VOWEL DURATION
IN MALAYALAM LANGUAGE

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MYSORE - 570 006
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Dedicated to

My dear Parents

for their brilliant strategies for living

Mr. C.S. Venkatesh

my beloved teacher

CERTIFICATE

This is to certify that the dissertation entitled "**VOWEL DURATION IN MALAYALAM LANGUAGE**" is the bonafide work done in part fulfilment for the Degree of Master of Science (Speech and Hearing) of the student with Register No. M 9320.

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This is to certify that the dissertation entitled **"VOWEL DURATION IN MALAYALAM LANGUAGE"** has been prepared under my supervision and guidance.

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DECLARATION

This diseration entitled **"VOWEL DURATION IN MALAYALAM LANGUAGE"** is the result of my own study undertaken under the guidance of **Mr. C.S. Venkatesh,** Lecturer, Department of Speech Science, All India Institute of Speech and Hearing, Mysore and has not been submited earlier at any University for any other Diploma or Degree.

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INTRODUCTION

"Speech is a form of communication in which the transmission of information takes place by means of speech waves which are in the form of acoustic energy. The speech waveforms are the result of interaction of one or more source with the vocal tract filter system" (Fant, 1960).

To understand the speech sounds of a language it is necessary to learn about the articulatory and acoustic nature of the speech sounds. Earlier phoneticians have described the articulatory nature of speech sounds thoroughly. However, the speech sounds are perceived by the human being as an acoustic event. These acoustic events are the consegeunce of articulatory movements. The study of acoustic characteristics of speech sounds will give information about the articulatory nature of the sound and also how these sounds are perceived (Picket, 1980).

Acoustic analysis of speech sounds provides information about the source characteristics like fundamental freguency, intensity .... etc., the filter characteristics like formant freguencies, formant bandwidths, ... etc., and the temporal characteristics like vowel duration, consonant duration, ... etc., apart from spectral characteristics.)

Duration may have different linguistic functions in different languages. In certain languages, a meaningful difference may be associated with a change in the duration of a consonant or vowel. In some languages, however, changes in the duration of a sound may be determined by the linguistic environment and may be associated with preceding or following segmental sounds, initial or final position in an utterance, or type and degree of stress. Such durational changes in turn may become cues for the identification of the asscciated phonemes (Peterson & Lehiste, 1967).

The major aims of the work on duration is to provide distributions temporal features that may be helpful in the implementation of acoustic speech recognition procedures that make use of probabilistic information on segmental tining to provide understanding regarding the speech production and for text- to-speech synthesis. Experiments with synthetic speech have shown that vowel duration is an important cue for the voicing distinction of the following consonant in word final position. One of the reguirements for natural speech synthesis rule is an adeguate durational model of human speech. An incomplete understanding of how durations vary in natural speech is one of the major failures of current efforts to make computer-generated speech more acceptable. Much of what is often termed as "machine accent" in synthetic speech is due to a faulty allocation of the time on each phoneme in an utterance. When duration is not a factor, as in simple /CV/ & /VC/ sequences, synthesizers are capable of producing very good quality speech (Peterson and Lehiste, 1967).

Describing and quantifying the effects of various factors of vowel duration leads to predictive rules that could be effectively used in speech recognition and in speech synthesis. For eg., if there are consistent and systematic temporal relationships among the various constituents of speech, these relationships could be used in speech recognition in addition to spectral clues. Further, the description of durational regularities of speech segments in the form of rules would be useful when the purpose of synthesis is to model the process of speech production and secondly, in order to generate high quality synthetic speech. Systematic and controlled studies of temporal factors of speech segments would add to the understanding of the processes of speech production (Gopal, 1987).

The speech sounds of a language are classified into vowels and consonants. Vowels are the result of interaction of minimally obstructed vocal-tract and vocal fold vibration. The laryngeal acoustic energy is modulated by various configurations of the vocal tract producing different vowels. The vowels are described basically in terms of:

a) the relative position of the constriction of the tongue in the oral cavity (front, central and back),
b) the relative height of the tongue (high, mid and low),
c) the relative shape of lips (spread, rounded and unrounded),
d) the position of soft palate (nasal and non-nasal) and
e) the phonemic length of the vowel (short and long).

The subtle differences between the vowels of different languages can be studied by subjecting them to acoustic analysis (Ladefoged, 1975). Therefore, the study of acoustic characteristics of the vowel sounds of a language became important.

The description of a sound segment for the purpose of identification and understanding may be based on the following parameters:

a) duration of the sound,
b) intensity of the sound,
c) energy (area under the intensity - time curve),
d) fundamental frequency of the sound,
e) formant pattern (F_1, F_2 , F_3 , F_4, etc...,),
f) formant structure (frequency - intensity distribution) and

g) the fine structure; referring to speech production, the source (voiced, unvoiced, mixed or silence) (Fant, 1973).

The actual duration of any particular vowel will depend on its height, its tonal or accentual properties, its position in the word, the nature of the adjoining segments, word length, grammatical complexity, speaking rate and the psychological and physical state of the individual. The theoretical motivation guiding studies of temporal aspects of speech is to quantify the effects of each of these factors acting in isolation and in interaction with other factors and to postulate hypothesis concerning the temporal organization of speech which explain the variability of speech segments (Maddieson, 1993).

Umeda (1975) suggests that these durational rules are a reflection of the performance of the speaker's control of temporal factors in speech. Mechanisms that underlie the temporal organization of speech are very complex and not fully understood (Gopal, 1987).

(vowel duration is one of the powerful factors to determine both the phonetic and phonemic quality of the vowels. The intrinsic duration of vowel refers to the duration of a segment (vowel) as determined by its phonetic quality (Lehiste, 1970). Gopal (1987) defines vowel duration as the duration from the onset of the vowel to the offset of the vowel. The onset and the offset of a vowel are determined by the presence and absence of clearly visible first two formants on the spectrogram respectively.

(In English and other Western languages several researchers have studied the acoustic characteristics of the vowels of their respective languages. There are very few studies regarding the acoustic characteristics of the vowel system of Indian languages. In Malayalam there is only one study which have made an attempt to measure the vowel duration in isolation as well as in a variety of phonemic contexts (Velayudhan, 1975).

Velayudhan (1975) studied the vowel duration of Malayalam vowels based on the utterances of only two subjects. He did not control the dialectal variations and the influence of another language on Malayalam. (Hence the present study was taken up for extensive acoustic analysis of the vowels of Malayalam language,) The language investigated in the present study is Malayalam, the official language of Kerala state, on the South - West coast of India. Malayalam is an important member of Dravidian family of languages, the other equally important members being Kannada, Tanil and Telugu.

The dialect of a language is broadly divided into regional and social. With respect to the three hundred dialectal maps of Kerala, the regional dialects are divided into twelve major divisions and thirty two subdivisions. This was based upon a study carried out on the dialect of Ezhavas. There is no assurance that other religions and castes will have the same number and boundary for the dialects (Somashekharan Nair, 1973). The present study is carried out on the Peak dialect of Malayalam language (Northern part of Cannanore district - this name is given because it is the top most part of Kerala).

Malayalam has eleven vowel phonemes; /i, i:, e, e:, a, a:, o, 0:, u, u:/ and /U/. The short vowels /i, e, a, 0, and /U/ in the word find position are a little longer than in other environments. They have half long duration in those environments which is non-phonemic. In monosyllabic words, finally all vowels are long. The short vowel /o/ does not occur in the word final position. The front vowels /i/, /e/ and back vowels /0/ and /u/ have an on glide of /y/ and /w/ respectively in the word initial position. The low back vowel /a/ has an allophone /a/, a central vowel in the medial position excepting the first syllable. This /a/ does not occur with length. /U/ occurs in the medial position in free variation with /u/. Otherwise it occurs only word finally. In addition to the above six vowels, there is a low front vowel /æ/ which occurs with length in certain loan words from English. Its distribution is limited only to medial position (Shyamala Kumari, 1972.).

"It has become the present need to study and analyze acoustic characteristics of speech sounds of Indian languages to understand the production and perception of the speech sounds in their culture" (Savithri, 1989). Hence, the present research is planned for studying the vowel duration, syllable duration, word duration and sentence duration in Malayalam language.)

Aim of the study:

a) To study the temporal parameters (duration of sentence, word, syllable and vowel) in Malayalam language.

b) To study the interaction of temporal parameters between:

   i) high, mid and low vowels,

   ii) front, central and back vowels and

   iii) long and short vowels.

c) To compare the temporal parameters between males and females.

The objectives of the present study was to determine some temporal characteristics of the vowels of Malayalam language (Peak dialect). Ten normal adults (five males and five females) having Peak dialect of Malayalam as their mother tongue were chosen for the study. The subjects uttered three groups of randomised lists of two hundred and fifty sentences in a sound treated room. These words had one of the ten Malayalam vowels in initial, medial or final position as the test vowel. These sentences had a meaningful disyllabic test word (VCV or CVCV). The following temporal parameters were measured upon acoustical analysis of the spoken sentences using DSP Sonograph i.e., duration of the vowel, duration of the syllable having the test vowel, duration of the word having the test vowel and sentence duration. The temporal features were extracted from the utterances of all the ten subjects. The data was subjected to statistical analyses using descriptive statistics, ANOVA, paired 't' tests and discriminant analysis.

Implications of the study:

Acoustic analysis of the temporal parameters of the vowels of the Malayalam language provided information regarding the acoustic description of the vowels. This data can be used to construct a guantitative perceptual model of the representation of vowels based on auditory models. This data is useful in synthesizing intelligible and natural sounding speech and recognition of the same. This can also be used in evaluating the speech deviations of hearing impaired, spastics and other patients with speech disorders.

Review of Literature

"One form of communication which people use most effectively in inter-personal relationship is speech. Through it, human beings give out their innermost thoughts, their dreams, ambitions, sorrows and joys. Without speech, they are reduced to animal noises and unintelligible gestures. In real sense, speech is the key to human existence. It bridges the differences and helps to give meaning and purpose to their lives". (Fischer, 1975).

[11] Human being is a social animal with higher cognitive and symbolic processing capabilities. These unique capabilities of human being were possible because of his ability to communicate effectively and efficiently." (Dance & Larson, 1972).

Travis (1971) defines communication as the process by which the individual interacts with his or her environment and with himself or herself. In the process of communication the individual relates and exchanges experiences, ideas, knowledge and feelings with others through symbols and transmits those symbols either through acoustical or through visual modes. For communication, human beings use several symbolic systems, eg., speech, sign language, writing, singing, morse code ....etc. Speech is one of the most commonly used and efficient modes of communication.

Skinner & Shelton (1978) define speech as the process of encoding a linguistic message by producing coded vocal patterns which carry the meaning. It is well known that no one definition can encompass all aspects of "speech" completely. According to Fant (1960) "Speech is a form of communication in which the transmission of information takes place by means of speech waves which are in the form of acoustic energy. The speech waveform is the result of the interaction of source and filter."

$$P = S * T$$

where P = Speech, S = Source, mainly glottal pulses

T = Transfer function of the vocal tract.

Thus the speech is a coded complex acoustic signal which is produced by the action of vocal tract and has an encoded linguistic message.

Speech is a unigue complex communication system observed only in human beings. According to Hockett, (1958) and Dance & Larson (1972), it has the following features:

1. Vocal-auditory channel (i.e., acoustic)
2. Broadcast transmission and directional reception
3. Rapid fading (Transitiveness)
4. Interchangeability
5. Complete feedback
6. Specialization

7. Semanticity
8. Arbitrariness
9. Discreteness
10. Displacement
11. Productivity
12. Cultural transmission
13. Duality of patterning
14. Learnability
15. Reflexivity and
16. Prevarication

Most of the features mentioned earlier are due to the acoustic nature of speech. The acoustic symbols which are used in a language for speech communication are known as "speech sounds or phonemes". More than one sound combines to form a syllable. Similarly one syllable or combination of more than one will form a word, which is considered as the minimal unit of language (Dance & Larson 1972).

To understand the nature and function of speech sounds, it is necessory to know the mechanism involved in their production. Speech production is a process where the concepts, ideas and feelings are converted into linguistic code; linguistic code into neural code; neural code into muscular (articulatory) movement and finally muscular movement leads to acoustic signal (Ainsworth, 1975). Hence, speech is just a particular type of acoustic signal and its production can be explained in terras of resonances of the vocal tract, and it can be analysed into its component frequencies by conventional methods.

The vocal tract is evolved primarily as part of the respiratory and digestive systems. The apparatus used for speech production, the vocal tract evolved primarily as a part of the respiratory and digestive systems.Human beings have learnt to use these systems to produce speech. The diagram of the vocal apparatus is given in figure 2.1. Vocal apparatus consists of the lungs, trachea, larynx, pharyngeal, oral and nasal cavities. In the process of breathing, air is drawn into the lungs by expanding the rib cage and lowering the diaphragm. This reduces the pressure in the lungs and air flows in, usually via. nostrils, nasal tract, larynx and trachea. The air is normally expelled by the same route. By contracting the rib cage and relaxing the diaphragm. This increases the air pressure in the lungs and the air flows out Human beings have learnt to use these systems to produce speech.

While speaking , the lungs are filled with air and the pressure inside the lungs is increased by the contraction of rib cage and diaphragm. This increase in pressure forces the air from the lungs to the environment. At the superior end of the trachea, there is a structure known as larynx. The larynx is a valvular system consisting of three valves. The lower most valve is formed by vocal folds and is made up of ligaments and muscles. The orifice between the vocal folds, the glottis, is opened, by the pressure of expiratory air. Once the vocal folds are opened the pressure below the vocal folds reduces due to the escape of air. As the air flows through the glottis, the subglottal pressure is reduced. The air flow from subglottal cavity to supraglottal cavity through a narrow opening, leads to a negative pressure at the glottis, and draws the vocal folds together which can explained using the Bernouli principle. The elasticity of the vocal folds also helps in drawing the vocal folds to the midline. As the vocal folds close, the pressure again builds up, forcing the folds apart and the cycle is repeated, thus the vocal folds setting into vibration. This process produces a weak quasi-triangular acoustic signal and is known as phonation. The quasi-triangular air pulses so produced excite the resonance cavities in the oral and nasal tracts. The sound will radiate from lips or from the nostrils depending upon the closing and opening of the velopharyngeal port respectively. The rate at which the vocal folds vibrate depends upon its tension, mass, length and the sub glottal air pressure. The sounds generated by the vibration of vocal folds are known as voiced sounds. The voiceless sounds, are produced by a turbulent flow of air caused by a constriction at some point in the vocal tract. This constriction may be formed by the lips, the tongue or the velum. Another source

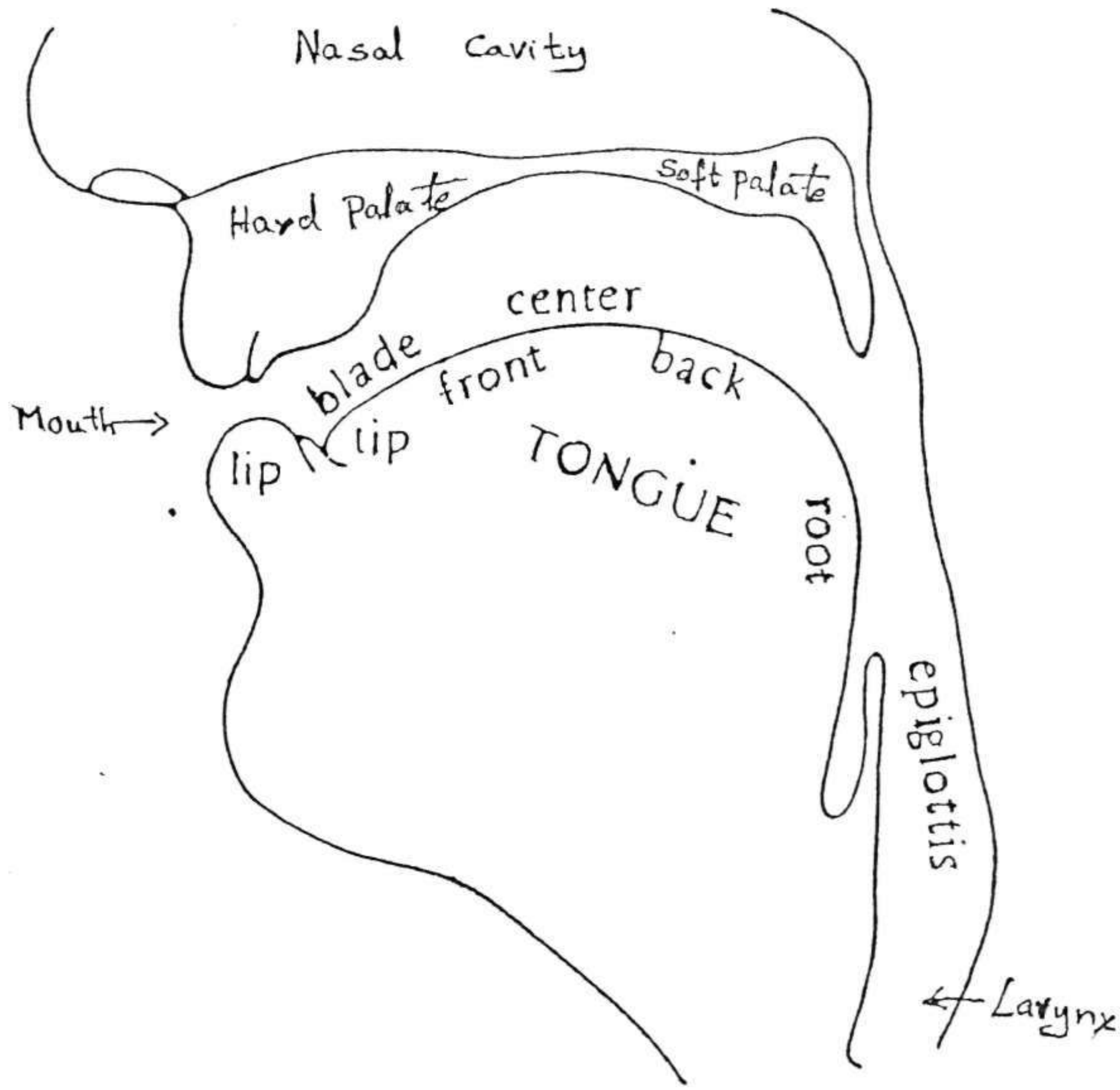


Fig 2.1 : The vocal apparatus.

of excitation can be created by closing the vocal tract completely or partially at some point, allowing the pressure to build up, and then suddenly releasing it or creating the friction of air. This form of excitation is employed in the production of plosive or fricative consonants. Whispered speech is produced by partially closing the glottis so that the turbulent air flow replaces the periodic excitation during voicing.

The modulated or unmoduleted airflow through the glottis is further modified by the vocal tract to form speech sounds, which are mainly divided into vowels and consonants. The production of these sounds are explained below briefly.

Production of Vowels:

The vowels are produced by voiced excitation of the vocal tract. For the production of a vowel the vocal tract normally maintains a relatively stable shape and offers minimal obstruction to the air flow. This facilitates the laminar flow of glottal pulses through the vocal tract. During the production of vowels in English and Kannada (an Indian language), the velum is normally elevated to prevent the excitation of the nasal tract. In some languages such as French, the vowel nasalization is phonemic in nature.

The vocal tract may be considered to be a tube of about 17 cm long, closed at the source end (the glottis) and open at the radiatory end (the lips). The cross sectional area of the vocal tract is small compared to its length, so acoustic waves propagate longitudinally in the tract. These waves may be described by the sound pressure (p), and the volume velocity (u), as functions of distance along the tract from the glottis.

The effect of the open end on the sound in the tube can be represented by the radiation impedance. At low frequencies this consists of a resistance pc/A in parallel with an acoustic mass, $m = 0.4\ p\ A^{1/2}$, where A is the cross-sectional area, p the density of the air and c the velocity of sound (Stevens & House, 1961).

If Pr is the pressure at the distance r from the mouth and u_0 is the volume velocity at the mouth opening, then the radiation of the sound from the mouth is given by:

$$R_{(jw)} = p_r\ (jw)\ /\ u_o(jw)$$

where $w = 2\pi f$ is the radian frequency of the sound. For a point source, it has been shown by Morse, (1948) that

$$R(jw) = jwp/4\pi r$$

The transfer function of the vocal tract is given by

$$T(jw) = u_o(jw) / u_s(jw)$$

where u (jw) is the volume velocity of the source. Hence the sound pressure at a distance r from the lips during the production of vowel can be considered as the product of the volume velocity of the source, transfer function of the vocal tract and the radiation of the sound from mouth.

$$p_r(jw) = u_s(jw) * T(jw) * R(jw).$$

The different vowels are produced by changing the articulatory configuration which change the transfer function of vocal tract T(jw). The vocal tract during the production of vowel is similar to the one end closed rigid tube that can

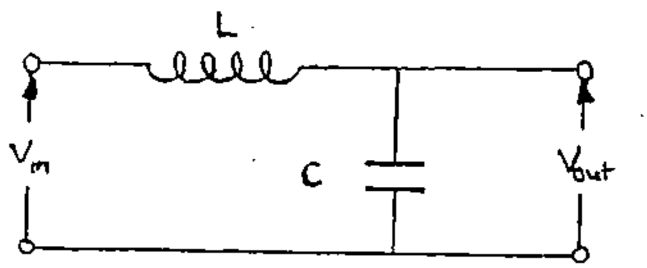


Fig. 2.2: Electrical eguivalent of a lossless resonator

be considered as a loss - less resonator represented by a capacitance, C, and inductance, L, in parallel as shown in Fig 2.2. This will have a resonance at a frequency Fl, & F1 is $F1 = \frac{1}{2} \pi \sqrt{LC}$.

Flanagan (1965) has shown that for a uniform tube of length 1 and cross-sectional area A.

$C = Al/pc^2$ and $L = p^l/A$.

In a real physical system there will be losses through the walls of the vocal tract. The transfer function is then given by:

$$T(jw) = \frac{s_1 s_1^*}{(j\omega - s_1)(jw - s_1^*)}$$

where $s_1 = \sigma_1 + jw_1$, $s_1 = \sigma_1 - jw_1$, $w_i = 2\pi F_1$, and σ_1 is a constant which depends on the amount of dissipation. The complex numbers s_1 & s_1 are the poles of the transfer function.

