPTER IV

RESULTS

The purpose of the study was to investigate the influence of native language Malayalam on the production of English vowels. Hence, the data analyzed was computed in order to find out the fundamental frequency and frequency of first three formants of the 10 vowels spoken by 30 female Malayalam speakers.

Single sample t test was performed to compare the mean of F0 and F_1, F_2 and F_3 of 10 English vowels spoken by Malayalam speakers(figure 6) with the mean of American English speakers (figure 7). Results of each parameter will be described separately.

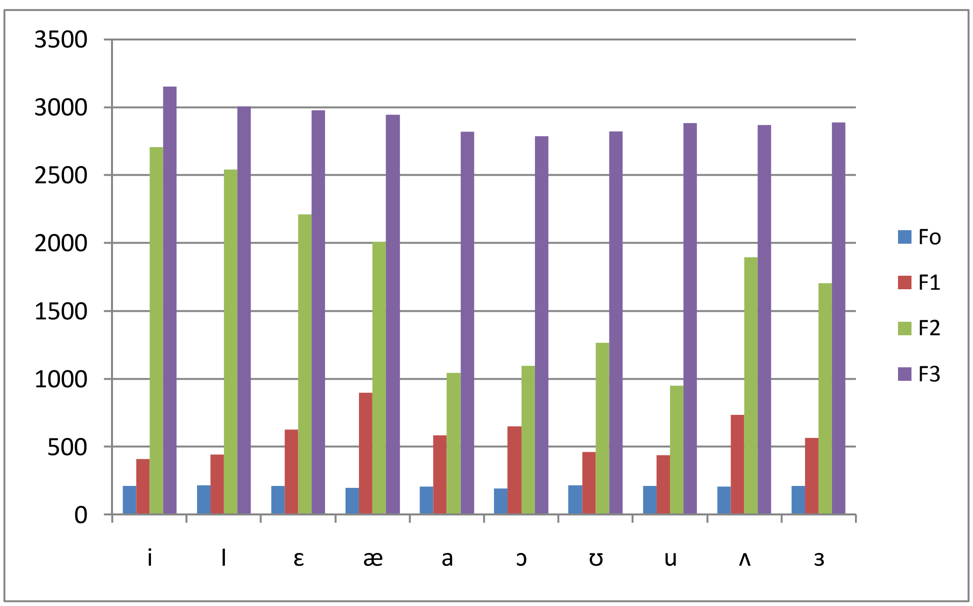

Figure 6**:** Graph showing mean for F0, F_1, F_2 and F_3 (Hz) for the 10 vowels produced by 30 female Malayalam speakers**.**

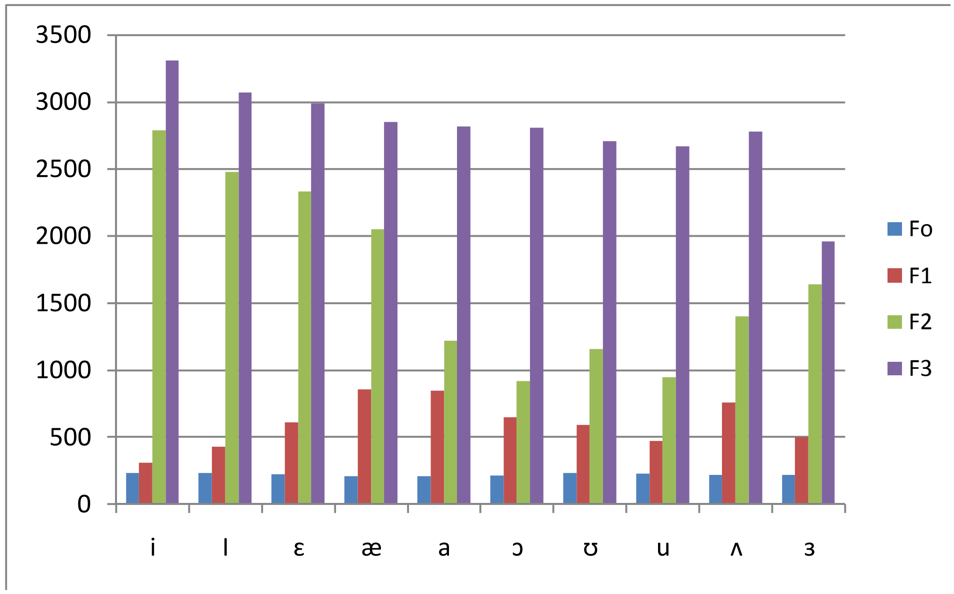

Figure 7: Graph showing mean for F0, F_1, F_2 and F_3 (Hz) for 28 female American English speaker from Peterson and Barney study.

Fundamental frequency

The results of single sample t-test showed significant difference between groups on fundamental frequency of vowels except /a/ and /ɜ/. F0 in Malayalam speakers was significantly lower compared to English speakers. Table 25 shows the mean and standard deviation of the F0 and p value in both the groups.