Vocal tract is not a simple resonator. It is more like a transmission line. The wave is reflected back from the opening at the mouth, interfering with the wave from the source. Such a system has an infinite number of resonances with the transfer function given by:

$$T(jw) = \frac{s_1 s_1^*}{(jw - s_1)(jw - s_1^*)} \quad \frac{s_2 s_2^*}{(jw - s_2)(jw - s_2^*)} \quad \frac{s_n s_n^*}{(jw - s_n)(jw - s_n^*)}$$

where $s_1 = \sigma_1 + jw_1$, etc., are the poles of the function (Fant 1960) .

For a uniform tube, open at one end and closed at the other, the modes of vibration are shown in Fig 2.3. The wavelength (λ) of each mode is given by

$$\lambda = 4l/(2n+1).$$

Now $\lambda = c/f$, so $f_n = (2n+1)c/4l$.

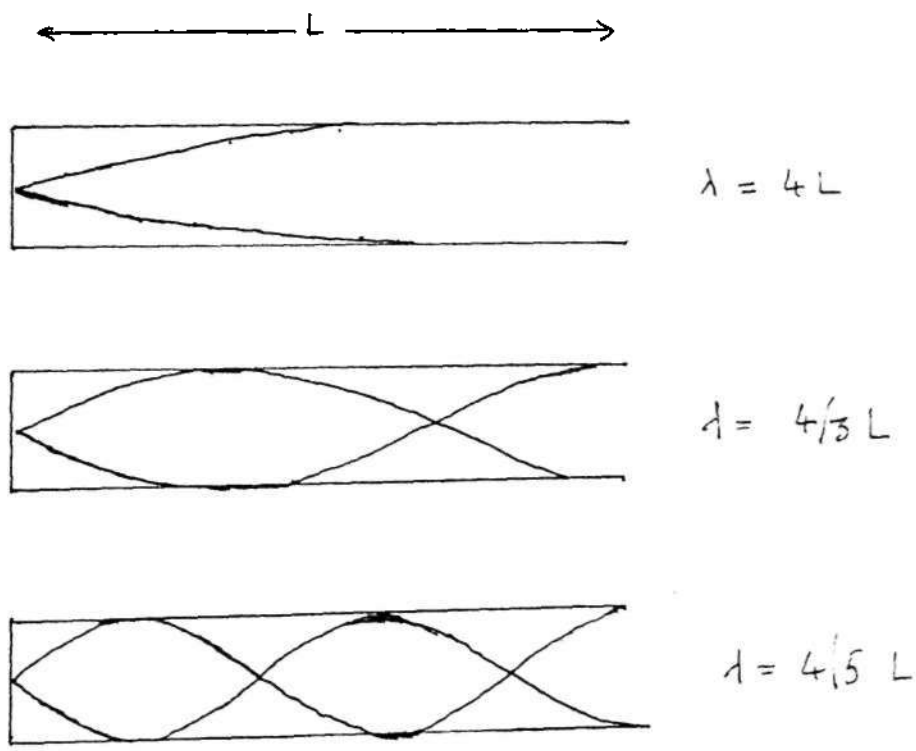


Fig 2.3: Resonances in a uniform tube, open at one end and closed at the other.

The vocal tract in the production of neutral vowel /a/ has configuration similar to a uniform tube. Therefore, its resonances are about 500, 1500, 2500 and 3500 Hz. The energy spectrum of the source falls with increasing frequency by about 12 dB/octave, so only the first few resonances can be observed in the waveform.

Tosi (1979) defines vowel "as a continuant sound (it can be produced in isolation without changing the position of articulators), voiced (using the glottis as the primary source of sound), with no friction (noise) of air against the vocal tract." In other words, vowel "is a speech sound resulting from the unrestricted passage of the laryngeally modulated air stream, radiated through the mouth or nasal cavity without audible friction or stoppage" (Nicolosi, Harryman, & Kreshech, 1978) . Vowels are described in terms of:

(a) the relative position of the constriction of tongue in the oral cavity (front, central and back),
(b) the relative height of the tongue in the oral cavity (high, mid, and low),
(c) the relative shape of the lips (spread, rounded and unrounded),
(d) the position of the soft palate (nasal and oral),
(e) the phonemic length of the vowel (short and long) and

(f) the tenseness of the articulators (lax and tense).

Consonants are defined as the speech sounds produced with or without vocal fold vibration, by certain successive contractions of the articulatory muscles which modify, interrupt, or obstruct the expired air stream so that its pressure is raised and facilitates the production of burst or frication, etc., (Nicolosi, Harryman, & Kreshech, 1978). Consonants are described based on:

(a) the manner of articulation (stop, fricative, affricate, glide, trill,... etc.).

(b) the place of articulation (bilabial, dental, alveolar, retroflex, velar....etc.).

(c) role of vocal folds (voiced and voiceless)

(d) the position of the soft palate (nasal and oral),

The function of the vowels can be divided into linguistic and nonlinguistic.

1) Vowels are the segmental sounds of speech. They carry information.
2) As the vowels are longer in duration and higher in energy, they carry the speech for a longer distance, i.e., in speech transmission the vowels acts like carriers.
3) Even though the consonants carry more information, due to their nonlinearity, shorter duration and low energy they

dimmish very fast. Hence it is difficult for the listener to perceive them. Vowels like a string binds the consonants together and helps even in the perception of consonants and thus speech.

4) As the vowels are voiced and of longer duration, the speech prosody (intonation, stress and rhythm) is determined by the vowels.

5) The voicing feature of the vowels can reveal:

   (a) the speaker identity,

   (b) emotions,

   (c) some aspects of semantic condition and

   (d) serve aesthetic function.

Cardinal Vowels:

Jones (1849) proposed a series of eight cardinal vowels, evenly spaced around the possible vowel area and designed to act as fixed reference points. The quality of a cardinal vowel is not commonly the same as that of an English vowel. There may be a few languages which have vowels, identical to the cardinal vowels. For example, French vowels are similar to cardinal vowels. But by definition the cardinal vowels are arbitrary references.

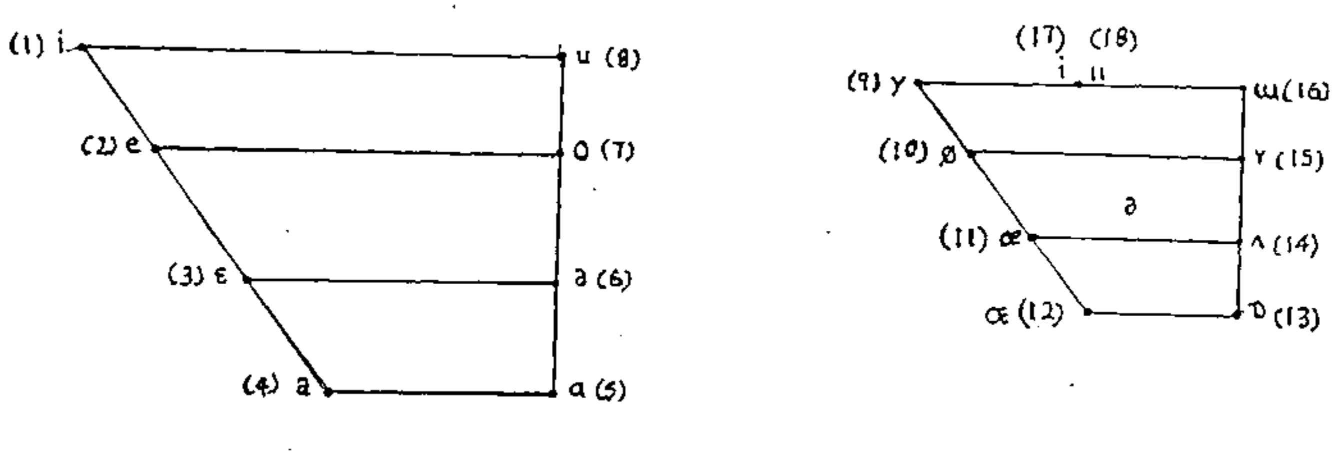


Fig. 2.4: Primary and secondary cardinal vowels.

There are two sets of cardinal vowels named primary and secondary cardinal vowels. The vowel chart of primary and secondary cardinal vowels are shown in the figure 2.4. The vowels of English and Kannada languages are explained briefly.

Vowel System of American English

MacKay (1987) and Ladefoged (1975) listed and described the following 14 vowels in American English. They are:

	Vowel	Description
1.	[i]	high, front, tense (spread)

2.	[I]	high, front, lax (unrounded)
3.	[e]	(upper) mid, front, tense (unrounded)
4.	[ɛ]	(lower) mid, front, lax (unrounded)
5.	[æ]	low, front (unrounded)
6.	[u]	high, back, tense (rounded)
7.	[ʊ]	high, back, lax (slightly rounded)
8.	[o]	upper mid, back (rounded)
9.	[ʌ]	lower mid, back (or central) unrounded
10.	[ɔ]	lower mid, back, rounded
11.	[a]	low, back (unrounded)
12.	[ə]	mid central
13.	[ɚ]	central, rhotic (unstressed)
14.	[ɝ]	central, rhotic (stressed).

Vowel System of Malayalam Language:

Malayalam is one among the four important Dravidian languages, which is spoken predominantly in South India. It has eleven vowel phonemes; /i, ii, e, ee, a, aa, o, oo, u, uu/ and /U/. The short vowels /i, e, a, o/ and /U/ in the word final position are a little longer than in other environments. They have half long duration in those environments which is non-phonemic. In monosyllabic words, finally all vowels are long. The short vowel /o/ does not occur in the word final position. The front vowels /i/ and /e/ and back vowels /o/ and /u/ have an onglide of /y/ and

/w/ respectively in the word initial position. The lew back vowel /a/ has an allophone /ə/, a central vowel in the medial position excepting the first syllable. This /a/ dees not occur with length. /U/ occurs in the medial position in free varaiation with /u/. Otherwise it occurs only word finally. In addition to the above six vowels, there is a low front vowel /æ/ which occurs with length in certain loan words from English. Its distribution is limited only to medial position (Shyamala Kumari, l982) .

The detailed description of the vowels present in the Peak dialect of Malayalam are given below.

[a] is a short low central vowel.
[a:] is a long low central vowel.
[i] is a short high front unrounded vowel.
[i:] is a long high front unrounded vowel.
[u] is a short high back rounded vowel.
[u:] is a long high back rounded vowel.
[e] is a short mid-front unrounded vowel.
[e:] is a long mid-front unrounded vowel.
[o] is a short mid-back rounded vowel.
[o:] is a long mid-back rounded vowel.

To understand the speech sounds of a language it is necessary to learn about the articulatory and acoustic nature of the speech sounds. Earlier, phoneticians have described the articulatory nature of speech sounds thoroughly. However the speech sounds are perceived by the human being as an acoustic event. These acoustic events are the consequence of articulatory movements. Hence the study of acoustic charateristics of speech sounds will give information about articulatory nature of the sound and also how these sounds are perceived (Picket, 1980). Fant (1973) stated that the description of a sound segment for the purpose of identification and understanding may be based on the following parameters:

(a) duration of the sound,
(b) intensity of the sound,
(c) energy (area under the intensity - time curve),
(d) fundamental frequency of the sound,
(e) formant pattern (Fl, F2, F3, F4, etc.,),
(f) formant Structure (Frequency - intensity distribution) &
(g) the fine structure; referring to speech production, the source (voiced, unvoiced, mixed, or silence).

Hence, the present study was aimed at studying the intrinsic duration of the vowels of Malayalam language and other segmental durations.

VOWEL DURATION

"Duration is an important aspect of the message comprehended. Several studies on the durational structure of speech sounds have conducted which reveal marked variations as well as snail variations in the segmental duration" (Carlson & Grar.strom, 1975).

"Variations in segmental duration are important causes of acoustic variability in the realization of linguistically identical units. Study of the systematic variations in vowel duration may possibily reveal some aspects of the organization in the mental structures of language, particularly those that are not studied by the conventional methods of linguistics. Physical measurement of acoustic aspects of speech production indicate the regularities in the timing of speech. These regularities are found to be language specific and thus reflect learned aspect of verbal behavior. A study of such regularities may lead to the formulation cf rules which form the model part of the knowledge, the speaker has about his language. The physical measurement would be the best way to gain insight into the structure of language" (Nooteboom, 1973).

Further, data on duration can be used to understand the nature and organization of speech production, speech perception and phonological theory (Khozhevnikov & Chistovich, 1965). The durational patterns reflect the speakers mood, speaking rate and the locations of the emphasized material. The phonetic identity of different types of segments is cued by their duration (Klatt, 1976). Perceptual studies of natural and synthetic speech that have been altered with regard to temporal aspects indicates that the listener can perceive very small changes in segmental duration as deviant (Huggins, 1972 and Nooteboom, 1971). Duration also plays an important role in speech perception also. The speech sounds heard, are determined by the duration of gradually changing speech acoustic events such as formant transitions (Liberman, Delattre, Gerstman & Cooper, 1956 and Suzuki, 1970). It has been shown that duration can effectively disambiguate, syntactically ambiguous sentences even in the absence of clues provided by fundamental frequency and pauses (Lehiste, Olive & Streeter, 1976).

Among segmental durations "vowel duration" is an important parameter which provides information on the prosodic as well as linguistic aspect of speech. Vowel duration can be used to signal the stressed syllable (Fry, 1955); mark the word boundaries (Lehiste, 1959); identify the syntactic units (Gaitenberg, 1965) and to distinguish between similar phonetic segments (Denes, 1955 and Lisker & Abramson, 1964).

In addition, durational data is of immense use in applied research, viz; automatic generation of speech for a reading machine for the blind and the automatic recognition of speech from the acoustic waveform. Thus it is essential to study vowel duration to understand the speech production, perception and the language structure.

The term intrinsic duration of vowel refers to the duration of a segment (vowel) as determined by it's phonetic quality (Lehiste, 1970). Gopal (1987) defines the vowel duration as the duration from the onset of vowel to the offset of the vowel. The onset and the offset of a vowel are determined by the presence and absence of clearly visible first two formants on the spectrogram, respectively.

Many have investigated the duration of these vowels and quantified the relationship between different subclasses of vowels in many languages. It was found that there was an invariant relationship between tense and lax vowels across several contexts that influence the vowel duration, while others did not find such a relation. In English - Heffner (1937); House & Fairbanks (1953); Peterson & Lehiste (1960);

House (1961); and Umeda (1975); in German - Maack (1949); in Danish - Fischer Jorgensen (1955); Nooteboom (1972); in Swedish - Elert (1964); in Thai - Abramson (1962); in Spanish Navarro Tomas (1916) and in French -O'Shaughnessy (1981) have studied the vowel duration. There are only few studies in Indian languages. The studies carried out in Indian languages are: in Telugu by Majumder, Datta & Ganguli (1978) and Nagamma Reddy (1988); in Tamil by Balasubramanian (1981); in Malayalam by Velayudhan (1975); in Hindi by Agrawal (1988); and in Kannada by Rajapurohit (1982); and Savithri (1986, 1989). These studies had varied purposes; i.e., to know:

(1) the durational organization of speech segments,

(2) physiologic vs linguistic nature,

(3) factors that influence the duration and

(4) to incorporate the durational rules of vowels in speech synthesis to improve its quality.

Peterson & Lehiste (1960) investigated the intrinsic duration of vowels in American English. They also studied the influence of postvocalic voicing on vowel duration and compared the differences in the intrinsic nucleus duration for various vowels. They defined intrinsic nucleus duration as ". . . . .the average duration of respective minimal pairs (of following voiced and voiceless consonants)" (Peterson &

Lehiste, 1960). They found that the nuclei could be divided into two main subclasses, long or tense vowels (symbolized as V: from here on) and short or lax vowels (symbolized as V from here on), although the relationship between the two subclasses was not guantified. They also found that there was an overlap in the duration between the tense and lax vowel types when the durations of the two were compared across the several consonantal contexts.

(House (1961) studied the duration of twelve American English vowels occurring in fourteen symmetrical consonantal contexts. The vowels and consonants formed the second syllable of a bisyllabic nonsense word of the form /he CVC/. The vowel duration measured from three speakers showed that some vowels could be classified in contrastive long-short pairs or tense-lax pairs, for eg., /i/ vs /I/; /u/ vs /U/; /a/ vs /ʌ/; and /ɔ/ vs /o/. He found that the long vowels were, on an average, 100 ms longer than the short vowels. His data also showed that the difference between tense and lax vowels varied as a function of voicing and the manner of articulation of following consonants. For instance, the difference between tense and lax vowels amidst voiceless stop consonants was about 30 ms, amidst voiced stop was about 80 ms and amidst voiced fricatives was about 120 ms. Not only did the duration difference vary across consonantal contexts, but so did the ratio of V/V:

Sharf (1964) observed that tense vowels were longer than lax vowels in both normal and whispered speech. In normal speech, the tense vowels were 258 ms. and the lax vowels were 185 m.s., a difference of 73 ms., and in whispered speech they were 321 ms and 238 ms. respectively, a difference of 83 ms. Using Stetson's (1951) theory to explain the durational difference between tense and lax vowels as being physiological, Sharf (1964) argued that ".... it is possible that linguistic structure is a precipitating factor in producing differences in vowel duration between tense and lax vowels and that dynamic properties of the speech system have acted as a perseverant factor".

In a series of studies, Nooteboom (1972a, 1972b) investigated various intrasyllabic factors that influenced vowel duration in Danish language, particularly the influence of phonological length and the influence of vowel height. He found that long vowels /o:, e:, o:, a:/ were consistently longer than the short vowels. However, Nooteboom (1972) also reported that the absolute difference in duration as well as the durational ratio between the short and long vowels (V/V:) varied depending on the position in the word and the presence or absence of lexical stress. In trisyllabic nonsense words of the type /pVpVpV/ with stress on second syllable, he found that the absolute difference between the short and long vowels was 15 ms, 40 ms and 50 ms for the three positions respectively. Further more, the ratio of V/V: was 0.85, 0.65 and 0.70 for the three positions respectively. Thus, neither the absolute durational difference nor the V/V: ratio remained constant in Danish language.)

Stalhammar, Karlsson & Fant (1973) and Fant, Stalhammar & Karlsson (1974) studied the duration of short and long vowels in stressed and unstressed conditions, occurring in isolation, in a /h V 1/ and in connected speech of Swedish language. They found that the durations of long vowels did not change much between isolated condition (350 ms) and monosyllabic context (315 ms), but changed markedly from monosyllabic to connected speech (120 ms). The average V/V: (stressed) ratio was 0.60 in monosyllabic context and 0.75 in connected speech. Unstressed vowel durations could be best represented by the following equation:

V(short) = 30 + 0.5 * V(long); for values of long vowels not less than 60 ms, averaged across all the contexts. At values of 60 ms, there was no difference between stressed long and short vowels. These researchers suggested that there existed an invariant linear relation between long and short vowel durations.

Lindblom (1964, 1968, 1970, 1973) and Lindblom & Rapp (1972, 1973) studied some of the intra and inter-syllabic variables to determine segmental durations in Swedish and postulated a theory of segment duration. The material used consisted of both nonsense and meaningful words, with increasing word length, which were embedded in a carrier phrase. There was no control of speech tempo although the investigators observed that ". . . . subjects pronounced test phrases at fairly regular interval of 3-4 seconds" (Lindblom & Rapp, 1972).

Phonological length was reported to be a major determinant of vowel duration. Initially using single subject, Lindblom & Rapp (1972, 1973) reported that the relationship between the short and long vowels could be represented by a simple constant, V/V: = 0.75. However, using data from other speakers they found that this relationship was better represented by the following eguation:

$$V\ (short) = K * V\ (long) + L$$

where K is the relationship factor (or slope) and L is the intercept. The durations calculated were for lexically stressed vowels. The slope and intercept varied for different contexts. For example, the slope for the context /s/ was 0.48, with an intercept of 52 ms; and for the context /n/ was 0.71 with an intercept of 5 ms. Thus the slopes and the intercepts were not invariant across contexts. The form of the relationship stayed the same but not the relationship itself. They also noted that the ratio of V/V: was not a simple constant across all conditions but tend to increase as absolute durations became smaller.

Although the findings for the Swedish vowels seem to be in conflict with one another, they are not. While the studies of Stalhammer et. al., (1973) and Fant et. al., (1974) reported an invariant relationship between the two vowel types, they were not referring to consonantal contexts. Their major goal was, "... to quantify general trends without going into details, such as the influence of the immediate consonantal frame...." (Stalhammer et. al., 1973). Thus their findings were based on an equation that best fit to the observed vowel durations which were averaged across various contexts and speakers. On the other hand, the series of studies by Lindblom (1973) and Lindblom & Rapp (1972, 1973) reported on the specific consonantal contexts and found that this relationship was not constant but varied depending on the contextual factors.

Games (1974a) has studied vowel quality in Icelandic language and she has also examined the durational relationship between long and short vowels in monosyllabic and disyllabic conditions, with the varied voicing and manners of articulation of the following consonant. She found that the duration of short allophones in both monosyllabic and bisyllabic situations constituted one half of the duration of long allophones, maintaining a ratio of 1:2 regardless of absolute durations, segmental environment and the syllable structure. However, this observation was based on a small number of tokens (i.e., 5) of each vowel and this relationship was an average across all of the long vowels and averaged across different consonants. Gopal (1987) with reference to the study by Games (1974) commented that the relationship for each long - short vowel pair specifically for each of the consonantal contexts separately, had not been considered. Individual long - short pair relationships for specific contexts may be quite different from averaged ones. Thus this notion of invariance may well be questioned. More importantly, these findings were based on the data collected from one speaker. Thus its generalization is highly questionable (Gopal, 1987).

It is widely accepted that the tense vowels are relatively longer than lax vowels. Since the approximate configuration for tense vowels is said to require a longer period than that for lax vowels (Mitleb, 1984).

Maddieson (1993) carried out a study on vowel duration in LuGanda language. He found a significant difference between the short vowel, compensatorily lengthened vowels and long vowels. However, the compensatorily lengthened vowels were much closer to the duration of the long vowels than to that of the short vowels. Both lengthened and long vowels were twice in their length when compared to the short vowels, whereas a lengthened vowel is only 40 ms shorter than a long vowel and has 80% of its duration. The mean duration of the compensatorily lengthened vowel in words was 191 ms, whereas that in short vowel words was 73 ms and that in long vowel words was 237 ms.

Maddieson (1993) also carried out a study on vowel duration in Sukuma language. The results were almost similar to LuGanda except for that "the surface durational patterns were different. The compensatorily lengthened vowels fell almost halfway between the duration of the long and short vowels, in fact, the mean for lengthened vowels was slightly closer to the duration of short vowels. The mean duration of the compensatorily lengthened vowel in words was 200 ms, whereas that in short vowel words was 129 ms and that in long vowel words was 280 ms. Tne long vowels were over twice the length of short vowels in this data, but lengthened vowels were only about one and half times the length of short ones.

Mc Donough, Ladefoged & George (1993) carried out a study on Navajo vowels and the results revealed that Navajo speakers made very clear distinctions between long and short vowels, at least when producing citation forms. Short vowels were less than half (114 ms in females and males) the length of long vowels. (266 ms in females and 264 ms in males).

Shalev, Ladefoged, & Bhaskararao, (1993) carried out a study on the phonetic properties of Toda, which is spoken by about 1,000 people in the Nilgiri Hills in Southern India. They found that the mean duration of short vowels was 68 ms and that of long vowels, 139 ms. The short-long ratio was therefore 1:2.04, or slightly more than 1:2. Engstrand & Krull (1994) conducted a study on the duration of vowels in Swedish, Finnish and Estonian languages and found short and long vowel contrasts, similar to the earlier studies.

The relationship between short and long vowels may be language dependent. In some languages, it may be invariant across contextual influences, whereas in other languages it may vary as a function of various other factors. The findings of Games (1974) for Icelandic vowels could be considered as a support to an invariant relationship. She found this relationship to be a constant across segmental environments and the structure of the syllable. It would be interesting to see whether this ratio truly remains a constant when individual long-short vowel pairs are compared for each consonantal context and across other determinants of vowel duration such as speaking rate, word length, sentence length and prosody. Thus the inferences of invariance by Games (1974) has to be treated with caution.

On the other hand the findings of Nooteboom (1972a, 1972b) for Dutch vowels which showed differences in absolute durations and also in ratio between the two vowel types remained variant across stress and position within the word. This observation by Nooteboom (1972) argues against invariance of vowel duration, at least in Dutch. Similar observations can be made about Swedish vowels (Lindblom, 1973 and Lindblom & Rapp 1973, 1974) as well as the American English vowels (House, 1961). While comparing specific tense-lax vowel pairs in the studies by Lindblom (1973); and Lindblom & Rapp (1973, 1974), the vowel durations were based on averages of all tense verses all lax vowels. Unless specific long-short vowel pairs are compared between specific consonantal contexts while controlling the influence of other factors, generalization based on the above studies ought to be treated with care.

FACTORS INFLUENCING DURATION OF VOWELS IN SPEECH PRODUCTION:

Durations of different segment vary widely depending upon several factors. Klatt (1976) classified these factors as:

1. Extralinguistic factors
2. Discourse level factors
3. Semantic factors
4. Syntactic factors
5. Phonetic factors and
6. Physiological factors.

1. **Extralinguistic Factors**

Under the extralinguistic factors, Klatt (1976) includes speakers mood, their physical condition and speaking rate. Further age and sex seems to influence the duration of vowels.

a. Speakers mood and physical condition: Speakers mood and physical conditions affect the durational patterns largely. Williams & Stevens (1972) have shown that actors, attempting to simulate various emotional states, speak differently under different emotional conditions. They speak very slowly when angry and slower than normal when expressing fear or sorrow.

b. Speaking rate: Researchers have studied the influence of speaking rate on long and short vowel types. Some of them have reported, that the two vowel types behaved differently with changes in the rate where as others found no difference between the two.

Change in speaking rate tend to change the durational patterns. For example it has been shown that a good fraction of the extra duration goes into pauses when speakers slow down (Goldman-Eisler 1968). Huggins (1964) showed that an increase in speaking rate shortened the vowels and consonants. Increase in speaking rate was also accompanied by phonological and phonetic simplifications.

Peterson & Lehiste (1960) observed that the changes in speaking tempo had little effect on the duration of stressed syllable nuclei. In a sub-experiment they found that syllable nuclei that were inherently longer in duration compresses less than the nuclei that were shorter in duration when the speaking rate increases. "...However, the notion that longer duration segments (stressed nuclei) compress less than the shorter duration segments is in direct contradiction to Klatt (1973), who just found the reverse" (Gopal, 1987). The main difference between Klatt's (1973) and Peterson & Lehiste's (1975) study was that Klatt did not investigate compression brought about by changes in speaking rate. He used increasing number of syllables to bring about a reduction in vowel duration.

Gay (1974) stated that the consonantal gestures were strengthened when the speaking rate was increased because of the complex reorganization of the motor commands to the articulators. However, the motor commands for vowels were not enhanced.

Gay (1978) investigated the effects of speaking rate on changes in the duration of nine vowels in four native American English speakers. He used utterances of the type /PVP/ in a carrier phrase, "It's a_______again". He found that as the speaking rate increased, durations of all vowels decreased for all speakers. Using percent change in vowel duration from one rate to other, Gay (1978) studied whether there were any systematic differences between long (/i:/, /ae /, /a// /u/) and short (/I/, /ʌ/, /ɔ/, /ʊ/) vowels. He found that the percent change was same for both vowel types (approximately 0.20 to 0.25), and concluded that there were no systematic differences in the amount of compression between the long and short vowels across rates.

Table 2.1: Comparison of mean vowel durations from different rates for different studies.

Peterson and Lehiste (1960); n=5				(averaged across voiced and voiceless contexts)			
	slow	Fast	(f/s)		Slow	Fast	(f/s)
/i/	207			/l/	161		
/ae/	284			/E/	204		
/u/	235			/u/	163		
Gay (1978); n=4				(Voiceless context)			
	Slow	Fast	(f/s)		Slow	Fast	(f/s)
/i/	120	90	(0.75)	/I/	105	85	(0.81)
/ae/	155	125	(0.81)	/E/	130	105	(0.81)
/a/	145	155	(0.79)	/A/	115	85	(0.74)
/u/	120	90	(0.75)	/U/	110	90	(0.82)
Crystal and House (1982); n=7							
	slow	Fast	(f/s)		slow	Fast	(f/s)
Long	141	115	(0.82)	Short	79	61	(0.85)
Port (1981); n=5				(voiced context)			
	Slow	Fast	(f/s)		Slow	Fast	(f/s)
/i/	122	83	(0.68)	/I/	80	61	(0.77)
				(voiced context)			
	Slow	Fast	(f/s)		Slow	Fast	(f/s)
/i/	105	69	(0.74)	/I/	78	61	(0.89)
Gopal and Syrdal (1984); n=10				Voiced context)			
	Slow	Fast	(f/s)		Slow	Fast	(f/s)
/i/	230	99	(0.43)	/I/	176	78	(0.44)
/ae/	263	120	(0.46)	/E/	179	87	(0.49)
/a/	260	119	(0.46)	/A/	182	87	(0.48)
/u/	249	108	(0.43)	/u/	178	86	(0.48)

Crystal & House (1982) investigated segmental duration and their distribution in connected speech, in an attempt to establish probabilistic rules that could be applied in the identification of speech segments and classification of phonetic categories. They studied the durational pattern of various segments between two speaking rates using only a subset of sentences. In describing the durational behaviour of the segments, they did not control for effects of stress, intonation, position... etc. They found that there were no differential effects of rate on various categories of speech.

Port (1981) investigated the interaction of postvocalic consonant voicing and vowel length, across varying word length and changes in tempo. She found that with 28% change in speaking tempo from slow to fast, as measured by the compression in the sentence duration, the long and short vowels behaved differently with changes in speaking rate for both voiced and voiceless situations. In general long vowels were compressed more than the short vowels and the effect seemed to be more pronounced in voiced context. Her findings favoured the hypothesis that "there was differential behavior of long and short vowels across the changes in tempo". However, this was contrary to the findings of Gay (1978) who did not find a difference in the amount of compression between two vowel types.

Gopal & Syrdal (1984) found that the vowel durations of fast and slow speakers changed from 40% to 50%. Gopal (1990) investigated the effects of speaking rate on the durations of four pairs of American English tense and lax vowels (i-I, ʌ - a, ɛ-) , u-U) in four different consonantal contexts (t, d, s, z) using seven subjects. Results showed that the durational behaviour of tense and lax vowels as a function of rate was context dependent. It followed one of the two broad patterns (i) in certain contexts most of the tense-lax vowel pairs maintained a constant absolute durational difference across different rates and (ii) in other contexts the change in the tense vowel durations as a function of rate was significantly different from their lax vowel counter-parts, so that the vowels maintained neither an absolute duration difference nor a consonant proportional relationship. Gopal & Syrdal (1984) stated that his results could support partially additive and incompressibility models. He also stated that none of the models were able to capture the durational behaviour of these vowels as a function of rate and this suggests a speech timing system that is more complex than the present models proposed (Gopal, 1990). There are no studies which have investigated the influence of rate of speech in Indian Languages.

c. Age: According to Di Simoni (1974), the mean duration of vowels in the voiceless consonant environment remains constant, whereas that in the voiced consonant environment increased with the age of the speaker. He also found that the variation (i.e., standard deviations) in vowel duration tends to become smaller as a function of age, indicating less speaker variability. The results of this study indicate that the observed vowel durational variations due to consonant environment develop over a long period of time. Durational differences already begin to emerge by age three years, although the differences do not reach statistical significance until the age of six years. The developmental period in which the most rapid rates of change occur was identified as three to six years of age. Sweetings (1980) found that the vowel duration increased with the age of the speaker.

d. Sex: Zue & Lafferiere (1979) observed that longer vowel durations characterized female speech. This phenomenon was also observed by Savithri (1983,1986), in Sanskrit and Kannada languages. Mc Donough, Ladefoged & George (1993) carried out a study on the vowels of Navajo language and found that there was no significant difference between males and females with respect to vowel duration.

2. Discourse Level Factors

The duration of the final sentence of a read passage will be longer than the non-final sentence of the passage. (Klatt, 1976). It has been observed by Klatt (1976) that the vowel duration has primary importance only in phrase final environments. The final syllable of the sentence was lengthened when compared to the non-final syllable. It was as if the speakers tend to slow down at the ends of the conceptual unit.

3. Semantic Factors

Semantic factors also play a prominent role in altering the duration of the vowels. Emphasis and semantic novelty are listed as semantic factors affecting the duration of speech sounds.

a. Emphasis: The first semantic factor to be considered was emphasis or contrastive stress. The acoustic correlate of emphasis is an increase in the duration of the word. Studies have indicated that the vowel duration was more for stressed vowels (Klatt, 1976 and Savithri, 1986).

b. Semantic novelty: An unusual word would be longest, the first time it appeared in a connected discourse infering that semantic novelty had an influence on segmental durations (Klatt, 1976).

4. Syntactic Factors

a. Phrase structure lengthening: Gaitenby (1965) found that the syllable or syllables at the end of a sentence were longer than they would be within an utterance. Similar results were observed by Klatt (1976).

b. Prepausal lengthening: The syllables before the pause are lengthened when compared to syllables in other positions (Klatt, 1976). Martin (1970) showed that the segments tend to be lengthened in spontaneous speech just prior to major grammatical constituent boundaries. Lengthening was observed at the end of noun phrases and conjoined or embedded clauses.

It may be a natural tendency to slow down at the end of all motor sequences or the speaker may learn to lengthen the prepausal syllables to enable the listener decode the message better or it is probably related to the general deceleration of motor activity at the end of speaking acts (Klatt, 1976).

c. Position of the vowel: Nooteboom (1972) studied the influence of position of vowel in the word on vowel duration. He reported that the absolute difference in duration,as well as in the duration ratio between the short and long vowels (V/V:) varied depending on its position in the word and the presence or absence of lexical stress. In trisyllabic non-sense words of the type /pVpVpVp/ with stress on the second syllable, he found that the absolute difference between two vowel types was 15 ms, 40 ms, and 50 ms, for three positions respectively, and the ratio V/V: was 0.85, 0.65, and 0.7 for the three positions respectively. Thus neither the absolute duration nor the V/V: ratio remained constant in Dutch. The word final syllables are somewhat longer in duration than the nonfinal syllables (Oiler, 1973 and Klatt, 1975).

5. Phonetic Factors

a. Inherent phonological duration: Each phonetic segment has its own intrinsic phonological duration. Some vowels are short and some vowels long and some are overlong (Savithri, 1984). The duration of the vowels appears to be related to tongue height. Other factors being equal, a low vowel is longer than a high vowel. Experimental evidence for this emerges from studies in English, German, Danish, Swedish, Thai, Lappish, Spanish (Lehiste, 1970 and Klatt, 1976) and Kannada (Savithri, 1986). According to Klatt (1976) the reason for this might be found in the physical processes. It is a known fact that velar height and the degree of closure of the velopharyngeal port varies systematically with vowel articulation. In general, the velum is characteristically lower and the port is more open for low vowels than for high vowels. This takes more time thus explaining the longer duration for low vowels.

Temporal analysis of vowels in Tamil carried out by Balasubramanian (1981), revealed that the phonologically long vowels are almost twice as long as the phonologically short ones. Other things being equal, open vowels are longer than close vowels.

0' Shaughnessy (1981) reported a weak tendency for vowel duration to vary inversely with vowel height in French vowels. This study showed that high vowels, on average, were shorter than other vowels, but this relation did not occur when mid (long) vowels were compared to low (long) vowels.

Mitleb (1984) studied the vowel durations using spectograms, in English and Arabic languages and found that the vowel duration of low vowels were more than high vowels in both languages. The fact that low vowels tend to be longer than high vowels was attributed to the degree of jaw lowering needed in the production of low vowels. He opined that the temporal structures were language specific variables which must be taken into consideration in the acoustic analysis of languages.

Lindau-Webb (1985) carried out a study on Hausa vowels and diphthongs and the results revealed that in open syllables the durational differences between long and short vowels were quite large. The long vowels were about 40-45% longer than the short vowels.

Choi (1992) studied the vowel duration with respect to the vowel height of Kabardian, a Circassian language spoken in the northwest Caucasus. The results showed that vowel duration was inversely proportional to the vowel height.

Shalev, Ladefoged and Bhaskararao (1993) carried out a study on the phonetic properties of Toda, a Dravidian language which is spoken by about 1,000 people in the Nilgiri Hills in Southern India. Toda vowels showed an apparent variation from the expected results; high vowels were shortest, (60 ms), followed by mid and low vowels (76 ms) which appeared to have the same mean duration. Since mid and low vowels were virtually identical in duration, the contrast in intrinsic length in Toda appeared to be between high and non-high vowels.

b. Effect of linguistic stress: Stress pattern of ar. utterance modifies the segmental duration. Stressed vowels were generally longer than unstressed vowels (Fararaenter & Trevino, 1936; Oiler, 1973 and Lehiste, 1975). In Dutch, the duration of the stressed vowel decreased with increasing number of syllables in the word. The effect was more pronounced in stressed long vowels than in stressed short vowels and stronger for isolated words than for embedded words (Nooteboom, 1972).

c. Effect of post-vocalic consonants on the vowel duration: Peterson & Lehiste (1960) studied the duration of syllable nuclei in English and found that vowels had shorter duration when followed by a voiceless consonant and had longer duration when followed by a voiced consonant. Many investigators have agreed with these findings; in English, (Delattre, 1962; House & Fairbanks, 1967; Umeda, 1975; Whitehead & Jones, 1976; Fox & Terbeek, 1977; Crystal & House 1988; Davis & Summers, 1989 and Jong, 1991) in German, (Fourakis & Iverson , 1984); in Japanese, (Homma, 1981); in French (O'Shaughnessy, 1981); in Swedish, (Lyberg, 1981); in Tamil, (Balasubramanian, 1981); in Malayalam, (Velayudhan 1975); in Toda, (Shalev, Ladefoged & Bhaskararao, 1993); and in Kannada, (Savithri, 1986).

The reasons for this as hypothesized by Halle & Stevens (1967) was that the vocal folds are widely open for the voiceless consonants, whereas for the production of voiced sounds fine adjustments are required. These fine adjustments consume more time than that of wide separation for the voiceless consonants. Further, the velopharyngeal width will be more for voiced stops when compared to the voiceless stops. This widening of the velopharynx for voiced stops requires more time which lengthens the vowels preceding voiced stops. In the production of voiced stops, the larynx is depressed to maintain a pressure difference above and below the glottis. However, when compared to the movement of the other articulators, the movement of larynx is sluggish. Thus the more rapidly reacting articulators are delayed to coordinate with the sluggish larynx (Hudgins & Stetson, 1935). Hence vowels are lengthened preceding voiced consonants.

Balasubramanian (1981) studied the duration of vowels in Tamil in various phonetic environments. Word initial and word medial vowels followed by voiceless and voiced consonants are examined in terms of their duration. The study revealed that in syllables of the structure V and CV, vowels were longer when followed by voiced consonants than when followed by voiceless consonants. In syllables of the structure, VC and CVC, however, vowels were longer when followed by a voiceless consonant group than a voiced one. However, Mitleb (1984) studied the vowels in Arabic language and the results revealed that Arabic vowels did not exhibit a difference in vowel duration as a function of the segmental voicing feature.

d. Segmental interactions: In German, it has been observed that the front vowels were longer before labials and velars than before dentals and back vowels were longest before velars (Maack, 1953). House and Fairbanks (1953) found that English vowels were generally longer before labials or velars.

Peterson & Lehiste (1960) carried out a study to determine the duration of syllable nuclei in English. The durations of all syllable rules in English were significantly affected by the nature of the consonants that followed the syllable nuclei. The influence of the initial consonants upon the duration of the syllable nuclei appeared to be negligible. They found a tendency for vowels preceded by fricatives to have somewhat shorter durations than vowels preceded by other consonants. Kenneth (1976) found that vowel duration in fricative environment was longer than in the plosive environments. Whereas, Whitehead & Jones (1976) found that the duration of vowels were significantly longer when it was followed by a fricative than when it was followed by a plosive.

Another secondary influence of consonantal environment on vocalic duration w as a p lace of articulation effect discussed by Fischer Jorgensen (1964). His findings were (i) before labials and dentals, the duration of back vowels were more than that of front vowels and (ii) before velars, the duration of back vowels were less than that of front vowels. He also observed that the duration of the vowels after voiced stops were longer than those after voiceless stops. In a study carried out by House & Fairbanks (1967), on the influence of consonant environment upon the secondary acoustical characteristics of vowels, it was found that the variations were systematically related to the attributes of the consonants, the most powerful attribute being the presence or absence of vocal fold vibration, followed by manner of articulation & place of articulation. Chen (1970) reported that the lengthening of the vowel was more when it was followed by a dental sound than when it was followed by labial or velar sounds.

Umeda, N. (1975) carried out an extensive study on the temporal behaviour of vowels with respect to consonant position. The investigator found that duration of the vowels were least when followed by voiceless stops, and increased when followed by voiceless fricative, nasal, voiced stop and voiced fricative, respectively. Lehiste (1975), states that "vowel duration tends to increase as the point of articulation of the post vocalic consonant shifts farther back in the mouth".

A study was conducted by Fox & Terbeek (1977) which investigated dental flaps and their effect upon preceding vowel duration in American English. The mean duration of vowels preceding /d/ flaps were significantly longer than those preceding their /t/ flap. This would argue that vowel lengthening was ordered before voiced flapping. This ordering would claim that vowel lengthening was sensitive to the voicing characteristic of the underlying segment /t/ or /d/, and not to the voicing of the flap itself.

Balasubramanian (1981) studied the duration of vowels in Tamil in various phonetic environments. He found that vowels were longest when followed by retroflex consonants & shortest when followed by bilabial consonants, in words having identical syllable structures. There was no appreciable difference between the durations of vowels followed by dental, palato-alveolar and velar consonants.

From a study of French vowels, O'Shaughnessy (1981) reported that there were two "strong" preconsonantal effects on vowel duration. He reported (i) lengthening of vowels before voiced fricative and (ii) shortening before voiceless obstruents. He also reported a weak tendency for vowels to be longer after stops than after other consonants.

A study carried out on the temporal analysis of the vowels and consonants in Japanese by Homma (1981) revealed that as the place of articulation of the adjacent stops moved toward the back, both voice onset time and vowel duration became longer in the first syllable. In the second syllable, on the contrary, vowel durations became shorter in this direction. Acoustic measurements conducted by Luce & Luce (1985) revealed that durations of vowels produced before bilabials (mean duration is 155 ms) were longer than those produced before alveolars (mean duration is 147 ms) and velars (mean duration is 146 ms). Savithri (1986) reported that in Kannada language vowels preceding retroflex sounds were longer than vowels preceding velars. Because velars involved least coordination of articulators and that the retroflex involved more precise control of the articulators as the tongue has to curl back and touch the palate. Crystal & House (1988) studied the effects of voicing characteristic and found that the place of articulation of the post vocalic consonant did not had reliable interaction effects on vowel duration. Santen (1992) studied the effects of several contextual factors on vowel duration. The results revealed that vowel duration varied depending upon the voicing and manner of articulation of postvocalic consonants. The vowel duration increased with respect to the post vocalic consonant as follows; voiceless stops, voiceless affricate, liquids, voiceless fricatives, nasals, voiced stops, voiced affricate and voiced fricatives. The effects of prevocalic stops on vowel duration, were smaller than those of the post vocalic stops and were not amplified by utterance position. The vowel duration was found to be shorter when preceded by a stop liquid cluster than when preceded by just the voiceless stop or the liquid. Vowels in word initial syllables were lengthened by about 20 ms when not preceded by a consonant in the same word and vowels in word final syllables were lengthened by a smaller amount when not followed by a consonant in the same word (Santen, 1992).

According to Klatt (1976) "the durational recording in clusters may have its origin in physical constraints on the speed of various articulators, their ability to act independently so that consonantal gestures partially overlap in time and on the articulatory distances to be traversed. It is hard to believe that constant word duration is a very important constraint in English since duration has already been implicated as a factor to differentiate inherently tense (long) from lax (short) vowels, voiced from voiceless fricatives etc.," (Klatt, 1976).

e. Polysyllabic environment: Nooteboom (1972 a, 1972 b) reported that under the influence of an increasing number of following syllables, Dutch vowels decreased in their duration and however, the vowels with shortest duration were least affected. This suggests that there may be differential effects of similar factors on the two vowel types. It could also mean that when a certain minimum vowel duration is reached the compression effect disappears. Nooteboom (1972) found that the influence of number of syllables on both duration of long and short vowels could be predicted by the formula:

$V = D/ (m * a)$ where

V = predicted vowel duration

D = Duration of the vowel in monosyllabic conditions,

m = No. of syllables, and

a = a constant less than 1.