Vowels	Malayalam Speaker	American English Speaker	P value
/i/	213.61(18.64)	235	.000
/I/	218.30 (19.88)	232	.001
/ɛ/	211.45 (21.98)	223	.007
/æ/	198.52 (21.89)	210	.008
/a/	207.41 (22.01)	212	.263
/ɔ/	194.24 (31.51)	216	.001
/ʊ/	218.73 (20.48)	232	.001
/u/	211.13 (19.70)	232	.000
/ʌ/	209.22 (17.66)	221	.001
/ɜ/	210.04 (24.67)	218	.088

Table 25: Mean and standard deviation of the F0 (Hz) and p value in Malayalam and English speakers.

Frequency of First formant (F_1)

Result of single sample t-test indicated significant difference between groups for vowels [i, I, æ, a, ɔ, u, ʌ, ɜ]. F_1 was significantly higher in Malayalam speakers compared to English speakers except for /ɛ/ and /ʊ/. Table 26 shows the mean and standard deviation of F0 and p values for the two groups.

Vowels	Malayalam Speaker	American English Speaker	P value
/i/	408.56(40.51)	310	.000
/I/	441.96(27.99)	430	.026
/ɛ/	627(50.39)	610	.067
/æ/	897.58(78.29)	860	.014
/a/	584.04(91.08)	850	.000
/ɔ/	650.00(115.73)	590	.008
/ʊ/	463.21(34.35)	470	.288
/u/	437.99(36.00)	370	.000
/ʌ/	735.94(49.94)	760	.013
/ɜ/	562.58(53.14)	500	.000

Table 26: Mean and standard deviation of F_1 (Hz) and p values for the Malayalam speakers and American English Speakers.

Frequency of Second formant (F_2)

The results t- test indicated significant difference ($p<0.05$) between groups on F_2 for the vowels [i, ɛ, a, ɔ, ʊ, ʌ]. F_2 of /i/, / ɛ /, and /a/ were significantly lower than that of /ɜ/**,** /ʊ/, ʌ/ it were significantly higher in Malayalam speakers compared to English speakers. Table 27 shows the mean and standard deviation of F_2 and p values in both the groups.

Vowels	Malayalam Speaker	American English Speaker	P value
/i/	2706(160.02)	2790	.008
/I/	2541.46(174.54)	2480	.064
/ɛ/	2211.66(141.13)	2330	.000
/æ/	2008.66(170.52)	2050	.195
/a/	1044(107.56)	1220	.000
/ɔ/	1094.82(126.34)	920	.000
/ʊ/	1267.62(158.65)	1160	0.001
/u/	951.89(124.88)	950	0.934
/ʌ/	1895.73(90.48)	1400	0.000
/ɜ/	1703.50(260.57)	1640	0.192

Table 27: Mean and standard deviation of F_2 (Hz) and p values in Malayalam speakers and American English Speakers.

Frequency of the third formant (F_3)

Results of single sample t-test indicated significant difference between groups for the vowels [i, I, æ, ɔ, ʊ, u, ʌ, ɜ]. F3 was significantly higher in Malayalam speakers compared to English speakers on all vowels except /i/ and /I/. Table 28 shows the mean and standard deviation of F3 and p values in both the groups.

Vowels	Malayalam Speaker	American English Speaker	P value
/i/	3154(139.38)	3310	0.000
/I/	3008.06(150.36)	3070	0.032
/ɛ/	2979.23(129.47)	2990	0.652
/æ/	2944.20(167.44)	2850	0.004
/a/	2817(245.30)	2810	0.053
/ɔ/	2785.13(203.97)	2785	0.053
/ʊ/	2821.70(199.55)	2680	0.001
/u/	2881.70(236.32)	2670	0.000
/ʌ/	2869.13(137.69)	2780	0.001
/ɜ/	2888.30(200.43)	1960	0.000

Table 28: Mean and standard deviation of F_3 (Hz) and p values in both the groups.

Vowel space

Vowel space of Malayalam speakers and American speakers was estimated by plotting each group's mean formant values for 10 English vowel productions along an F_1 versus F_2 plane. The vowel space in Malayalam speakers was reduced compared to English speakers. The figure 8 shows vowel space for the two groups in this study.