Even though the same formula was used for both long and short vowels implying that the effect is similar for the two vowel types, the exponent 'a' could vary for the tense and lax vowels. This study showed that the duration range for the two vowel types differed. In case of tense vowels, the monosyllabic vowel duration was around 170 ms and in trisyllabic context it was 100 ms. In case of lax vowels, the monosyllabic duration was around 90 ms and trisyllabic condition it was around 70 ms. Thus, although lax vowels exhibited a resistance to compression when the number of syllables were increased, the tense vowels may also exhibit incompressibility at similarly short durations.

Lehiste (1972) measured the durational data from the polysyllabic words formed by combining base words with suffixes such as -y, -er, -ing, -ily, -iness. The durations of both the base component and of the syllable nucleus tend to decrease in such series. "The major effect was the conditioning of the durational structure by the number of syllables rather than either by the number of segments or by the presence of morpheme or word boundaries" (Lehiste, 1972).

Lehiste (1975), investigated the temporal differences in intrinsically long and intrinsically short vowels as a function of number of syllables in the word. She found that the addition of an unstressed syllable had different effects on the long vowels and on the short vowels, specifically in the voiceless condition, where the tense vowel underwent more compression than the lax vowel. These findings have been compared with the findings of other investigator in Table 2.2. Additionally, the influence of the position in the word showed that the effects of lengthening in final syllable position was more for the short vowels than for long vowel. Lehiste (1975) inferred that the behaviour of the two vowel types, long and short, are different under the influence of addition of another syllable. This was true not only in terms of absolute duration but also in terms of percent change.

Table 2.2: Comparison of tense and lax vowel durations with increasing number of syllables in a word.

	Lehiste (1975)			Port (1981)				
	No. of syllables							
	1	2	(2/1)	1	2	(2/1)	3	(3/2)
Voiced context								
Tense	248	172	(69.4%)	149	115	(77%)	110	(95%)
Lax	153	104	(68%)	113	84	(74%)	79	(94%)
Voiceless context								
Tense	198	146	(73.6%)	113	101	(89%)	96	(95%)
Lax	103	84	(81%)	82	71	(85%)	71	(101%

Port (1981), on the other hand, found that the two vowel types behaved similarly with an increasing number of syllables, i.e., reduction of vowel duration, for both the voiced and voiceless contexts. This is also shown in Table 2.2. This finding is contradictory to Lehiste's (1975) finding. This may be due to lack of control over the rate of speech. These conflicting findings may be due to the effect of "incompressibility" (Klatt, 1973), when the minimum duration is reached.

Lindblom (1975) states that vowel duration decreased as the number of syllables in the word increased. When studying connected speech materials, Umeda (1972) failed to find evidence for this phenomenon and subsequently Harris & Umeda (1974) asserted that the polysyllabic effect was negligible, or non existent, in connected speech.

Study carried out by Umeda (1975) regarding the temporal behaviour of vowels under many phonological conditions revealed that average duration of vowels can be arranged in a descending way as follows: prepausal, monosyllabic words, polysyllabic words and function words. He came to the conclusion that "these durational rules are a reflection of performance of the speaker's subconscious control of temporal factors". "In English polysyllabic words, phoneme durations shrink as the number of syllables increase. This has been cited as evidence for English being stress-timed, with relatively equal spacing between stressed syllables. French is considered syllable-timed, due to its relatively equal - duration syllables. Some evidence supporting that view was found in the study regarding the effects of polysyllabic words on vowel and consonant duration in French. The shortening of duration was not so much due to the increased number of syllables as to the fact that the reduced phonemes became word - internal. The greatest reductions occurred in syllables in non-word-final position, because pre-pausal lengthening is eliminated. Adding further syllables to the word did not have the shortening effect that is usually found in English words" (O'Shaughnessy, 1981).

Temporal analysis of vowels in Tamil carried out by Balasubramanian (1981) revealed that vowel durations were longer in monosyllables than in words having more than one syllable. He also established the fact that vowels were longer, in syllables with simple structures than in syllables of complicated structures. Bhaskar Rao (1988) carried out a study to determine the extent of compressibility of test vowel when the word was made progressively longer by the addition of inflectional suffixes to the root word in Malayalam, Kannada (Dravidian family), Sindhi and Marathi (Indo-Aryan family) languages. In Kannada and Malayalam which have phonemic vowel length, the reduction of root word was more than the reduction of test vowel. In Malayalam the test vowel was slightly more reduced than in the case of Kannada. The overall reduction of the root word was being done at the expense of the rootword excluding the test vowel. In Sindhi and Marathi, though both the root word and the test vowel got shortened considerably, the reduction was more in the case of test vowel than in the rest of the root word. The reduction in Sindhi was of a larger magnitude than in Marathi. They concluded that increase in number of syllables, decreased the vowel duration.

6. Physiological Factors

Finally the physiological efforts (to minimize the articulatory efforts) have been used to explain the difference in inherent phonological.durations of vowels. For example the longer duration of low vowels has been attributed to the extra effort to open the jaw in the context of a consonant (Lindblom, 1968). Some of the physiological efforts have already been mentioned with relevance to the other factors.

DURATIONAL MODELS:

Several models have been proposed to explain the way in which control over duration was achieved. Currently two models are recognized. They are the Comb model and the Chain model.

The "Comb model" (Kozhevnikov & Chistovich, 1965) holds that the units of speech are executed according to some underlying preprogrammed time schedule; i.e, the duration of speech sounds to be uttered are determined before they are produced. For example, if the speech sound /a/ is to be produced, the duration for which it is to be produced is determined before its production.

According to the "Chain Model", there is no underlying time program or a given speech gesture is executed after the preceding gestures have been completed successfully (Ohala, 1973), i.e. the duration of the speech sound to be produced is not pre-determined. Ohala (1973) suggests the "Chain Model" for long term timing and the "Comb model" for the short-term timing. Kozhevnikov & Chistovich (1965) presented evidence for the "Comb model". They stated that the durational structure of a sentence was preplanned and that the open syllable was an important unit in this process.

Preplanned sequential commands change the articulatory processes, which results in compensatory effect in speech production. This further gives rise to lengthening of the preceding segment when the following segment was shortened or vice versa.

Ohala (1975) questions these findings and claims that a chain model is as relevant as a comb model. If the comb model is the most basic model, compensatory effects in speech perception to minimize the influence of local disturbances while decoding the message is needed. If chain model is true, there is no immediate need for such a compensatory behaviour.

Some models describe the way in which timing information takes place in brain. (Creelman, 1962; Triesman, 1963; Michon, 1967 and Allen, 1972). This timing information has been explained by Allen (1972) in two ways. Allen (1972) using the vowel duration, states that the commands to produce a vowel articulation could include the information;
"simultaneous with the start of the commands for the vowel, send out a neural impulse along a nerve loop type known to the motor control program, specific to vowels or this particular duration, continues to issue with commands for this vowel production until impulses arrive back on the

return branch of this loop" (Allen, 1972). According to Allen (1972) the neural loop would act like a delay line, with each class of articulatory durations having its own fixed delay between initiation and cessation of neuromotor command. The second model involves a "Clock and a Countdown number". The vowel command would include the instruction "simultaneous with the start of the commands for this vowel, begin counting down cycles of the speech time clock; when 'n' cycles are complete, the vowel is complete. The number would be computed by the brain for each articulatory duration" (Allen, 1972). Other models involving time quarter have been developed by Creelman (1962), Triesman (1963) and Michon (1967). Creelman (1962) suggests a poisson's source and says that no constantly running "internal clock" will account for the data of his experiments. Triesman (1963) suggests a "Pace maker" or "Clock like generator" whose rate may be subject to small errors. Michon (1967) assumes a "Pacemaker source" whose rate of pulsation is highly task dependent, to account for a variety of periodicities in his data.

"Another model called the "Condenser model" suggests that the duration may be stored in terms of the interval of time in a given condenser with a given charge, which needs to discharge to a certain threshold level. Therefore each unit which is to be assigned a duration is assigned a charge for a condenser. Thus duration rules would be operations on the charge of condensers" (Carlson & Granstrom, 1975).

At present none of the models on timing information in speech behaviour could be accepted or rejected fcr lack of empirical evidence. It could be hypothesized that a model for the storage of timing information must have the possibility of storing in a duration with an accuracy of a few milliseconds and must have a higher absolute accuracy for shorter intervals than for longer intervals. However, the question of the accuracy of the descriptive model still remains (Savithri, 1984).

CONTRIBUTION OF SANSKRIT LITERATURE TO THE DURATIONAL MODELS:

It is interesting to know that the ancient Sanskrit scholars had knowledge regarding the durational aspects and their importance. This is evident from the definition of phonetics as well as from the classification of speech sounds (Savithri, 1984).

In the treatise Taittiriya Upanishat phonetics is defined as the study of speech sounds, their pitch, quality, intonation and conjunction (Taittiriya Upanishat 11-29-32). Paniniya Siksa classified the speech sounds on the basis of various factors like the quantity, place of articulation, manner, aspiration, nasality etc., among which quantity is given the second place (Panini:ya Siksa 6-7). According to quantity, speech sounds were divided into 'hrasva', 'dhirgha' and 'plutha' (Panini:ya Siksa - 8) (Short, long and prolated), which are one, two & three 'matra' (unit of quantity / duration) respectively. They had set the units of quantity, the lowest unit was termed a 'paramanu' which is considered to be equivalent to two 'anus' (V.R.P.S. 23). Next was a 'matra', the more commonly used unit, equivalent to two 'paramanus'. It was compared to the time taken for the snap of a finger, eye blink or a flash of lightening (V.S 27-3; N.S. 2-2-3; Y.S-8). The vowels were classified as short, long and prolated. (B.S-8) and consonants are considered to be half a 'matra' long. (V.R.P.S.-22; T.P.l-38; S.Y.P.Y.S. I. 57). It was noticed that the final syllable was prolated in calling someone at a distance, in reply to a greeting and in case of a doubt. (Ashtadhyayi 8-2-83, 84, 97) . .

In Natyasastra, one of the oldest treatise in dramatics, the durational differences in different intonation patterns and the duration of pause are mentioned. It states that there exists a direct relationship between the duration of a pause and the length of the syllable. When the pause is of greater duration, the syllable produced will always be longer. However, the duration of the pause should not exceed six 'kalas' (a measure of time). (N.S - Chap. 15).

It has been advocated that slow rate of speech should be used while teaching, moderate rate while speaking and fast rate while reciting. The importance of duration was observed in considering the normalcy of speech which could be noticed by the fact that the durational deviations are included under articulation disorders (Rig Veda Pratisakhya Chap. 15).

Finally, the physical processes underlying the speech behaviour was also explored. Kaiyyata connects the perception of different rates of speech to a psychophysical process affecting the nervous system. The ratio of slow to normal to fast rate of speech was considered to be 9:12:16. According to him, the ratio implied that 9, 12 and 16 drops of nervous fluid flow from the 'sushumna'(?) nerve of the listener, when he hears a sound in slow, normal and fast rate (Kaiyyata pradipa 1-1-70).

ROLE OF DURATION IN SPEECH PERCEPTION:

"The theory of segmental duration has some interesting implications for the way in which sentences are perceived by the listener. The segmental duration contributes to the perception of constituent structure, phrasal and lexical patterns. It serves as a cue to word boundaries (Klatt, 1974).

It has been proved that the listeners are particularly sensitive to the rhythmical aspects of sentence timing (Huggins, 1972). It appears that they are aware of an average speaking rate and adjust their durational criteria accordingly. Systematic changes in just noticeable differences of about 20% or more may serve as perceptual cues (Klatt, 1976). Because of the listener's internal representation of duration, the durational differences between the short and long vowels are perceived (Nooteboom, 1972). It has been shown that duration is a sufficient cue to change the identity of a fricative from voiceless to voiced (Cole & Cooper, 1975).

Klatt (1976) suggests that "the marking of phrase-boundaries by increasing the duration of the phrase-final syllable can serve as a primary perceptual cue to the decoding of surface structure in spoken sentence". Emphasis is signalled by an increase in the segmental duration and change in the fundamental frequency (Klatt, 1976).

Durational cues are capable of carrying considerable information in connected speech. The listerners may be aware of the durational rules. However, research is necessary on the type of rules used by the listeners as cues in perception (Savithri, 1984).

(VOWEL DURATION IN INDIAN LANGUAGES:

Savithri (1989) has studied the duration of vowels in ten Sanskrit speakers and the durational data is presented in the Table 2.3. She found that the duration of long vowels was approximately twice than that of the short vowels, their duration being approximately 180 ms and 80 ms. She found that female subjects had longer vowel durations than male subjects. She reported that the vowels preceding strongly aspirated stops were longer than the slightly aspirated stops and the vowels were longer before voiced stops than the voiceless stops. She also found that the vowels were longer preceding retroflex stops and shorter preceding velar stops. Vowels preceding retroflex /r/ were lengthened when compared to other semivowels. The duration of diphthongs were similar to the duration of long vowels.

Table 2.3: Mean duration of vowels in Sanskrit (Savithri, 1989)

Mean duration of vowels in Sanskrit		
Vowel	Short	Long (in m.secs.)
a	81	178
i	88	190
u	87	180
r	121	-
e	-	196
o	-	197
ai	-	198
au	—	197

Ganesan, Agarwal, Ansari and Pavate (1985) studied the vowels of Hindi language in eleven speakers. The Table 2.4 shows the values of the vowel duration in Hindi.

Table 2.4: Mean duration of vowels in Hindi
(Ganesan et.al., 1985)

Vowels	Duration (in m.secs.) Short	Long
i	151.8	286.2
e	263.5	268.2
a	156.5	248.6
o	159.2	276.1
u	159.2	257.7

Nagamma Reddy (1988) studied the vowel duration in Telugu language taking one subject. She used sound spectrograph and electro - kymograph for the durational measurement. The duration of Telugu vowels in isolation and in connected speech is presented in Table 2.5 (as reported by Nagamma Reddy).

Table 2.5: Mean duration of vowels in Telugu (Nagamma Reddy, 1988)

Vowels	Duration in centi seconds									
	a	i	u	e	o	a:	i:	u:	e:	o:
Isolation	9	7	7.5	10	10	28	25	26	26.5	27
Connection speech	5	6	4.5	6.5	5.5	13	11	11	11	11

Vowels	Duration (in m. secs.) Short	Long
i	75	148
e	-	152
a	84	160
o	82	151
u	77	151
E	80	-
d	78	154
i	86	154

Balasubramanian (1981) investigated the duration of vowels in Tamil, using four native speakers and the vowels occurring in various positions. He examined about 3000(?) spectrograms and electrokymographic tracings to obtain intrinsic vowel durations. The vowel duration in Tamil is given in the Table 2.6 as reported by Balasubramanian (1981)

Balasubramanian (1981) concluded that:

(a) the phonemically long vowels (v:) were almost twice as the corresponding short (v) vowels in identical environments.

(b) in general when other factors are controlled, open vowels were longer than close vowels

(c) Vowels in simple syllables were longer than vowels in more complicated, cluster syllable structures. As the number of segments in syllables increased the duration of vowels in that syllable decreased.

(d) Vowels were longest when followed by a retroflex consonant and shortest when followed by bilabial consonant in word having identical syllable structures. There was no appreciable difference between the durations of vowels followed by dental, palato-alveoar and velar consonants.

Savithri (1986) studied the vowel duration in Kannada language and also aimed at identifying some of the variables influencing the duration of Kannada vowels. She used six subjects and 82 trisyllabic meaningful Kannada words for the purpose of durational analysis. She studied the influence of voicing, aspiration, nasality, clustering, place of articulation of post vocalic consonant on only three short vowels of Kannada. They were /a/ /i/ & /u/. The average vowel durations in males and females are given in Table 2.7

Table 2.7: Mean duration of vowels in Kannada
(Savithri, 1986)

Vowels	Vowel duration Males	Females	Average
/a/	77	86	81.5
/i/	69	97	80.5
/u/	81	79	80.0

Savithri (1986) observed that:

(a) high vowels were shorter in duration than low vowels.

(b) the voicing, aspiration and retroflexion of the post vocalic consonant, lengthened the vowel duration.

(c) nasality of the post vocalic consonant reduced the vowel duration.

(d) the vowel duration of the test vowel in simple syllable structure was longer than the vowel in a clustered syllable. She also observed that the vowel produced by female speakers had longer duration than the male speakers.

Rajapurohit (1982) studied the vowel duration in Kannada language using a single utterance in a single subject using 405 words. These words were not controlled for word length, post vocalic consonants, post vocalic voicing etc. The vowel durations were measured using oscillograph. The obtained vowel duration of Kannada vowels is given in Table 2.8.

Table 2.8: Mean duration of vowels in Kannada
(Rajapurohit, 1982)

Vowel	Duration (in m. sees.) Initial	Medial	Final
i	75.00	60.77	80.81
i:	132.00	136.41	138.16
e	114.00	83.16	118.85
e:	-	151.16	-
a	67.13	71.84	68.54
a:	169.05	157.80	138.06
o	98.0	84.00	-
o:	196.66	146.22	-
u	64.73	58.05	84.98
u:	150.00	168.00	-
a	75.14	64.08	-
a:	194.00	—	-

Savithri (1989) further investigated the vowel duration in Kannada using ten subjects, in 100 words and the obtained durational data are presented in Tables 2.9, 2.10 and 2.11. She used B & K High Resolution Signal Analyzer (Oscillographic method) for the measurement purpose. She made the following observations:

(a) the ratio between the duration of short and long vowels in Kannada language was 1:1.6, their duration being 76 & 120 m.secs respectively

(b) in the word or sentence end, the vowels were lengthened. The short vowels were lengthened by 62 m.sec and the long vowels were lengthened by 370 m.secs. The ratios of their durations in non-word-end and word-end were 1:1.8 for short vowels and 1:1.4 for long vowels respectively.

(c) vowels preceding voiced stops were longer than those preceding the voiceless. The mean duration of short and long vowels preceding voiced stops were 75 and 132 m.secs and those preceding voiceless stops were 66 and 123 m.secs respectively. However, the vowels /a/ and /u/ were exceptions for these.

(d) the short vowels preceding nasal continuants were shorter than those preceding voiced stops but were longer than those preceding the voiceless stops. Among the long vowels, those preceding the voiced stops were the longest followed by those preceding voiceless stops and nasal continuants.

(e) vowels preceding the semivowels /r/,/i/ and /v/ were the longest followed by those preceding fricative and stops.

(f) vowels preceding the palatal stops were the longest. These were followed by the vowels preceding dentals, bilabials, velars and retroflexes. However, there were no significant differences in the duration of vowels.

Table 2.9: Duration of vowels preceding stop consonants and nasal continuants (in m.secs) (values in parenthesis represent the duration of vowels in words and sentences occurring at the end) (Savithri, 1989).

Vowels	Following stops Voiceless	Voiced	Nasals
a	57	72	65
a	190	155	107
i	65	72	64
	(132)	-	-
l	99	112	-
u	64	61	66
	(120)	(132)	(142)
u	117	128	-
e	64	94	73
	(143)	(85)	(11)
e	86	131	106
o	81	-	-
o	124	–	100
Mean short vowels	66	75	67
	(132)	(109)	(127)
Mean long vowels	123	132	107
			(131)

Table 2.10: Vowel duration as a function of the manner of articulation of the post-vocalic consonant in m.secs. (Savithri, 1989)

Preceding Vowels	Stops				Fricatives	
	Voice-less	Voiced	Nasal	Semi-vowels	Voice-less	Voiced
Short	66	75	67	100	72	77
Long	123	132	107	131	113	140
Mean		95		115.5	100	

Table 2.11: Vowel duration as a function of the place of articulation of the post-vocalic stop consonant in m.secs. (Savithri, 1989)

Place of articulation	Velars		Palatals		Retro-flexes		Dentals		Bilabials	
	VL	VD	VL	VD	VL	VD	VL	VD	VL	VD
Vowel duration	64	67	75	76	54	62	69	76	62	67
Mean	65.5		75.5		60.5		72.5		64.5	

Velayudhan (1975) carried out a study in Malayalam, official language of Kerala State, on the South-West coast of India, to study the durational aspects of Malayalam vowels in isolation as well as in a variety of phonetic contexts. His work was based on the citation forms of the vowels, minimal/

Table 2.12: Mean duration of vowels in Malayalam
(Velayudhan, 1975)

Vowels	Vowel duration (in m. secs.) Short	Long
i	135	300
e	150	270
a	145	320
o	145	265
u	100	205

subminimal pairs of words set in a carries sentence and to a less extent on connected speech. The main objectives of his study were to ascertain the nature of the duration of short and long vowels and the influence of a following short/long consonant on the duration of a preceding vowel. The results which are presented in Table 2.12 revealed that the short and long vowels tend to keep their ratio in the range of 1:2. In all cases, whether the vowels measured were from the speech samples of citation forms or those in words produced in a carrier sentence or in running speech, the long vowels were found to be invariably longer than the short ones by more than 100%. The result also showed that the duration of a preceding vowel was significantly affected by the nature of the following consonant. The duration of a vowel (whether short or long) was found to be shorter when followed by an occlusive rather than by a non-occlusive. The duration of the vowel preceding a voiceless long consonant was reduced considerably (as much as 50 percent) as compared to that of the same vowel preceding a short lenis stop which was often fricativized with mild voicing. The ratio of the short versus long opposition was found to be in the range of 1:2.

The study carried out by Velayudhan (1975) suffered from the following limitations. The sample size was small (two subjects). It is not possible to generalize the findings based on only two samples to the population under concern. He did not control the dialectal influence on the subjects. One of the subjects hailed from Northern Kerala, and the other subject belonged to South Kerala. Moreover, the influence of the foreign language (English) upon the

Table 2.13: Comparison of the duration of vowels across different languages.

Peterson & Lehiste, 1960 English		Ganesan, Agrawal, Ansari & Pavote. Hindi (1985)		Savithri, (1989) Sanskrit		Rajapurohit, (1982) Kannada		Savithri, (1966) Kannada		Balasubramanian (1981) Tamil		Velayudhan, (1975) Malayalam		Majumder, Datta & Ganguli (1978) Telugu		Nagamma Reddy (1988) Telugu		Fant, Henningson & Stalhammar (1969) Swedish.		Venkatesh (1995) Kannada	
V	VD	V	VD	V	VD	V	VD	V	VD	V	VD	V	VD	V	VD	V	VD	V	VD	V	VD
i	180	i	151.8	i	88	i	60.77	i	80.5	i	75	i	135	i	70	i	60			i	80
i:	240	i:	286.2	i:	190	i:	136.41			i:	148	i:	300			i:	110	i:	410	i:	166
		e	263.5			e	83.16					e	150	e	110	e	65			e	96
		e:	268.2	e:	196	e:	151.16			e:	152	e:	270	e:	205	e:	110	e:	400	e:	176
a	260	a	156.5	a	81	a	71.84	a	81.5	a	84	a	145	ə	105	a	50			a	89
		a:	248.6	a:	178	a:	157.80			a:	160	a:	320	a:	230	a:	130	a:	410	a:	178
.		ɔ	251.1			o	84.0			o	82	o	145	o	120	o	55			o	92
:		o:	276.1	o:	197	o:	146.22			o:	151	o:	265	o:	200	o:	110	o:	410	o:	168
u	200	u	159.2	u	87	u	58.05	u	80.0	u	77	u	100	u	100	u	45			u	77
u:	260	u:	255.7	u:	180	u:	168.00			u:	151	u:	205	u:	200	u:	110	u:	390	u:	160
ai	350			ai	198													u:	410		
ɛ	200			r	121					ɛ	80							Y:	125		
æ	330			au	197													ae	410		
ə	230					ə	64.08			a	78							o:	410		
ɔ	310									a:	154										
ou	220									i	86										
au	300									i:	154										
ei	270																				
i	370																				
r	240																				

durational data collected from subjects is also not taken into account. Hence, the present study was taken up for an extensive temporal analysis of the vowels in Malayalam. The temporal parameters studied were sentence duration, word duration, syllable duration and vowel duration.

From the review of literature it is evident that vowel duration is one of the powerful factors to determine both the phonetic and phonemic quality of the vowels. Phonemically vowels are divided into short and long vowels. Several investigators have studied the durations of vowels in many languages and these durational data are presented in a consolidated Table 2.13. The several factors which influence the vowel duration has been discussed in length in the previous pages.

In Indian Languages also there are several studies, which describes the vowel duration of different languages. The present study aims at studying the intrinsic durations of vowels of Malayalam language. It plans to study the influence of vowel height, vowel place and vowel length on the intrinsic duration of vowels. It is also aimed at establishing the relationship between short and long vowels and the relationship between word, syllable and vowel durations.

METHODOLOGY

METHODOLOGY

The main objective of the study was to determine the temporal characteristics of vowels in Malayalam language used by normal adults (Peak dialect of Malayalam). For this purpose the acoustic analysis of vowels of Malayalam language in /VtV/, /PVtV/ and /KVtV/ environment with test vowel in the initial, medial and final positions respectively, were carried out.

Based on the review of literature, Maack, 1949; House & Fairbanks, 1953; Fischer-Jorgensen, 1955; Peterson & Lehiste, 1960; House, 1961; Elert, 1964; Lehiste, 1970; Umeda, 1975; O'Shaughnessy, 1981; Balasubramanian, 1981; Rajapurohit, 1982; Shadle, 1985; Steel, 1986; Savithri, 1986; Gopal 1987; Agrawal, 1988; Nagamma Reddy, 1988 and Zawadzki & Gilbert, 1989; four temporal parameters were considered essential to describe the vowel sounds. The temporal parameters considered for the study were:

a) duration of the vowel (VD),

b) duration of the syllable having test vowel (SD),

c) duration of the word having test vowel (WD) and

d) duration of the sentence having the test vowel (STD).

Subjects:

Ten (five males and five females) normal adults were selected as subjects on the criterion that they;

a) had normal speech, language and hearing functions and did not had any history of hearing loss or speech problems.
b) were within the age range of eighteen to thirty years of age.
c) were natives and residents of Cannanore district for at least past fifteen years.
d) had Peak dialect of Malayalam as their mother tongue.
e) were well versed in reading and writing Malayalam and primary and high school education was in Malayalam medium.
f) had Malayalam as their dominant language and a reasonable fluency in Indian English. (This was because it is very difficult to find a true monolingual in an urban literate population. Most of the urban population are exposed to some amount of English and have at least partial fluency in English).
g) were not exposed to any other language other than English as second language during their childhood (up to twelve years).

Test Material:

According to Shyamala Kumari (198), there are only eleven vowels in this dialect of Malayalarn. They are, /a, a:, i, i:, u, u:, e, e:, o, o:/ and /U/. In addition to these vowels, there is a low front vowel /æ/ which occurs with length in certain loan words from English. Its distribution is limited only to medial position. In this study, it was intended to analyze ten basic vowels in the Peak dialect of Malayalarn. They were:

	Front	**Central**	**Back**
High	i i:		u u:
Mid	e e:		o o:
Low		a a:	

As the vowel (its spectral and temporal parameters) gets affected by the preceding or following sounds it was decided to use /VCV/ and /CVCV/ words where only the test vowel varied. After extensive search using Malayalarn - Malayalarn, English, Hindi Dictionary (Balakrishnan & Leeladevi, 1960), the words with test vowel in the initial, medial and final positions were selected.

The test material consisted of a list of twenty five meaningful, non-emotional, Disyllabic words. Each word consisted of one of the ten test vowels in the initial, medial or final positions. Only the short vowels were studied in the word final position, because in Malayalam the words does not end with vowels in their final position. The vowel /U/ was not taken up for the study because it occurs rarely and hence it was not possible to extract enough meaningful words containing the vowel /U/. Thus twenty five words with one test vowel in each, were selected for the study. The twenty five bisyllabic words with test vowel in the initial, medial and final positions were given in Appendix A. The phonetic environment of these test vowels (i.e., the following and preceding speech sounds) were constant. Thus the effect of following and preceding sounds were kept constant. These test words were embedded in the medial position of two and three word carrier sentences. They were:

1. /i: va:ku_______a:nu/ (this word is______) and
2. /itu_______enna:nu/ (this is_____).

Thus a set of fifty sentences (twenty sentences with test vowel in the word initial position, twenty sentences with test vowel in the word medial position and ten sentences with test vowel in the word final position) were prepared.

After this each sentence was repeated five times and random sampling was carried out in order to group them. They were made into five groups of twenty sentences in case of test vowel in the word initial and medial positions and five groups of ten sentences in case of test vowels in the word final postion. Each of these sentences were written on cards and were used as test material.

PROCEDURE:

Instrumentation: Recording and analysis

The following instruments were used for the recording and analysis of speech samples:

a) Sony Stereo Cassette Deck (TC - FX 170) with cardioid dynamic microphone and

b) DSP Sona-Graph, Model 5500 (used to generate spectrograms and speech wave forms and to measure the duration).

Test environment:

The recordings were done in a sound treated room. The overall noise level was measured using B & K Sound Pressure Level Meter at the beginning of the recording of each session. The average noise level measured on 20 different occasions was 32 dB A.

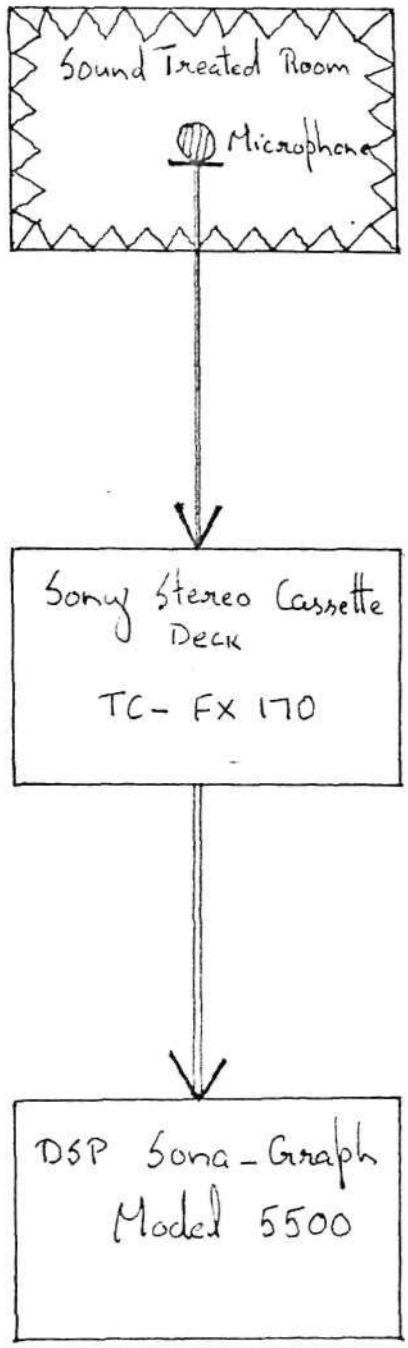
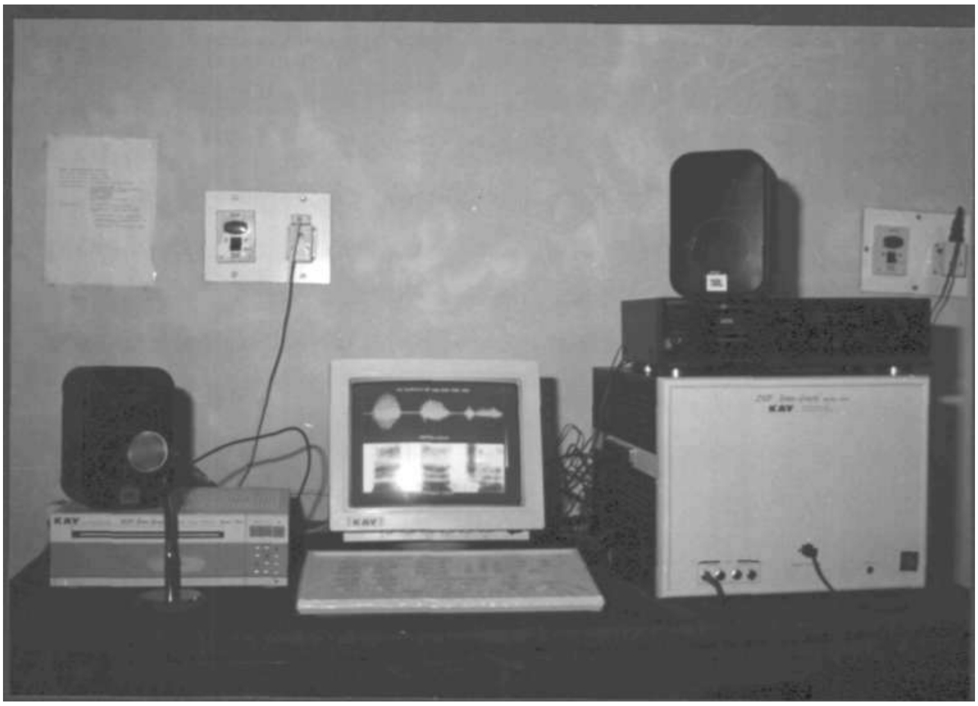


Fig.3.1 : Block diagram showing the arrangement of the instruments for recording and acoustic analysis.



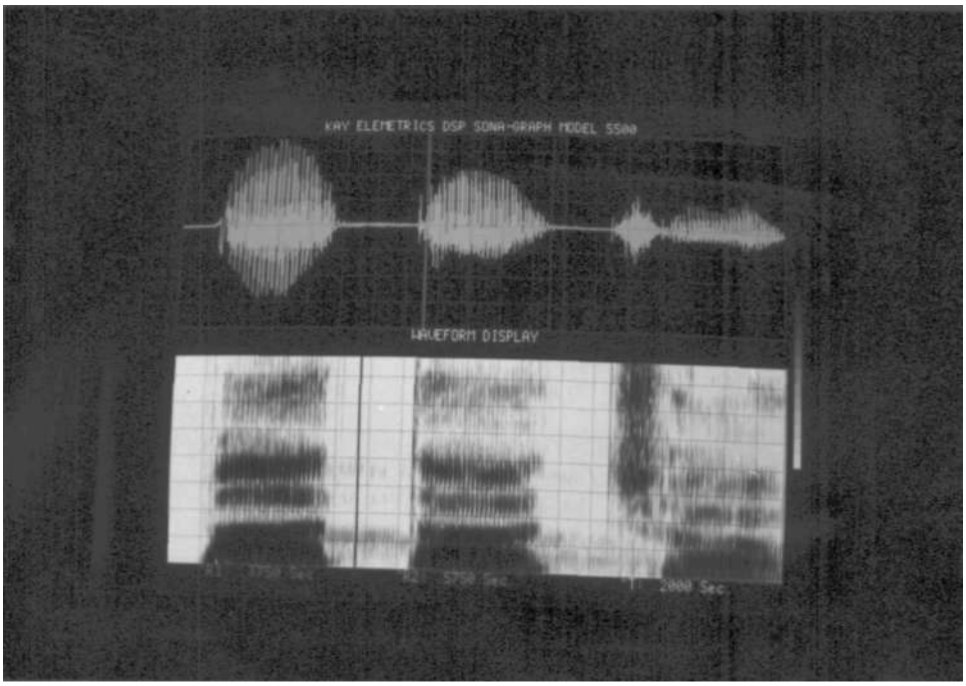


Fig 3.2 : Photograph showing the arrangement of the instruments for recording and acoustic analysis.

Recordings of speech sample:

The subjects were seated comfortably in the sound treated room. The cardioid dynamic microphone (AKG D-222) were kept in front of the subject at a distance of about 15 cms from the mouth. The output from one microphone was fed to a Sony Stereo Cassette Deck (TC - FX 170) with Hi-Fi CrO_2 cassette for recording the speech samples. The speech samples were recorded at a recording speed of 1 7/8 ips. The recorded samples were played back to the input of the DSP Sona-Graph, Model 5500 for spectrographic analysis.

The recording was done for individual subjects by presenting one flash card at a time. The randomized list of two hundred and fifty Malayalam sentences, with test vowel in the word initial, medial and final positions were presented using flash cards and the recording was carried out.

The subjects were instructed in Malayalam as follows:

" ka:rḍil eḻutiya chiḷa va:kkugaḷ niŋaḷe ippo:ḷ
ka:ṇikkum. a:dyam niŋaḷ aṯu mauṉama:yi
va:yikkuga. aṯiṉu ʃe:ʂam sukʰakarama:ya
ʃabdaṯiḷ sa:dʰa:raṇa ri:tiyiḷ ava va:yikkuga "

("Now you are going to see a sentence written on the flash cards. As the flash cards are presented, read the sentence silently and later say them at comfortable loudness and as naturally as possible").

The flash cards were presented to the subjects, with an interval of approximately ten seconds between each presentations. On presentation of the flash cards, the subjects uttered the sentences as naturally as possible at comfortable loudness. The uttered sentences were recorded using a cassette tape recorder. The recording level of tape recorder was kept constant during the recording of each subject. The recorded samples were played back to the input of the DSP Sona-Graph, Model 5500 for spectrographic analysis.

The waveform and the spectrographic display of the digitized acoustic signal of the sentences uttered by the subjects were displayed on the computer screen of the DSP Sona-Graph. The DSP Sona-Graph had facilities to mark the desired portion of the waveform and listen to the marked portion.

Acoustic Analysis:

The following temporal parameters were extracted using the DSP Sona-Graph:

a) vowel duration:

b) syllable duration:

c) word duration and

d) sentence duration

a) Vowel duration is the duration of the waveform from the onset of voicing to the offset of voicing of the test vowel. The vowel onset and offset were identified using the following criteria. Onset of voicing was defined as the beginning of the periodic portion of the wave form and the offset was defined as the point in the waveform, where there was discernable cessation of the acoustic energy of the test vowel and onset of the aperiodic energy of the following consonant. The onset and offset of vowel was determined by taking the first two formants into consideration.

b) Syllable duration is the duration of the syllable waveform having test vowel from the region of its onset to its offset. In the case of test vowels in the word initial position /VtV/ the syllable duration was same as duration of the first vowel. In the case of test vowels in the word medial position /PVtV/, the duration of the syllable was considered from the onset of burst /P/ to the offset of the intial vowel. Whereas, in the case of test vowel in the word final position /KVtV/, the duration of the syllable was considered from the onset of the burst /t/ to the offset of the final vowel.

c) Word duration of the test word is the duration of the waveform from the region of its onset to its offset. In the case of test vowel in the word initial position VtV/, the duration of the word was taken from the onset of the first vowel to the offset of second vowel. In the case of test vowel in the word medial position /PVtV/, the word duration was considered from the onset of burst /P/ to the offset of the second vowel. Whereas, in case of test vowel in the word final position /KVtV/, the word duration was considered from the onset of burst /K/ to the offset of the second vowel.

d) Sentence duration of the test sentence is the duration of the waveform from the region of its onset to its offset.

The boundary regions for the beginning and ending of the vowels, syllables, words and sentences were aided by looking at the spectrogram and by listening to the speech waveform. Thus the speech samples of all the ten subjects were analyzed and the above mentioned temporal data were obtained. Further the data was subjected to statistical analysis using descriptive statistics, ANOVA and discriminant analysis. The results are presented in the following chapter.

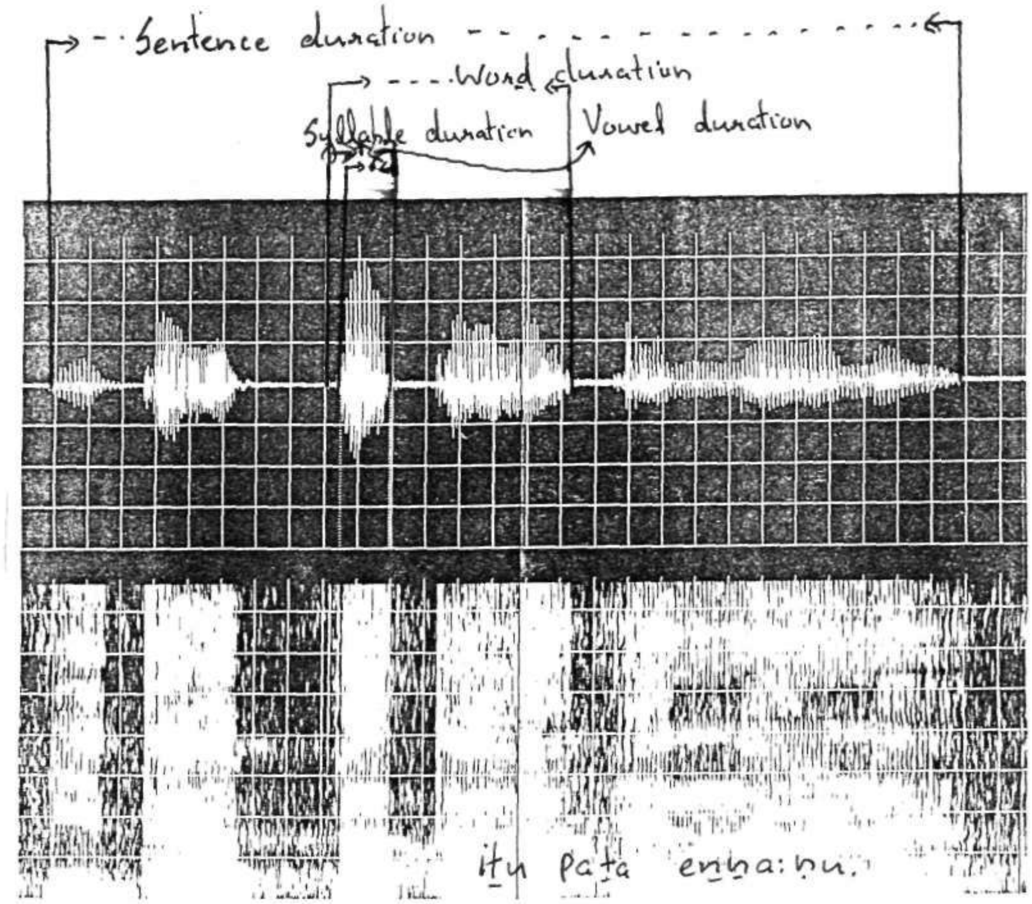


Fig. 3.3: Speech waveform and spectrographic display of the sentence, segmented test vowel, the segmented test syllable and the segmented test word.

To know the reliability of the temporal measurements, one set of sentences (twenty words) from each subject were selected randomly. The temporal parameters were extracted from the test vowels present in these words, using the procedures explained earlier. The values were tabulated and there was no statistically significant mean difference between the first measured values and the repeated measurements. There was also a high degree of correlation between them. Hence the measured values may be considered as reliable.

RESULTS
and
DISCUSSION

RESULTS AND DISCUSSION

The purpose of the study was to analyze the intrinsic duration of the vowels of Malayalam language with the test vowel in the initial, medial and final positions of the word and to investigate its relation with syllable duration, word duration and sentence duration. An attempt has also been made to analyze the vowel duration, syllable duration, word duration and sentence duration with reference to:

a) tongue height (high, mid and low),

b) tongue position (front, central and back) and

c) length of the vowel (long and short).

The vowel duration, syllable duration, word duration and sentence duration with the test vowel in the initial, medial and final positions of the word were obtained from the utterance of five female and five male subjects. These subjects produced ten malayalam vowels that were embedded in /CVCV/ or /VCV/ environments which in turn were embedded in two carrier phrases, thus resulting in a total of 2500 utterances, which were recorded. From these utterances the vowel duration, syllable duration, word duration and sentence duration were measured as described earlier.

The vowel duration was defined as the duration of the waveform from the onset of vowel to the offset of voicing of the test vowel. The onset and offset of vowels were determined by the clear onset and offset of first two formants, stronger periodic energy and clarity of the vowel perceived (Gopal 1987) . The syllable duration was defined as the duration of the test syllable waveform having test vowel from the region of its onset to its offset. The word duration of the test word was defined as the duration of the waveform from the region of its onset to its offset. The sentence duration was defined as the duration of the waveform from the region of its onset to its offset.

1) Duration of segments across carrier phrases:

Studies have shown that the sentence length affects the vowel duration (Lehiste, 1972, 1975; Nooteboom 1972; Lindblom 1975; Umeda, 1975; Balasubramaniam, 1981; 0'Shaughnessy, 1098; Port, 1981 and Bhaskara Rao, 1988). Therefore, an attempt was made to know the effect of carrier phrases on vowel duration vowel duration, syllable duration, word duration and sentence duration one way ANOVA was carried out using NCSS statistical software package (Hintze, 1992). In both males and females, there was significant difference between two carrier phrases with respect to the sentence duration having the test vowel in the word initial, medial and final positions (F ratio = 45.62, P = 0.0; F ratio = 43.05, P = 0.0 and F ratio = 34.85, P = 0.0 respectively).