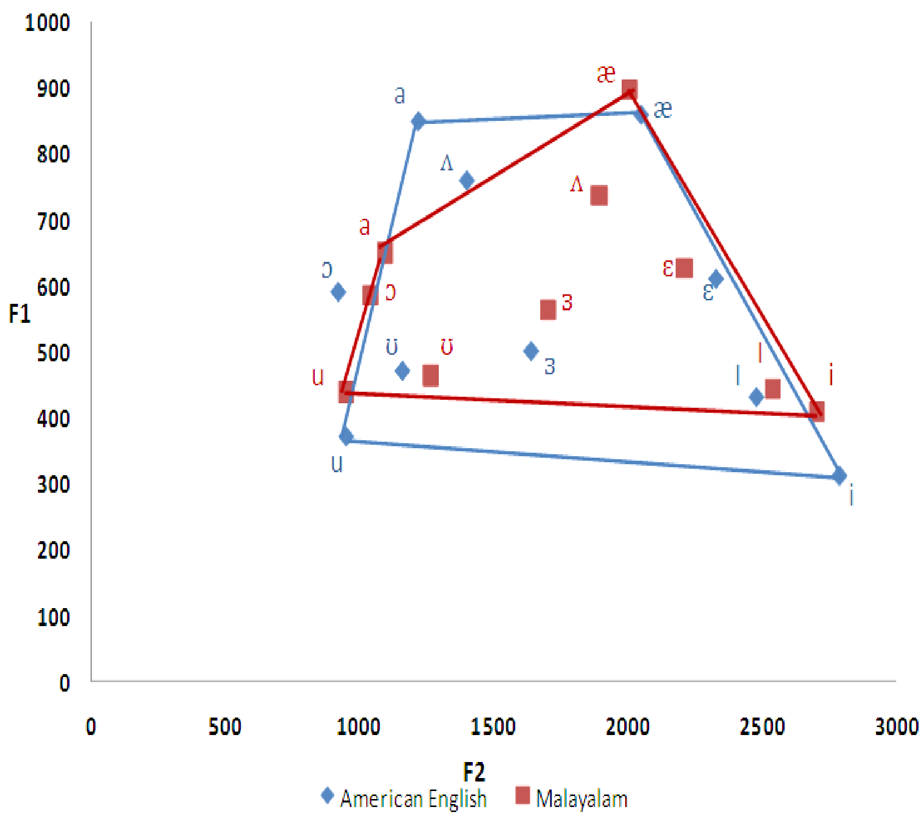

Figure 8: Vowel space for Malayalam English and American English

Isovowel line

Isovowel lines were plotted for the 10 English vowels produced by both the American English speakers (Peterson and Barney, 1952) and Malayalam speakers along a F_1-F_2 plane. The figure 9 shows the isvowel line for vowel / i/. The blue dots represent the value of formant frequency (F_1 –F_2) for each 30 speakers of Malayalam speakers. Since individual data is not available for Peterson and Barney data, the mean formant frequencies of vowel /i/ is represented by the red dot. The green line shows the isovowel line indicating the range of formant frequency values for Malayalam English vowels.

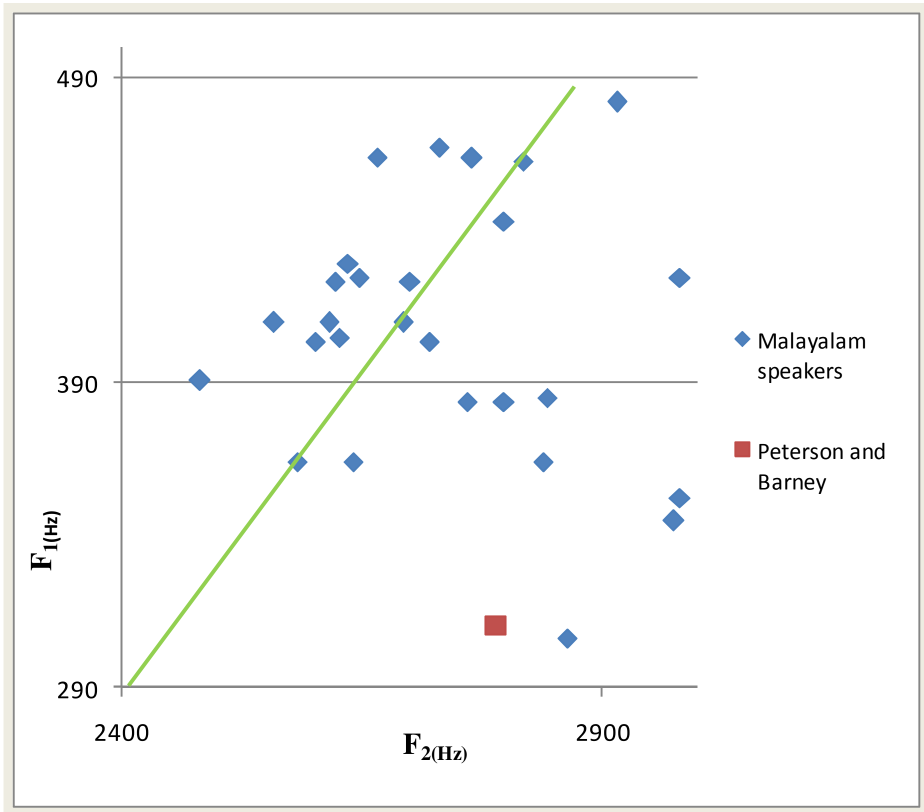

Figure 9: Isovowel line for vowel /i/

The figure shows that the red dot which represents the mean formant frequency of Peterson and Barney data, for vowel /i/ lies on the right side of the isovowel line for the Malayalam English vowels.