There was no significant difference between word durations measured from two different carrier phrases in both males and females having the test vowel in the word initial, medial and final position (F ratio = 204, P = 0.1568; F ratio =1.17 , P = 0.2815 and F ratio = 1.88, P = 0.1730 respectively). No significant difference in syllable duration with respect to the carrier phrases in both males and females was noticed with the test vowel in the word initial, medial and final position (F ratio = 0.43, P = 0.5132; F ratio = 0.65, P = 0.4213 and F ratio = 3.88, P = 0.0516 respectively) There was no significant difference in vowel duration with respect to the carrier phrases in both males and females with the test vowel in the word initial, medial and final positions (F ratio = 0.64, P = 0.4253; F ratio = 0.67, P = 0.4143 and F ratio = 4.29, P = 0.0409 respectively).

Significant difference found only in sentence duration with respect to the two carrier phrases in spite of same number of syllables (seven syllables). This might be due to the difference in the number of words in the respective sentences. No significant difference was found in word duration, syllable duration and vowel duration probably because the observed difference in duration between the sentences was not sufficient enough to cause a shift in their durations. Thus it may be concluded that the carrier phrases used in the study had not changed the word duration, syllable duration and vowel duration. Therefore the data collected from the two different carrier phrases were considered together.

2) Duration of segments in males and females:

Studies (Zue & Lafferiere 1979; Savithri, 1983, 1986) have shown that the vowel duration differed between males and females. Table 4.1 shows the mean and SD of sentence duration, word duration , syllable duration and vowel duration in males and females with the test vowel in the word initial, medial and final positions. Graph 4.1 shows the sentence duration in males and females with the test vowel in the word initial, medial and final positions. Graphs 4.2, 4.3 and 4.4 also shows the word duration, syllable duration and vowel duration in males and females with the test vowel in the word initial, medial and final positions. An attempt was made to know the influence of sex on segmental durations, before combining the durational data obtained from two different graphs of subjects. The examination of table 4.1 and graphs 4.1, 4.2, 4.3 and 4.4 indicates that all the four durations were longer in case of females than in males with the test vowel in the word initial, medial and final positions. The sentence duration was found to be shortest when the test vowel was in the word final position in males and females (1321.31 m.secs. & 1397.87 m. secs, respectively) and was longest when the test vowel was in the word medial position in males (1397.92 m. secs.) and word initial position in females (1502.69 m. secs.). The word duration was found to be shortest when the test vowel was in the word final position in males and females (345.11 m. secs. & 372.42 m. secs, respectively) and longest when the test vowel was in the word initial position (394.72 m. secs. & 422.82 m. secs, respectively). The syllable duration was found to be shortest when the test vowel was in the word medial position in males and females (155.58 m.secs. & 160.24 m. secs, respectively) and longest when the test vowel was in the word initial position in males (163.43 m. secs.) and word final position in females (178.76 m. secs.). The vowel duration was found to be shortest when the test vowel was in the word medial position in males and females (135.67 m. sees. & 145.07 m. secs, respectively) and longest when the test vowel was in the word initial position (163.43 m. secs. & 173.64 m. secs, respectively).

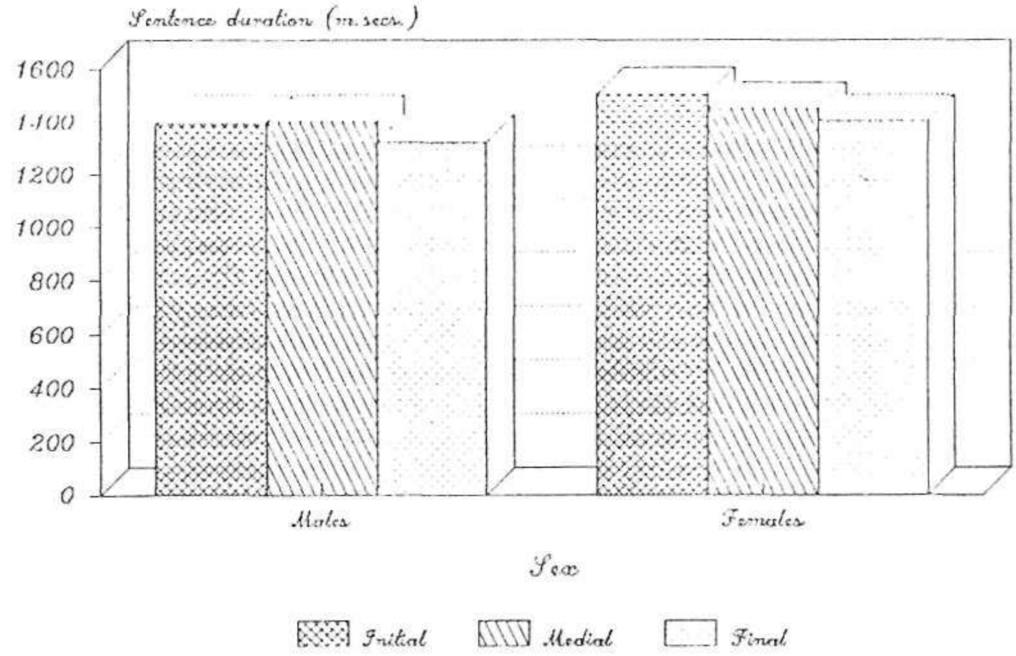
One way ANOVA was carried out using NCSS statistical software package (Hintze, 1992) to note the significance of difference in segmental durations with respect to sex. The results revealed that the sentence duration, word duration, syllable duration and vowel duration with the test vowel in

Table 4.1: Mean and SD of sentence duration, word duration, syllable duration and vowel duration in males and females in the initial, medial and final positions (in m. secs.).

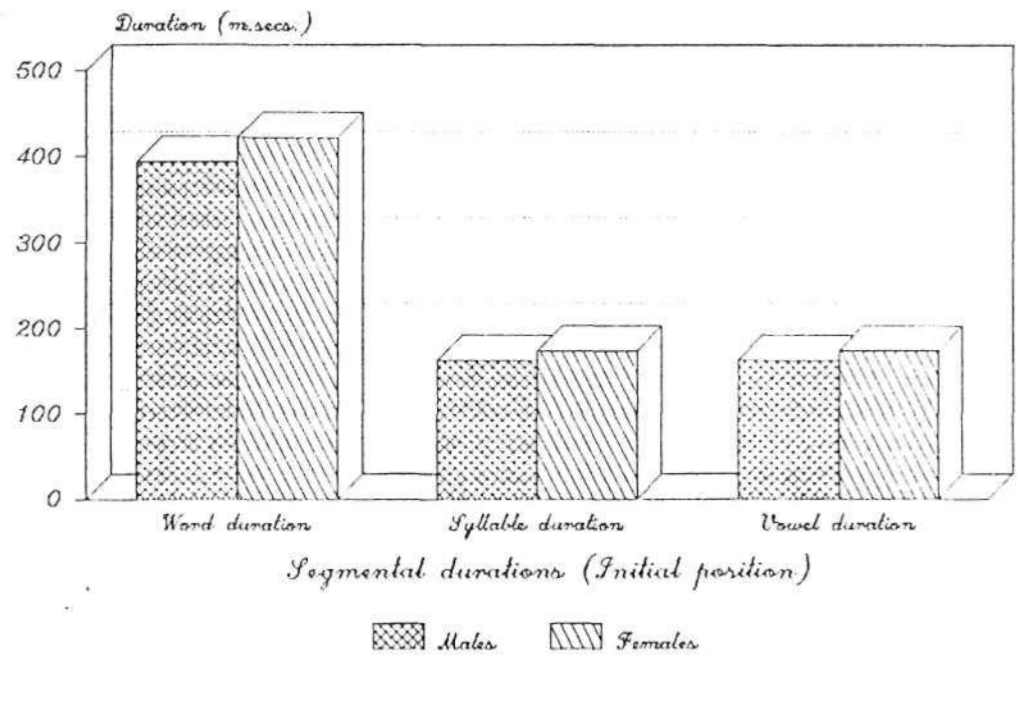
		Males		Females	
Position	Segmental duration	Mean	S.D.	Mean	S.D
Initial	Sentence duration	1391.55	127.82	1502.69	181.24
	Word duration	394.72	41.52	422.82	50.28
	Syllable duration	163.43	18.32	173.64	23.10
	Vowel duration	163.43	18.32	173.64	23.10
Medial	Sentence duration	1397.92	130.76	1447.69	174.19
	Word duration	368.13	30.62	403.13	36.82
	Syllable duration	155.58	12.61	160.24	18.99
	Vowel duration	135.67	11.68	145.07	13.63
Final	Sentence duration	1321.31	152.90	1397.87	125.01
	Word duration	345.11	38.33	372.42	34.20
	Syllable duration	158.75	26.67	178.76	28.50
	Vowel duration	143.06	21.87	163.09	24.36

the word initial and final positions showed significant difference between males and females. (F = 15.13, P = 0.0002; F = 13.21, P = 0.0004; F = 11.51, P = 0.001 and F = 10.37, P = 0.0017 respectively for the test vowel in the word initial position and F = 8.11, P = 0.0054; F = 20.35, P = 0.0; F = 27.14, P = 0.0 and F = 40.75, P = 0.0 respectively for the test vowel in the word final position). Whereas, when the test vowel was in the word medial position only the word duration and vowel duration showed significant difference with respect to sex (F = 26.58, P = 0.0; F = 15.55, P = 0.0002 respectively) and no significant difference was found in sentence duration and syllable duration with respect to sex ((F = 2.98, P = 0.0872; F = 2.92, P = 0.0904 respectively).

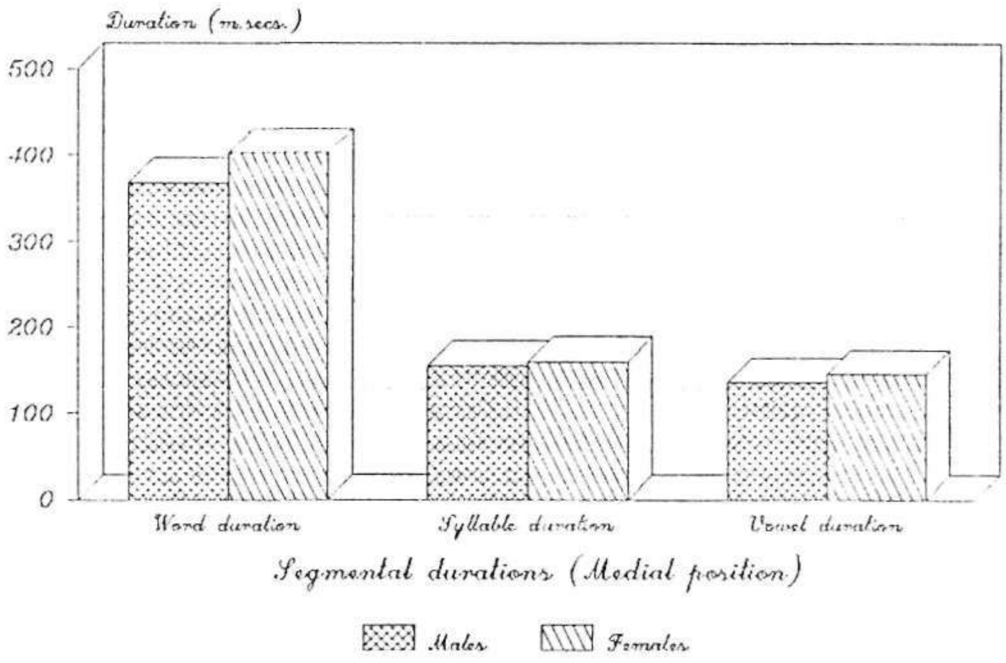
Zue & Lafferiere (1979) and Savithri (1983, 1986) have studied the vowel duration in males and females and found that females had longer vowel durations when compared with males. The results of the present study agrees with their findings. However, this view has been contradicted by Mc Donough, Ladefoged and George (1993). They found that there was no significant difference in vowel duration with respect to males and females. The results of the present study revealed that there was significant difference in segmental durations between males and females.



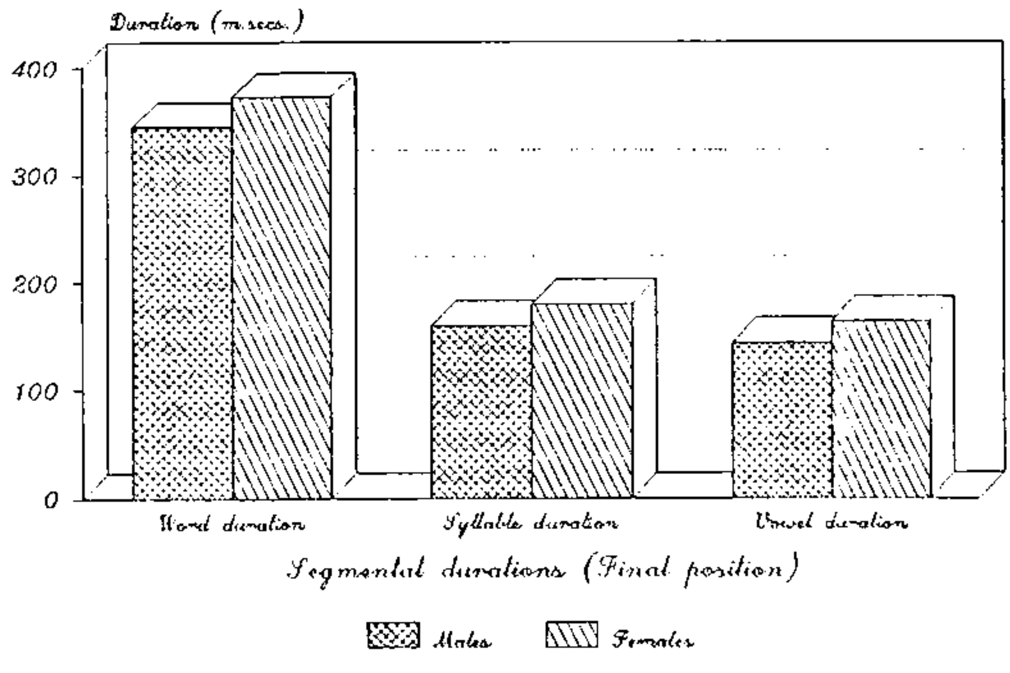
Graph 4.1: Mean of sentence duration in males and females with the test vowel in the word initial, medial and final positions.



Graph 4.2: Mean of word duration, syllable duration and vowel duration in males and females for the test vowel in the word initial position.



Graph 4.3: Mean of word duration, syllable duration and vowel duration in males and females for the test vowel in the word medial position.



Graph 4.4: Mean of word duration, syllable duration and vowel duration in males and females for the test vowel in the word final position.

3) Segmental durations and test position of vowel:

Table 4.2 shows the mean and S.D. of sentence duration, word duration, syllable duration and vowel duration for the short and long vowels in the word initial, medial and final positions. Statistical analysis was carried out to determine the effect of test vowel position on segmental durations.

a) Sentence duration:

Study of Table 4.2 and Graph 4.5 showing sentence duration with respect to the test vowel in the word initial, medial and final positions revealed the following:

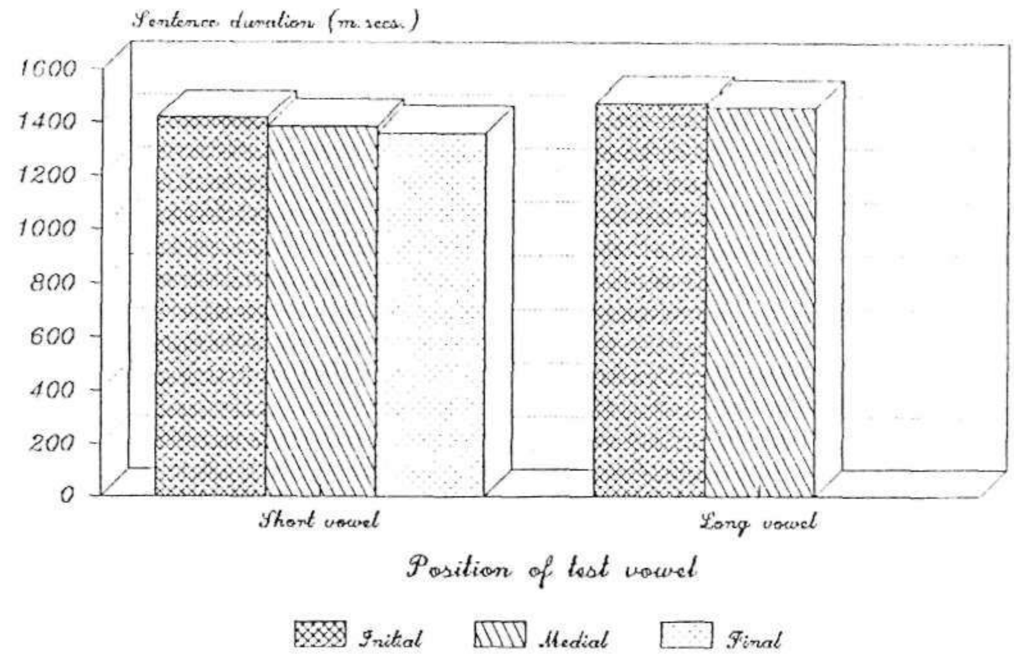
i) among short vowels the sentence duration was shortest for the test vowel in the word final position (1359.59 m.secs.) and longest in the word initial position (1418.98 m.secs).

ii) among long vowels the sentence duration was shortest for the test vowel in the word medial position (1461.15 m.secs.) and longest in the word initial position (1475.25 m.secs).

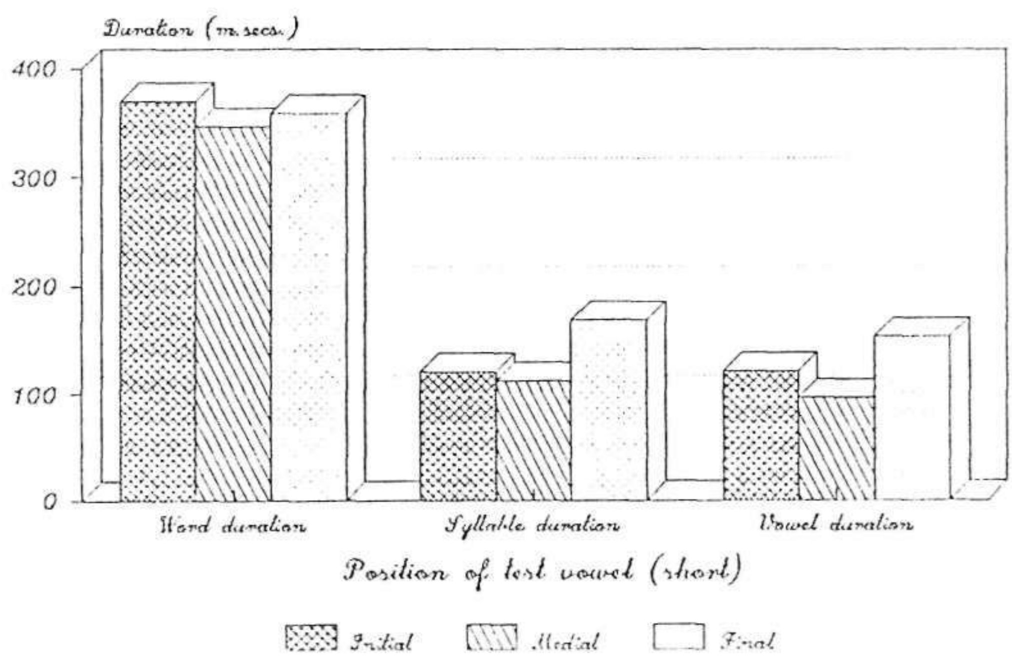
To study the significance of difference in sentence duration with respect to the test vowel position, repeated measures of ANOVA was conducted. The results revealed significant difference in case of short vowels ($F = 4.21$, $P = 0.0158$) and no significant difference in case of long vowels ($F = 0.42$, $P = 0.5167$). Duncan's test was carried out to determine the individual differences in case of short

Table 4.2: Mean and S.D. of sentece duration, word duration, syllable duration and vowel duration for the short and long vowel in the word, initial, medial and final positions (in m.sec.)

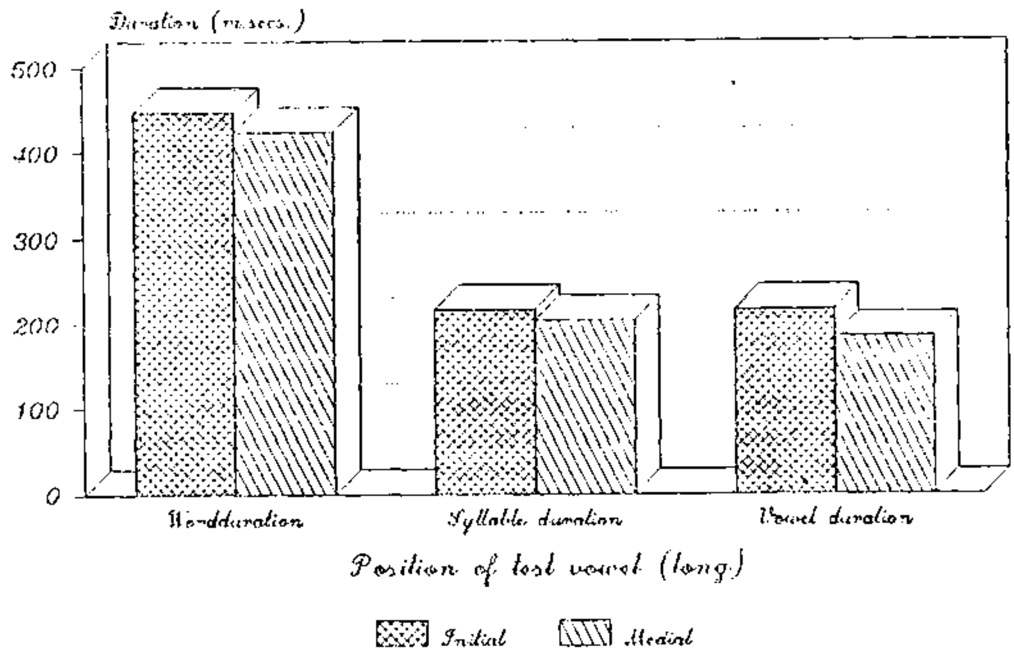
		Initial		Medial		Final	
Vowel Length	Segmental duration	Mean	S.D.	Mean	S.D	Mean	S.D
	Sentence duration	1418.98	166.18	1384.46	153.42	1359.59	154.94
	Word duration	370.12	45.37	346.89	39.47	388.77	38.09
Short	Syllable duration	120.70	24.33	112.64	18.44	168.75	28.70
	Vowel duration	120.70	24.33	96.70	16.39	153.08	23.64
	Sentence duration	1475.25	168.11	1461.15	162.31	–	–
Long	Word duration	447.42	51.10	424.37	47.61	–	–
	Syllable duration	216.36	25.63	203.18	25.06	–	–
	Vowel duration	216.36	25.63	184.04	23.11	–	–



Graph 4.5: Mean of sentence duration with respect to the test vowel position in case of short and long vowels.



Graph 4.6: Mean of word duration, syllable duration and vowel duration with respect to the test vowel position in case of short vowels.



Graph 4.7: Mean of word duration, syllable duration and vowel duration with respect to the test vowel position in case of long vowels.

vowels. The results showed that there was a significant difference in sentence duration between the initial and final test vowel position. All other combinations showed no significant difference in sentence duration.

b) Word duration:

Study of Table 4.2 and Graphs 4.6 & 4.7 showing word duration revealed the following:

i) among short vowels the word duration was shortest for the test vowel in the word medial position (346.89 m.secs) and

longest in the word initial position (370.12 m.secs).
ii) among long vowels the word duration was shortest for the test vowel in the word medial position (424.37 m.secs.) and longest in the word initial position (447.42 m.secs).

To study the significance of difference in word duration with respect to the test vowel position, repeated measures of ANOVA was conducted. The results revealed significant difference in case of short and long vowels. (F = 1033, P =0.0 and F = 14.27, P = 0.0002 respectively). Duncan's test was carried out to determine the individual differences in case of short vowels and the results revealed that there was significant difference in word duration across all the test vowel positions.

c) Syllable duration:

From the study of Table 4.2 and Graphs 4.6 & 4.7 showing syllable duration, the following conclusions were made,
i) among short vowels the syllable duration was shortest for the test vowel in the word medial position (112.64 m.secs.) and longest in the word final position (168.75 m.secs.).
ii) among long vowels the syllable duration was shortest for the test vowel in the word medial position (203.18 m.secs.) and longest in the word initial position (216.36 m.secs).

Repeated measures of ANOVA was carried out to study the significance of difference in syllable duration with respect to the test vowel position. The results showed significant difference in case of short and long vowels (F = 307.95, P = 0.0, and F = 28.52, P = 0.0 respectively). Duncan's test carried out to determine the individual difference revealed that in case of short vowels there was a significant difference in syllable duration across all the test vowel positions.

d) Vowel duration:

From the study of Table 4.2 and Graphs 4.6 & 4.7 showing vowel duration it is clear that:

i) among short vowels the vowel duration was shortest for the test vowel in the word medial position (96.70m.secs) and longest in the word final position (153.08 m.secs).

ii) among short vowels the vowel duration was shortest for the test vowel in the word medial position (184.83 m.secs.) and longest in the word initial position (216.83 m.secs.).

To study the significance of difference in vowel duration with respect to the test vowel position, repeated measures of ANOVA was conducted. The results showed significant difference in cast of short and long vowels (F = 326.85, P = 0.0, and F = 187.83, P = 0.0 respectively).

Duncan's test carried out to determine the individual differences revealed that in case of short vowels there was a significant difference in vowel duration across all the test vowel positions.

The findings can be concluded stating that there is a significant difference in sentence duration, word duration, syllable duration and vowel duration with respect to the test position of the vowel in case of short vowels. In case of long vowels there is a significant difference in word duration, syllable duration and vowel duration with respect to the test position of the vowel, whereas no significant difference was observed in sentence duration with respect to the test position of vowel.

4) Segmental durations and vowels

A) Test vowel in word initial position

Table 4.3 shows the mean and S.D. of sentence duration, word duration, syllable duration and vowel duration for the ten Malayalam vowels in the word initial position. Graph 4.8 shows the mean of sentence duration, word duration, syllable duration and vowel duration for the ten Malayalam vowels in the word initial position. Statistical analysis were carried out by considering the short and long vowels individually and by combining male and female groups.

a) Sentence duration:

Study of Table 4.3 and Graph 4.8 presenting sentence duration revealed the following:

i) among short vowels, the sentence duration was shortest (1401.10 m.secs.) in case of test vowel /a/ and it was longest (1449.54 m.secs.) in case of test vowel /e/.

ii) among long vowels, the sentence duration was shortest (1443.53 m. secs.) in case of test vowel /o:/ and it was longest (1498.71 m. sees) in case of test vowel /i:/.

To study the significance of difference in sentence duration having different vowels, repeated measures of ANOVA was conducted. The results reveled significant difference in case of short vowels (F = 7.97 and P = 0.0) and long vowels (F = 6.98 and P = 0.0). Duncan's test was carried out to determine the individual differences. The results revealed that in case of short vowels the vowel /e/ was significantly different from other vowels. In case of long vowels, significant difference was observed for the vowel /o:/ with all other vowels and also for vowel /u:/ with vowel /i:/. All the other vowel combinations did not show any significant difference in sentence duration.

b) Word duration:

Study of Table 4.3 and Graph 4.8 presenting word duration revealed that:

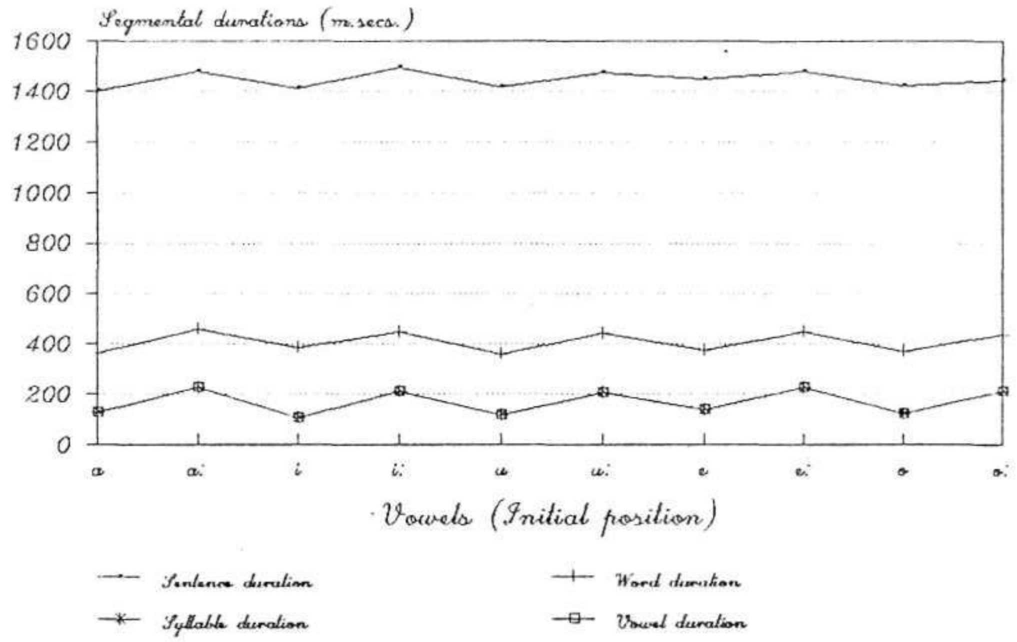
i) among short vowels the word duration of the test word having /a/ was shortest (359.65 m. secs) and the word duration of the test word having /i/ was longest (383.27 m. secs.).

ii) among long vowels, the word duration of the test word having /o:/ was shortest (437.41 m. secs.) and the word duration of the test word having /a:/ was longest (459.68 m. secs.).

Repeated measures of ANOVA was carried out to study the significance of difference in word duration having different vowels. The results revealed significant difference in case of test words with short and long vowels (F = 16.15, P = 0.0 and F = 10.97, P = 0.0 respectively). Duncan's test was carried out to study the individual differences. The results showed that in case of test words with short vowels there was no significant difference between /o/ & /e/ and /a/ & /u/. In case of test words with long vowels there was no significant difference between /o:/ & /u:/, /u:/ & /i:/ and /i:/ & /e:/. All the other vowel combinations showed significant difference in word duration.

Table 4.3: Mean and S.D. of sentence duration, word duration syllable duration and vowel duration across all the vowels in the word initial positions (in m.secs.).

Vowels		Sentence duration	Word duration	Syllable duration	Vowel duration
a	Mean	1401.10	361.85	125.32	125.32
	S.D.	167.27	48.33	22.70	22.70
a:	Mean	1479.90	459.68	224.96	224.96
	S.D.	160.59	47.14	24.82	24.82
i	Mean	1409.62	388.27	104.26	104.26
	S.D.	168.48	41.49	20.01	20.01
i:	Mean	1498.71	446.81	211.12	211.12
	S.D.	168.24	53.46	25.62	25.62
u	Mean	1414.40	359.65	115.11	115.11
	S.D.	162.84	41.85	20.74	20.74
u:	Mean	1473.05	441.86	207.00	207.00
	S.D.	163.10	50.46	24.08	24.08
e	Mean	1449.54	376.02	137.26	137.26
	S.D.	162.31	48.14	24.21	24.21
e:	Mean	1481.06	451.32	228.53	228.53
	S.D.	170.92	54.97	23.69	23.69
o	Mean	1420.25	369.80	121.57	121.57
	S.D.	169.12	43.15	21.15	21.15
o:	Mean	1443.53	437.41	210.21	210.21
	S.D.	175.81	47.07	22.78	22.78



Graph 4.8: Mean of sentence duration, word duration, syllable duration and vowel duration for the ten Malayalam vowels in the word initial position.

c) Syllable duration:

From the study of Table 4.3 and Graph 4.8 showing syllable duration, it can be stated that:

i) among short vowels the duration of syllable having /i/ (104.26 m. secs.) was shortest and the duration of the syllable having /e/ (137.26 m. sees.) was longest,

ii) among long vowels the duration of syllable having /u:/ (207 m. secs) was shortest and the duration of the syllable having /e:/ was longest (228.53 m. secs.).

To know the significance of difference in the syllable duration having different vowels, repeated measures of ANOVA was carried out and found that the syllable duration was significantly different in case of both short and long vowels ($F = 56.69$, $P = 0.0$ and $F = 32.50$, $P = 0.0$ respectively). Further to check the individual differences, Duncan's test was administered and the results revealed no significant difference between /o/ & /a/ in case of short vowels. Whereas, in case of long vowels no significant difference was observed between /i:/ & /u:/, /a:/ & /e:/, /i:/ & /o:/ and /u:/ & /o:/. All the other vowel combination showed significant difference in syllable duration.

d) Vowel duration:

From the study of Table 4.3 and Graph 4.8 showing vowel duration across short and long vowels, the following conclusions were made:

i) among the short vowels the vowel /u/ showed shortest duration (104.26 m. secs.) and the vowel /e/ showed longest duration (137.26 m. secs.)

ii) among the long vowels /u:/ showed that the shortest duration (207.00 m. secs.) and /e:/ showed the longest vowel duration (228.53 m. secs.)

Repeated measures of ANOVA was carried out to know the significance of mean difference across different vowels. The test revealed that vowel duration was significant in case of both short and long vowel groups (F = 60.74, P = 0.0 and F = 38.54, P = 0.0 respectively).

Further Duncan's test was conducted and the result revealed no significant difference between /o/ & /a/ in case of short vowel groups and no significant difference between /u:/ & /o:/, /o:/ & /i:/ and /a:/ & /e:/ in case of long vowel groups. All the other vowel combinations showed significant difference in vowel duration.

B) Test vowel in word medial position:

Table 4.4 shows the mean and S.D. of sentence duration, word duration, syllable duration and vowel duration for the ten Malayalam vowels in the word medial position. Graph 4.9 shows the mean of sentence duration, word duration, syllable duration and vowel duration for the ten Malayalam vowels in the word medial position. Statistical analysis was carried out by considering the short and long vowels separately and by combining male and female data.

a) Sentence duration:

Study of Table 4.4 and Graph 4.9 presenting sentence duration revealed the following:

i) among short vowels, the sentence duration was shortest (1365.62 m. secs.) in case of test vowel /a/ and was longest (1397.8 m. secs.) in case of test vowel /e/.

ii) among long vowels, the sentence duration was shortest (1448.58 m. secs) in case of test vowel /u:/ and was longest (1469.19 m. secs.) in case of test vowel /e:/.

To study the significance of difference in sentence duration having different vowels, repeated measures of ANOVA was carrried out. The results revealed significant difference in case of short vowels (F = 3.61, P = 0.0067). and no significant difference in case of long vowels (F = 1.39, P = 0.2377). Duncan's test was carried out to determine the individual differences in case of short vowels. The results revealed no significant difference between /a/ & /i/, /a/ & /u/ and /a/ & /e/. All the other vowel combinations showed significant difference in sentence duration.

b) Word duration:

Study of Table 4.4 and Graph 4.9 presenting word duration revealed that:

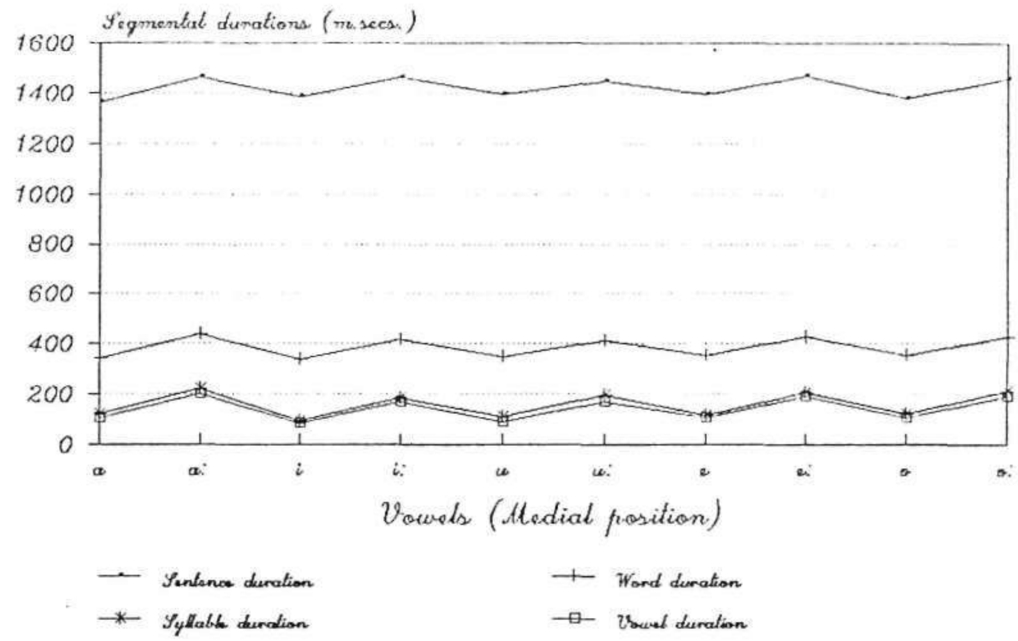
i) among short vowels the word duration of the test word having /i/ was shortest (338.79 m. secs.) and the word duration of the test word having /o/ was longest (352.76 m. secs.).

ii) among long vowels, the word duration of the test word having /u:/ was shortest (413.97 m. secs.) and the word duration of the test word having /a:/ was longest (438.11 m.secs)

Repeated measures of ANOVA was carried out to study the significance of difference in word duration having different vowels. The results revealed significant difference in case of test words with short and long vowels (F = 11.95, P= 0.0 respectively). Duncan's test was carried out to study the individual differences. The results showed that in case of test words with short vowels there was no significant difference between /i/ & /a/, /u/ & /e/, /u/ & /o/ and /e/ & /o/. In case of test words with long vowels there was no significant difference between /u:/ & /i:/ and /e:/ & /o:/. All the other vowels combinations showed significant differences in word duration.

Table 4.4: Mean and S.D. of sentence duration, word duration, syllable duration and vowel duration across all the vowels in the word medial positions (in m.secs.).

Vowels		Sentence duration	Word duration	Syllable duration	Vowel duration
a	Mean	1365.62	343.05	118.10	103.98
	S.D.	155.03	37.76	16.53	13.61
a:	Mean	1463.76	438.11	218.72	202.40
	S.D.	160.21	46.52	24.11	17.93
i	Mean	1385.93	338.79	96.05	85.59
	S.D.	157.36	40.56	15.67	11.67
i:	Mean	1462.30	415.97	184.69	170.05
	S.D.	172.13	45.56	21.81	19.91
u	Mean	1394.46	347.91	110.21	86.75
	S.D.	148.85	41.23	15.59	14.72
u:	Mean	1448.58	413.97	196.73	167.47
	S.D.	162.98	43.75	22.12	15.35
e	Mean	1397.80	351.95	116.76	104.69
	S.D.	145.81	39.98	16.67	14.30
e:	Mean	1469.19	426.61	204.89	191.59
	S.D.	155.61	51.88	24.53	21.92
o	Mean	1378.48	352.76	122.09	102.50
	S.D.	160.44	36.60	15.87	15.30
o:	Mean	1461.92	427.17	210.87	188.68
	S.D.	162.73	46.86	17.97	19.09



Graph 4.9: Mean of sentence duration, word duration, syllable duration and vowel duration for the ten Malayalam vowels in the word medial position.

c) Syllable duration:

From the study of Table 4.4 and Graph 4.9 showing syllable duration, it can be stated that:

i) among short vowels the duration of syllable having /i/ (96.05 m. secs.) was shortest and the duration of the syllable having /o/ (122.09 m. secs.) was longest,

ii) among long vowels the duration of syllable having /i:/ (184.69 sees) was shortest and the duration of the syllable having /a:/ was longest (218.72 m. secs.).

To know the significance of difference m the syllable duration having different vowels, repeated measures of ANOVA was carried out and found that the syllable duration was significantly different in case of both short and long vowels ($F = 96.19$, $P = 0.0$ and $F = 60.04$, $P = 0.0$ respectively). Further to check the individual differences, Duncan's test was administered and the results revealed no significant difference between /e/ & /a/. All other vowel combinations showed significant difference in the syllable duration.

d) Vowel duration:

From the study of Table 4.4 and Graph 4.9 showing vowel duration across short and long vowels, it is evident that:
i) among the short vowels the vowel /i/ showed shortest duration (85.59 m. secs.) and the vowel /e/ showed longest duration (104.69 m. secs.).
ii) among the long vowels /u:/ showed the shortest duration (167 47 m. secs.) and /a:/ showed the longest vowel duration (202.40 m. secs.).

Repeated measures of ANOVA was carried out to know the significance of mean difference across different vowels. The test revealed that vowel duration was significant in case of both short and long vowel groups ($F = 117.00$, $P = 0.0$ and $F = 145.91$, $P = 0.0$ respectively).

Duncan's test was conducted to know the individual differences and the results revealed no significant difference between /i/ & /u/, /o/ & /a/ and /a/ & /e/ in case of short vowel groups. In case of long vowel groups no significant difference was noticed between /u:/ & /i:/ and /o:/ & /e:/. All the other vowel combinations showed significant difference in vowel duration.

C) Test words in word final position

Table 4.5 shows the mean and S.D. of sentence duration, word duration, syllable duration and vowel duration for the the short vowels in the word final position. Graph 4.10 shows the mean of sentence duration, word duration, syllable duration and vowel duration for the short Malayalam vowels in the word final position. Statistical analysis was carried out by combining male and female groups.

a) Sentence duration:

Study of Table 4.5 and Graph 4.10, presenting sentence duration revealed that among the short vowels, the sentence duration was shortest (1335.07 m. secs.) in case of test vowel /u/ and was longest (1375.58 m. secs.) in case of vowel /a/.

To study the significance of difference in sentence duration having different short vowels, repeated measures of ANOVA was conducted. The results revealed significant difference in sentence duration (F = 4.54, P = 0.0014). Duncan's test was carried out to determine the individual differences. The results revealed that the short vowel /u/ was significantly different from all other vowels. All other combinations showed no significant difference in sentence duration.

b) Word duration:

Study of Table 4.5 and Graph 4.10, presenting word duration revealed that the word duration of the test word having /e/ was shortest (352.77 m. secs.) and the word duration of the test word having /a/ was longest (366.29 m. secs.).

Repeated measures of ANOVA was carried out to study the significance of difference in word duration having different short vowels. The results revealed significant difference in word duration (F = 6.66, P = 0.0). Further Duncan's test was carried out to study the individual differences. The results showed that there was no significant differences in word duration for the following combinations; /e/ & /u/, /u/ & /o/, /o/ & /i/ and /i/ & /a/. All other vowel combinations showed significant differences.

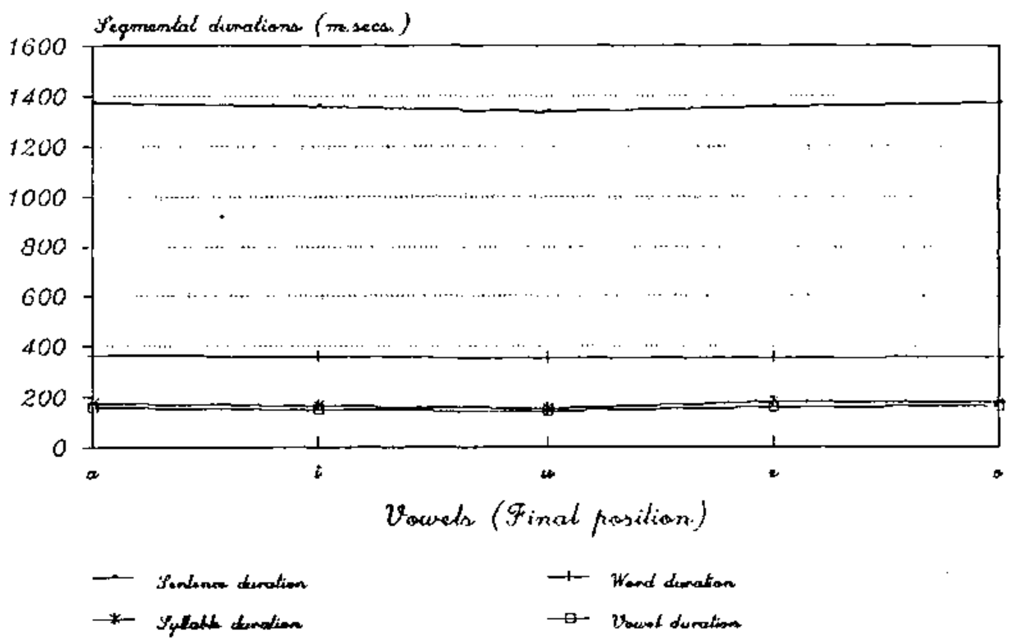
c) Syllable duration:

From the study of Table 4.5 and Graph 4.10, showing syllable duration, across short vowels it can be stated that, the duration of syllable having /u/ was shortest (153.95 m. secs.) and the duration of the syllable having /e/ was longest (177.32 m. secs.)