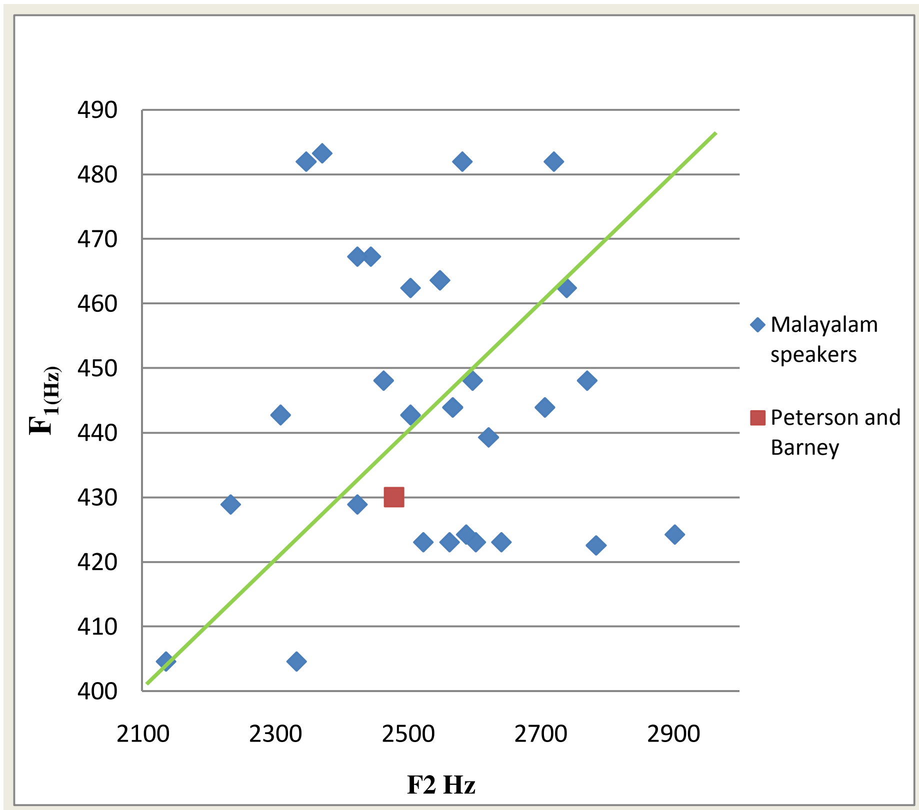

Figure 10: Isovowel line for vowel /I/

The figure shows the isovowel line for vowel /I/.Here the red dot which represents the mean formant frequency value of /I/ from Peterson and Barney data is falling on the right side of the range of formant frequency values of Malayalam English vowels.

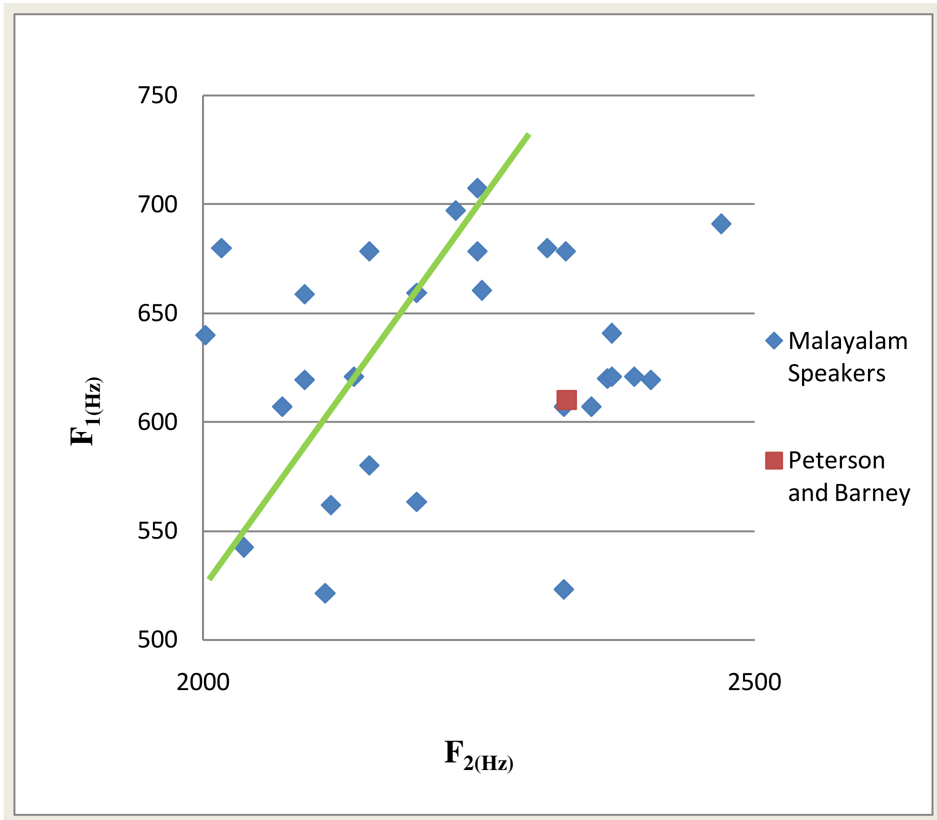

Figure 11: Isovowel line for vowel /ɛ/

The figure shows the isovowel line for vowel / ɛ /.Here the red dot which represents the mean formant frequency value of /ɛ/ from Peterson and Barney data is falling on the right side of the range of formant frequency values of Malayalam English vowels.

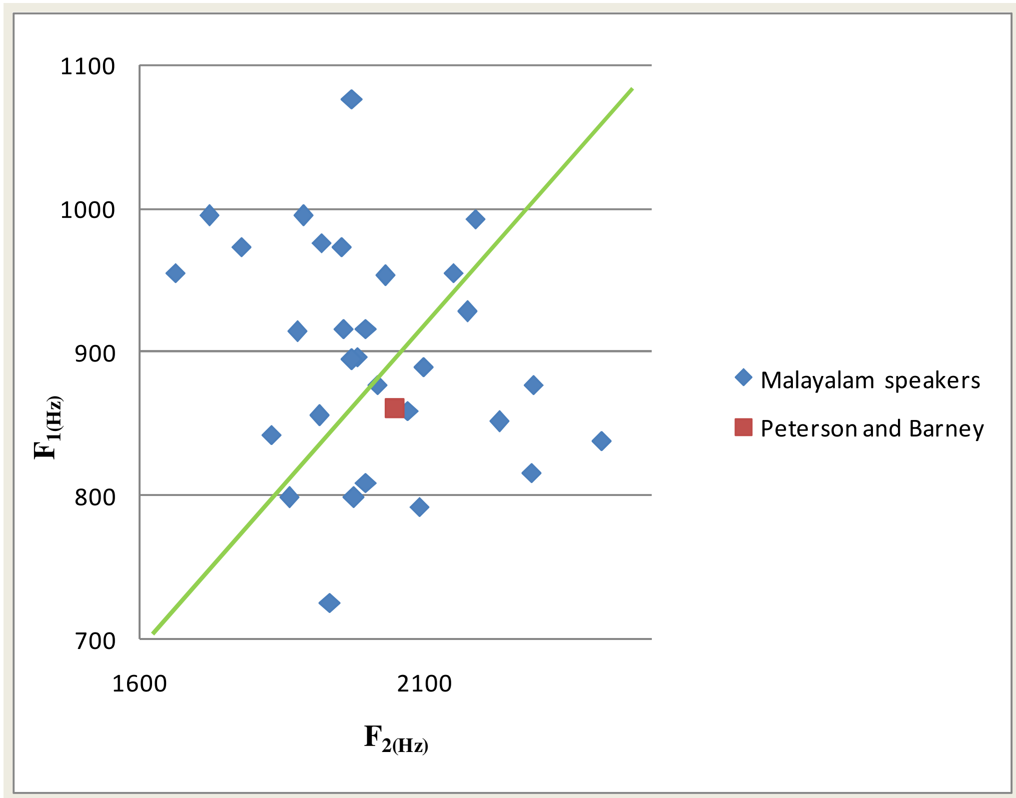

Figure 12: Isovowel line for the vowel /æ/

The figure shows the isovowel line for vowel / æ /.Here the red dot which represents the mean formant frequency value of /æ/ from Peterson and Barney data lies on the right side of the range of formant frequency values of Malayalam English vowels.

Figure 13: Isovowel line for vowel /a/

The figure shows the isovowel line for vowel / a /.Here the red dot which represents the mean formant frequency value of /a/ from Peterson and Barney data lies on the left side of the isovowel line for the range of formant frequency values of Malayalam English vowels.

Figure 14: Isovowel line for vowel /ɔ/

The figure shows the isovowel line for vowel / ɔ /.Here the red dot which represents the mean formant frequency value of /ɔ/ from Peterson and Barney data on the left side of the isovowel line for the range of formant frequency values of Malayalam English vowels.

Figure 15: Isovowel line for vowel /ʊ/

The figure shows the isovowel line for vowel / ʊ/.Here the red dot which represents the mean formant frequency value of / ʊ/ from Peterson and Barney data lies on the left side of the isovowel line for the range of formant frequency values of Malayalam English vowels.

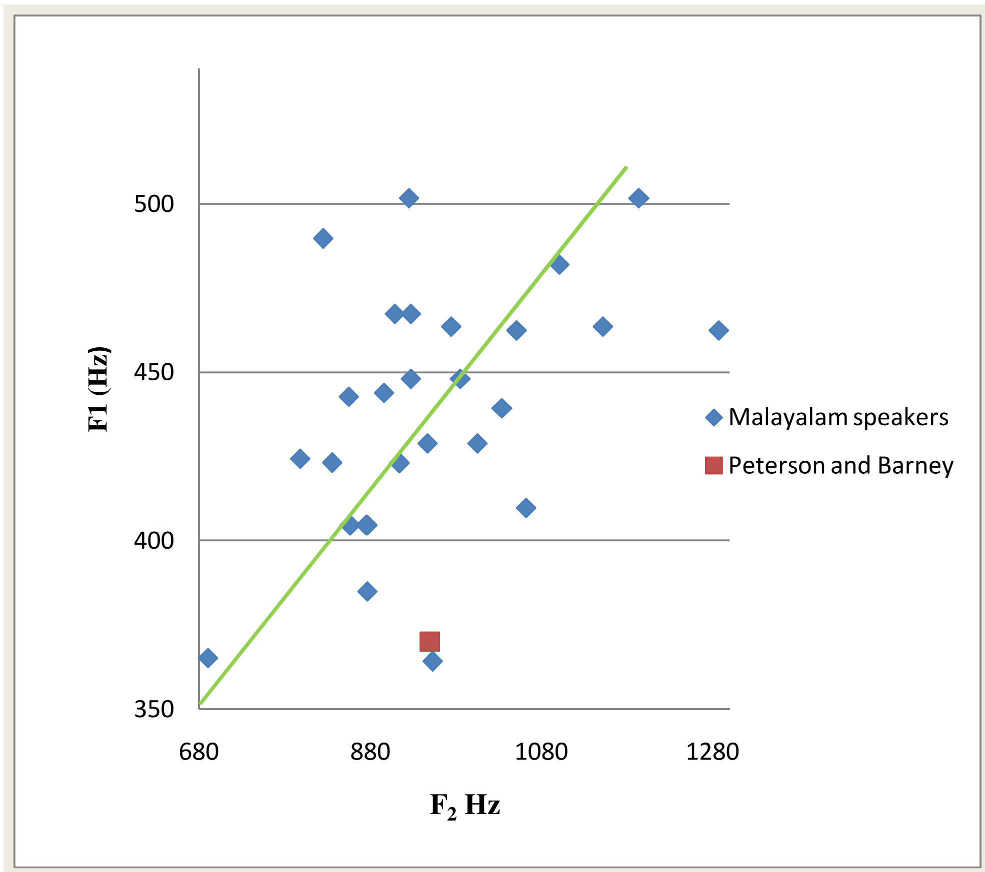

Figure 16: Isovowel line for vowel /u/

The figure shows the isovowel line for vowel / u/.Here the red dot which represents the mean formant frequency value of /u/ from Peterson and Barney data lies on the right side of the isovowel line for the range of formant frequency values of Malayalam English vowels.

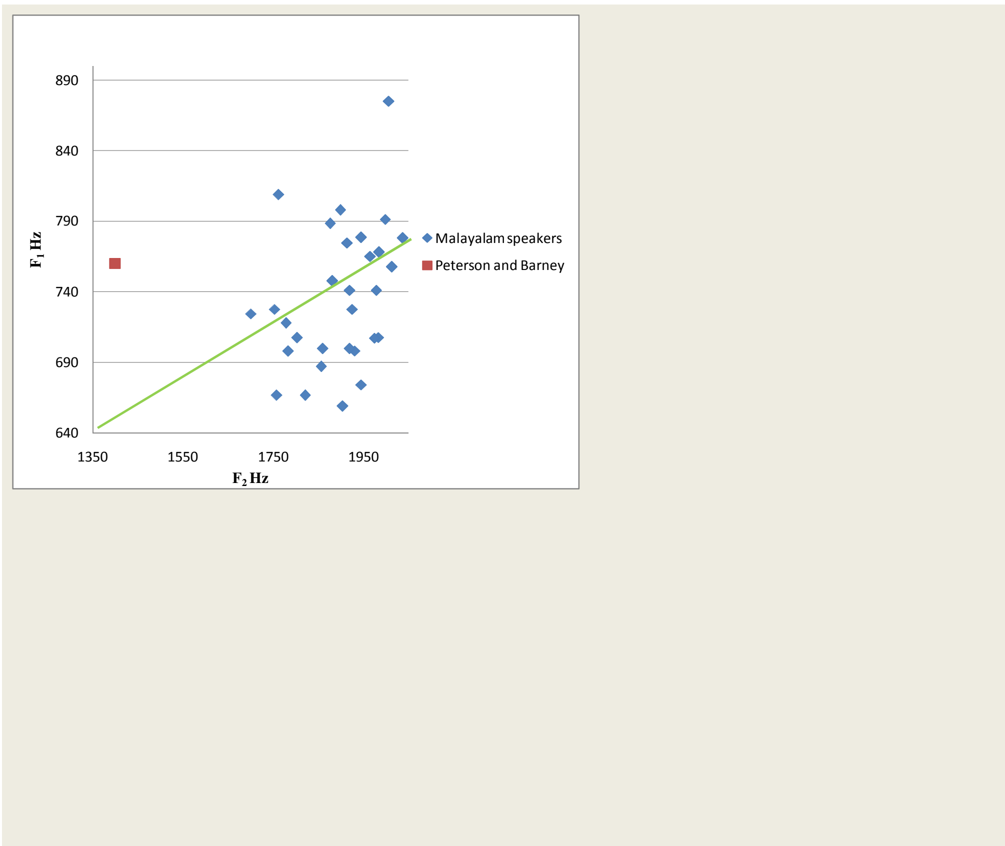

Figure 17: Isovowel line for vowel /ʌ/

The figure shows the isovowel line for vowel / ʌ/.Here the red dot which represents the mean formant frequency value of / ʌ/ from Peterson and Barney data lies far away from the isovowel line for the range of formant frequency values of Malayalam English vowels.

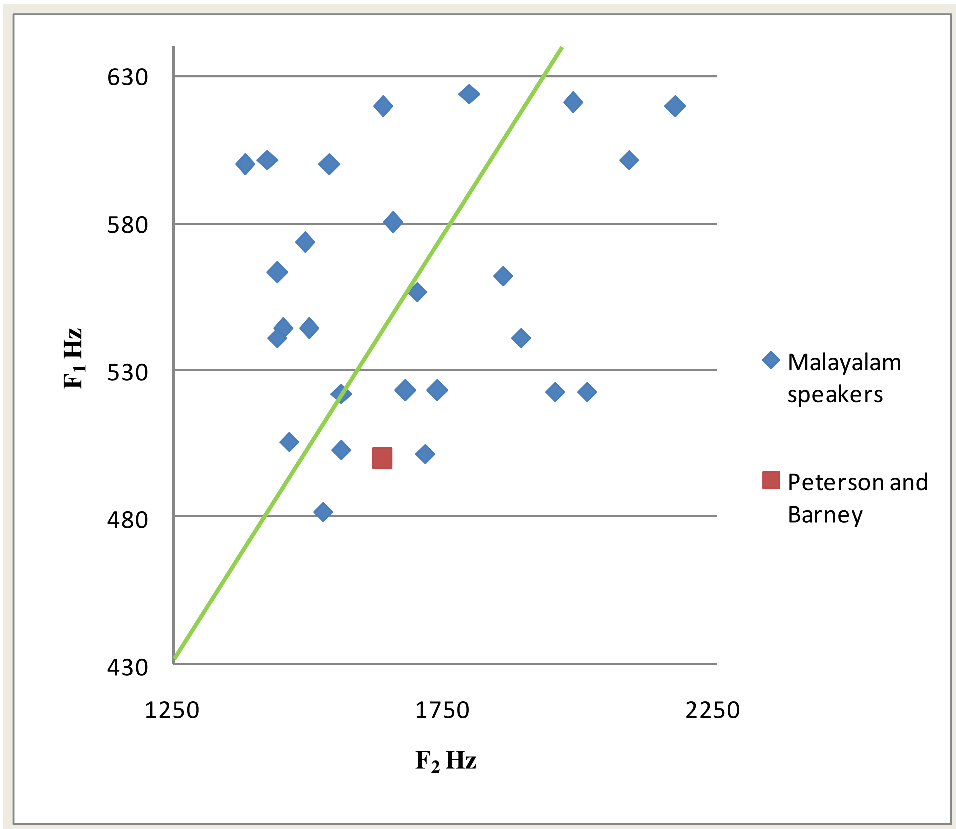

Figure 18: Isovowel line for the vowel /ɜ/

The figure shows the isovowel line for vowel / ɜ /.Here the red dot which represents the mean formant frequency value of /ɜ/ from Peterson and Barney data lies on the right side of the isovowel line for the range of formant frequency values of Malayalam English vowels.

CHAPTER V

DISCUSSION

The results indicated various points of interest. First of all, the results indicated that a significantly lower F0 in Malayalam speakers compared to American English speakers. Fundamental frequency depends on the length, tension and mass of the vocal fold. The length of the vocal fold should be proportionate to the size of the larynx which depends on the height of an individual. Based on this premise F0 in Malayalam speakers (shorter compared to English speakers) should have been higher than English speakers. However the results interestingly indicated the opposite. This might be attributed to either longer vocal folds or lowered laryngeal position.

Second, F_1 was significantly higher in Malayalam speakers compared to English speakers. F_1 is inversely proportional to the volume of the back cavity, though erroneously (Fant, 1960). It could be hypothesized that Malayalam speakers' vocal tract will be shorter compared to English speakers. Owing to the reduced height, their vocal tract will be shorter which might have resulted in higher F_1. Further, no significant difference between groups was observed on /ɛ/ and /ʊ/. These two are low vowels and hence there might not have been any significant difference. Also, F_1 is inversely related to tongue height. It could be presumed that the tongue was placed lower in Malayalam speakers compared to English speakers which might have resulted in higher F_1.

Third, F_2 was significantly lower for front and mid vowels and significantly higher for back vowels in Malayalam speakers compared to English speakers. F_2 is inversely proportional to the volume of front cavity, though erroneously (Fant, 1960). Also, F_2 is directly related to tongue fronting. Based on the results it could be hypothesized that Malayalam speakers used a back position for front and mid vowels and a front position for back vowels compared to English speakers.

Fourth, F_3 was significantly lower for high front vowels and significantly lower for all other vowels in Malayalam speakers compared to English speakers. The results of the formant frequencies are reflected in the vowel space. It appears that the tongue positions in Malayalam speakers are lower and concentrated towards the centre part of the oral tract compared to English speakers which is reflected by reduced vowel space in them.

The results indicate that there is an influence of Malayalam language on American English vowel production. The findings are in consonance with critical age hypothesis by Lenneberg, (1967) which states that that "foreign accent cannot be overcome easily after puberty". According to the critical age hypothesis it is believed that the sounds of an L2 cannot be learned perfectly once a neurologically-based critical period has been passed (Lenneberg, 1967, Patkowski, 1990, Long, 1990). The subjects selected for the present study were adult female Malayalam speakers who did not have exposure to second language English during childhood.

The native language is found to influence the pronunciation of second language which causes accented speech. This is explained on the phonetics and phonology levels of the languages spoken .i.e. cross-linguistic frequencies of certain segments, common phonological rules, and syllable structure differences between the native and target languages can affect the level of difficulty in learning the sounds of the L2 (Odlin 1989).

So the transfer of features between the languages is explained. In the present study the two language groups compared were Malayalam speakers and American English speakers. The phonetic inventories of these two languages are entirely different especially the vowel system. . The American English vowel system consists of 12 distinct vowels /i, I, e, ɛ, , æ , a , ɔ , ʊ , u, ʌ, o, ɜ / (Hillenbrand,1995) excluding the glides. The present study considered only 10 vowels from these [i, I, ɛ, æ, a, ɔ, ʊ, u, ʌ, ɜ] (Peterson and Barney, 1952). Whereas vowel system of Malayalam language has only six short vowels, /i, e, a, o, u, ə/ and six long vowels / i:, e:, a:, o:,u: / (Asher & Kumari, 1997). The findings from the present study indicated that majority of the English vowels produced by Malayalam speakers were significantly different from those of American English which was evident from the vowel space. There might exist some difficulty for the speakers of L2 language to perceive and produce the new phoneme since there is a phonological difference between the two languages and as a result, the speaker will substitute some phoneme from their native sound system to the second language (Lado, 1957). This substitution was evident from the mean values of F_1, F_2 and F_3 in majority of vowels.

According to Flege, Speech learning Model (SLM) deals with the production and perception of L2 speech sounds. SLM targets the changes that take place in the production and perception of speech sounds in people who have used L2 over a long period of time. According to this model, L1 and L2 sounds are related to one another as "position sensitive allophones." New categories are formed for the L2 sounds depending on the perceived differences between the L2 sound and the closest L1 sound. Flege proposed 'age of learning' effects on the ability to detect these differences, such that as the age of acquisition of L2 increases there are fewer chances of detecting the differences between the L1 and L2 sounds and hence, fewer chances for category formation for the L2 sounds. When new categories are not formed for similar L2 sounds, the L1 category will be used to process the L2 sounds. If this happens, the model predicts that, L1 and L2 sounds will resemble each other in production. The findings of the present study support the SLM model. The subjects were adult Malayalam speakers who got exposed to English later in life, hence one can assume that these speakers failed to detect and produce the difference between L1 and L2.

The findings of the study are also consonance with the Weinreich (1953, 1957) viewpoint that substitutions of the sounds between the two languages are based on "interlingual identification". That is, in general, L2 speakers will substitute the L1 phonemes they perceive to be most similar to L2 phonemes. It was observed that the vowels [u, I, and ʊ] were common in Malayalam and American English. However, Malayalam speakers might have substituted the English vowels by the closest in Malayalam.

The results of the present study have contributed to the literature on influence of L1 on L2. Frequencies of the first three formants of American English vowels were taken from the results of Peterson and Barney (1952). However, a control group of the English speakers would be better as it would provide the standard deviations. Future studies with a control group of English speakers and influence of various Indian languages on English are warranted

CHAPTER VI

SUMMARY AND CONCLUSIONS

The present study investigated the influence of native Malayalam Language on the English vowel production. The study compared the fundamental frequency and frequencies of first three formants of the 10 English vowels in native Malayalam speakers with those of American English speakers. The 10 vowels included were /i/, /I/, / ɛ/, /æ/, /a/, / ɔ/, /ʊ/, / u/, / ʌ/ and / ɜ/ from Peterson and Barney study (1952). These vowels were included in /hVd/ context and embedded in a carrier phrase. The carrier phrases as read by 30 female native Malayalam speakers were audio recorded and analyzed for fundamental frequency and frequencies of first three formants of the vowels.

The results indicated various points of interest. First of all, the results indicated a significantly lower F0 in Malayalam speakers compared to American English speakers. Fundamental frequency depends on the length, tension and mass of the vocal fold. The length of the vocal fold should be proportionate to the size of the larynx which depends on the height of an individual. Based on this premise F0 in Malayalam speakers (shorter compared to English speakers) should have been higher than English speakers. However the results interestingly indicated the opposite. This might be attributed to either longer vocal folds or lowered laryngeal position.

Second, F_1 was significantly higher in Malayalam speakers compared to English speakers. F_1 is inversely proportional to the volume of the back cavity, though erroneously (Fant, 1960). It could be hypothesized that Malayalam speakers' vocal tract will be shorter compared to English speakers. Owing to the reduced height, their vocal tract will be shorter which might have resulted in higher F_1. Further, the significant difference between groups was observed on /ɛ/ and /ʊ/. These two are low vowels and hence there might not have been any significant difference. Also, F_1 is inversely related to tongue height. It could be presumed that the tongue was placed lower in Malayalam speakers compared to English speakers which might have resulted in higher F_1.

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