To know the significance of difference in the syllable duration having different vowels, repeated measures of ANOVA was carried out and found that the syllable duration was significantly different among the short vowels (F = 32.63, P = 0.0). Further to check the individual differences, Duncan's test was administered and the results revealed no significant difference in syllable duration between /a/ & /o/, /a/ & /e/ and /e/ & /o/. All other combinations showed significant difference in the syllable duration.

Table 4.5: Mean and S.D. of sentence duration, word duration, syllable duration and vowel duration across all the vowels in the word final positions (in m.secs.).

Vowels		Sentence duration	Word duration	Syllable duration	Vowel duration
a	Mean	1375.58	366.29	174.63	155.90
	S.D.	144.66	38.18	28.57	24.15
i	Mean	1358.87	361.04	161.33	144.72
	S.D.	161.27	35.25	29.93	23.81
u	Mean	1335.07	354.64	153.95	143.97
	S.D.	161.91	39.08	25.11	20.94
e	Mean	1356.18	352.77	177.32	159.61
	S.D.	163.85	37.79	27.24	23.18
o	Mean	1372.25	359.09	176.53	161.20
	S.D.	141.29	39.26	24.93	20.47



Graph 4.10: Mean of sentence duration, word duration, syllable duration and vowel duration for the ten Malayalam vowels in the word final position.

d) Vowel duration:

From the study of Table 4.5 and Graph 4.10, showing vowel duration across short vowels, it is evident that, the vowel /u/ showed shortest duration (143.97 m. secs.) and the vowel /o/ showed longest duration (161.20 in. secs.).

Repeated measures of ANOVA was carried out to know the significance of mean difference across different vowels. The test revealed that vowel duration was significant across the vowels (F = 33.98, P = 0.0). However to study the individual difference Duncan's test was carried out and the results revealed no significant difference between /u/ & /i/, /o/ & /e/ and /e/ & /o/. All the other vowel combinations showed significant difference in their duration.

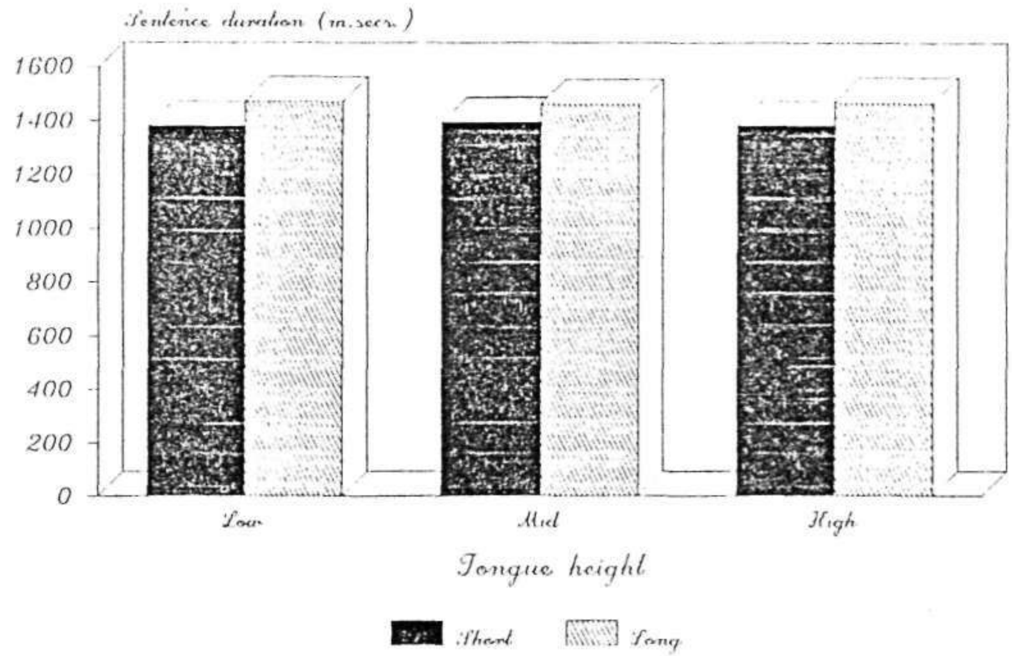
To conclude it can be stated that there is a significant difference in sentence duration, word duration, syllable duration and vowel duration with respect to the test vowels in the word initial, medial and final position.

5) **Segmental duration and tongue height:**

Further the sentence duration, word duration, syllable duration and vowel duration were g rouped according to the tongue height (low, mid and high) of the test vowel. Table 4.6 shows the mean and standard deviation of sentence duration, word duration, syllable duration and vowel duration for low, mid and high vowels.

a) Sentence duration and tongue height:

Table 4.6 shows the mean and S.D. of sentence duration for low, mid and high vowels, and Graph 4.11 shows the mean of sentence duration for low, mid and high vowels, in case of both short and long vowels. Following were the observations made from the table and graph:



Graph 4.11: Mean of sentence duration with respect to tongue height for short and long vowels (in m.secs.).

l) among the sentences having short (lax) test vowel, sentence having mid vowels had longest duration (1395.75 m.secs.) and sentences having low vowels had the shortest duration (1380.76 m. secs.).

ii) among the sentence having long (tense) test vowel, sentence duration was found to be shortest (1463.92 m. secs.) in case of mid vowels and longest in case of low vowels (1472.83 m. secs.).

To know the significance of difference in sentence duration between low, mid and high vowels, repeated measures of ANOVA was carried out. The results showed that there was no significant difference in sentence duration between low, mid and high vowels with reference to sentence duration having short or long vowels. (F = 1.29, P = 0.2746 and F = 0.23 P = 0.7975 respectively).

b) Word duration and tongue height:

Table 4.6 shows the mean and S.D. of word duration for low, mid and high vowels with respect to both short and long vowels. Graph 4.12 also shows the mean of word duration for low, mid and high vowels. Following were the observations made from the table and graph:

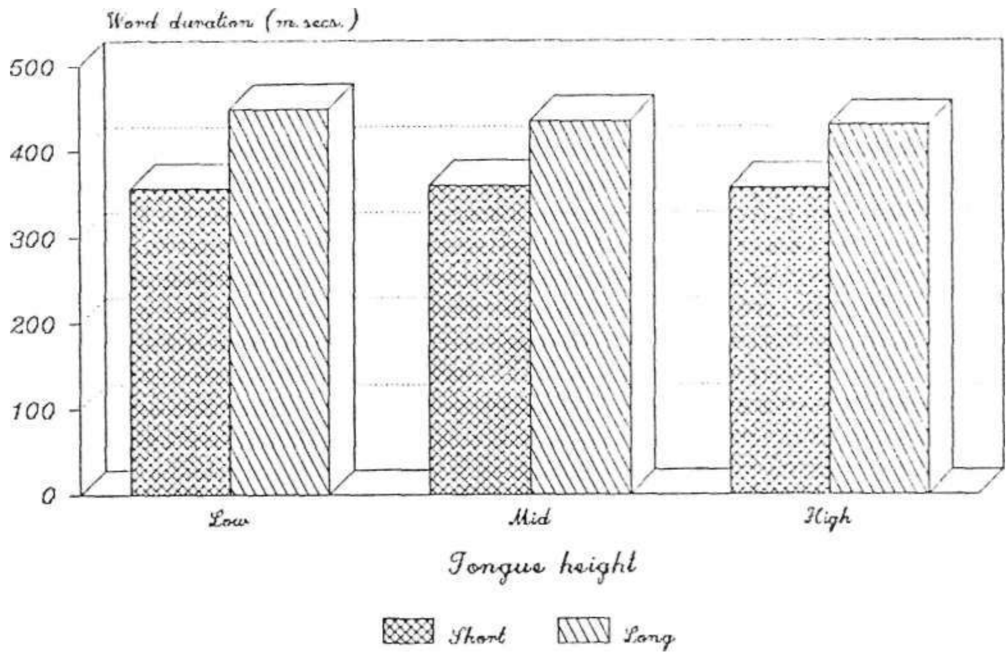
i) among the words having short (lax) vowels, words having mid vowels had longest duration (360.40 m. secs.) whereas words having low vowels had the shortest duration (357.06 m.secs.).

ii) among the words having long (tense) vowels, the word duration was found to be longest (448.89 m. secs.) in case of low vowels and shortest (429.65 m. secs.) in case of high vowels.

To know the significance of difference in word duration between low, mid and high vowels, repeated measures of ANOVA was conducted. The results showed that there was no significant difference between low, mid and high vowels with reference to word duration having short vowels (F = 0.93, P = 0.3943), Whereas significant difference was noticed in case of long vowels (F = 9.78, P = 0.0001). Duncan's test was carried out to study the individual differences in case of long vowels and the results revealed that there is a significant difference in word duration between low, mid and low and high vowels. No significant difference was noticed between mid and high vowels with respect to word duration.

Table 4.6: Mean and S.D of sentence duration, word duration, syllable duration and vowel duration for low, mid and high vowels ((in m.secs.).

		Sentence duration		Word duration		Syllable duration		Vowel duration	
Height	Length	Mean	S.D.	Mean	S.D	Mean	S.D.	Mean	S.D
High	Short	1383.06	162.01	357.55	42.11	123.49	33.06	113.40	30.72
	Long	1470.67	167.04	429.65	50.50	199.89	25.51	189.16	29.33
Mid	Short	1395.75	159.92	360.40	41.89	141.92	33.72	131.14	31.03
	Long	1463.92	166.38	435.63	51.12	213.62	24.02	204.75	27.11
Low	Short	1380.76	156.12	357.06	42.78	139.35	34.13	128.37	29.28
	Long	1471.83	160.20	448.89	47.95	221.84	24.61	214.35	23.52



Graph 4.12: Mean of word duration with respect to tongue height for short and long vowels (in m.secs.).

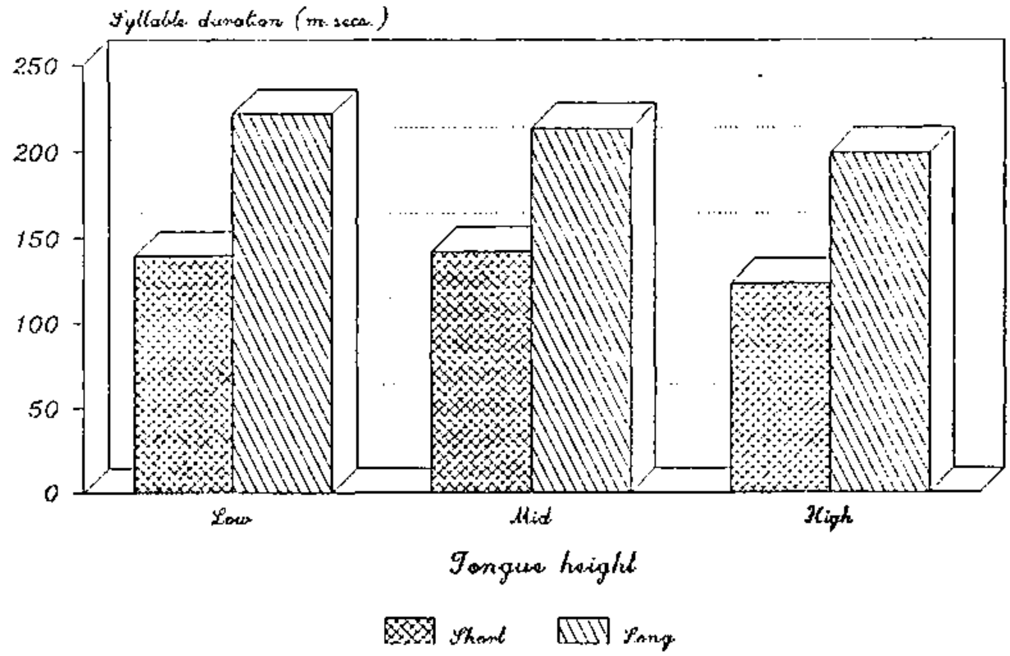
c) **Syllable duration and vowel height:**

Table 4.6 shows the mean and S.D. of syllable duration for low, mid and high vowels. Graph 4.13 shows the mean of syllable duration for low, mid and high vowels in case of both short and long vowels. Following were the observations made from the table and graph:

i) among the syllables having short (lax) vowels, syllables having mid vowels had longest duration (141.992 m. secs) and syllables having high vowels had shortest duration (123.49 m. secs.)

b) among the syllables having long (tense) vowels, the syllables having low vowels had the longest duration (221.84 m. secs.) and the syllables having high vowels had the shortest duration (199.89 m. secs.).

To know the significance of difference in syllable duration between high, mid and low vowels, repeated measures of ANOVA was carried out separately for short and long vowel groups. The results showed significant difference in syllable duration among both short and long vowels groups. ($F = 50.03$, $P = 0.0$ and $F = 60.58$, $P = 0.0$ respectively). To study the individual differences in syllable duration with respect to low, mid and high vowels Duncan's test was carried out. The results revealed that among the short vowels significant difference was observed between the low & high vowels and mid & high vowels; whereas, no significant difference was observed between low & mid vowels. Among the long vowel groups significant difference in syllable duration duration was observed between all the vowel groups.



Graph 4.13: Mean of syllable duration with respect to tongue **height for short and long vowels (in m.secs.).**

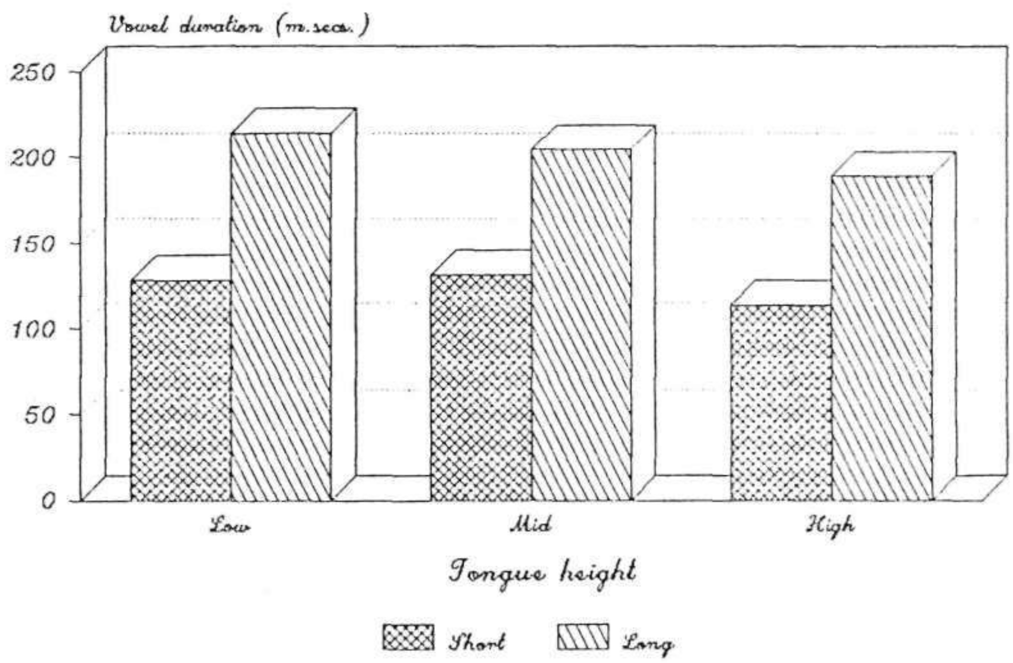
d) Vowel duration and tongue height:

Table 4.6 shows mean and S.D. of vowel duration for low, mid and high vowels and Graph 4.14 shows the mean of vowel duration for low, mid and high vowels. Observations of the table and graph revealed the following;

i) among the short (lax) vowels, mid vowels had the longest duration (131.14 m. secs.) and the high vowels had the shortest duration (113.40 m. secs.).

b) among the long (tense) vowels, low vowels had the highest duration (214.35 m. secs) and high vowels had the shortest duration (189.16 m. secs.).

ANOVA test was administered to measure the significance of difference in vowel duration with respect to tongue height. ANOVA test results showed a significant difference in vowel duration for the short and long vowel groups (F = 55.31, P = 0.0. and F = 64.79, P = 0.0 respectively). Further to study about the individual differences Duncan's test was administered and the test results revealed that in case of short vowels there was a significant difference between low & high vowels and mid & high vowels. Whereas, no



Graph 4.14: Mean of vowel duration with respect to tongue height for short and long vowels (in m.secs.).

significant difference was noticed between the low & and mid vowels in terms of vowel duration. In case of long vowels significant difference in vowel duration was found between all the vowel groups.

It can be concluded from the above that the tongue height had an effect on the intrinsic duration of the vowel. As the tongue height increased the duration of the vowel decreased and the change was gradual. The low vowels had longer duration, whereas the high vowels had shorter duration, except that among the short vowel groups the mid vowels showed longest duration. The shorter duration in case of high vowels may be due to the requirement of higher effort to produce them. This finding was in agreement with the studies conducted by Lehiste (1970); Klatt (1976); Balasubramanian (1981); O'Shaughnessy (1981); Mitleb (1984); Savithri (1984, 1986); Choi (1992); Shalev, Ladefoged & Bhaskara Rao (1993) and Venkatesh (1995). The syllable duration and vowel duration (in case of short vowel groups) and the word duration, syllable duration and vowel duration (in case of long vowel groups) were found to be significantly different with respect to vowel height. Whereas, no significant difference was found between low, mid and high vowels with respect to sentence duration and word duration in case of short vowels and sentence duration in case of long vowels.

6) Segmental duration and tongue position:

Further the sentence duration, word duration, syllable duration and vowel duration were grouped according to the tongue position (front, central and back) of the test vowel. The segmental duration were discussed separately for the short and long vowels. Table 4.7 shows the mean and standard deviation of sentence duration, word duration, syllable duration and vowel duration for front, central and back vowels.

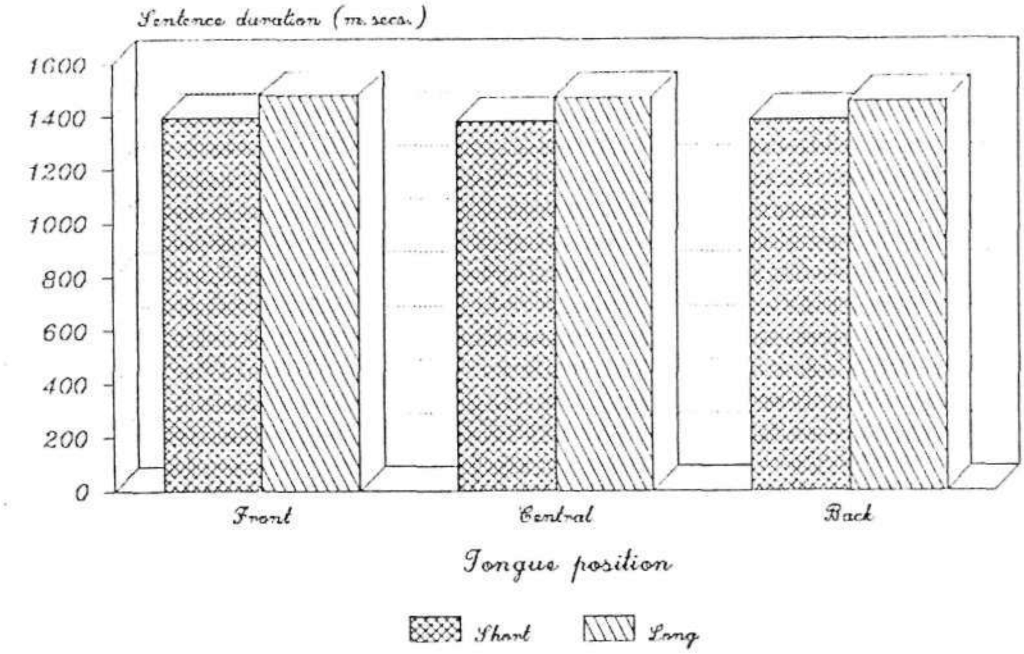
a) Sentence duration and tongue position:

Table 4.7 shows the mean and S.D. of sentence duration for front, central and back vowels and Graph 4.15 shows the mean of sentence duration for shorthand long vowels with respect to tongue position. Following observations were made from the table and graph:

i) among the duration of sentence with short (lax) vowel, the sentence having front vowel had longest duration (1392.99 m.secs.) and duration was shortest (1380.77 m.secs) in the case of sentence with central vowels.

Table 4.7: Mean and S.D of sentence duration, word duration, syllable duration and vowel duration for front, central and back vowels ((in m.secs.).

		Sentence duration		Word duration		Syllable duration		Vowel duration	
Position	Length	Mean	S.D.	Mean	S.D	Mean	S.D.	Mean	S.D
Front	Short	1392.99	162.48	360.64	43.28	132.16	37.34	122.69	32.96
	Long	1477.82	166.80	435.18	53.40	207.31	28.56	200.57	31.28
Central	Short	1380.77	156.11	357.06	42.78	139.35	34.13	128.37	29.28
	Long	1471.83	160.20	448.89	47.95	221.84	24.61	214.35	23.52
Back	Short	1385.82	159.61	357.31	40.66	133.24	31.70	121.85	31.26
	Long	1456.77	166.03	430.10	48.13	206.20	22.50	193.34	26.70



Graph 4.15: Mean of sentence duration with respect to tongue position for short and long vowels (in m.secs.).

ii) among the duration of sentence with long (tense) vowel, sentence having the front vowels had the longest duration (1477.82 m. secs.) and the duration was shortest (1456.77 m.secs.) in case of sentence with back vowels.

Repeated measures of ANOVA was conducted to know the significance of mean difference in sentence duration among the front, central and back vowels. The results revealed that there was no significant difference among the three vowels groups in terms of sentence duration for the short and long vowels (F = 0.65, P = 0.5224 and F = 1.68 P = 0.1864 respectively).

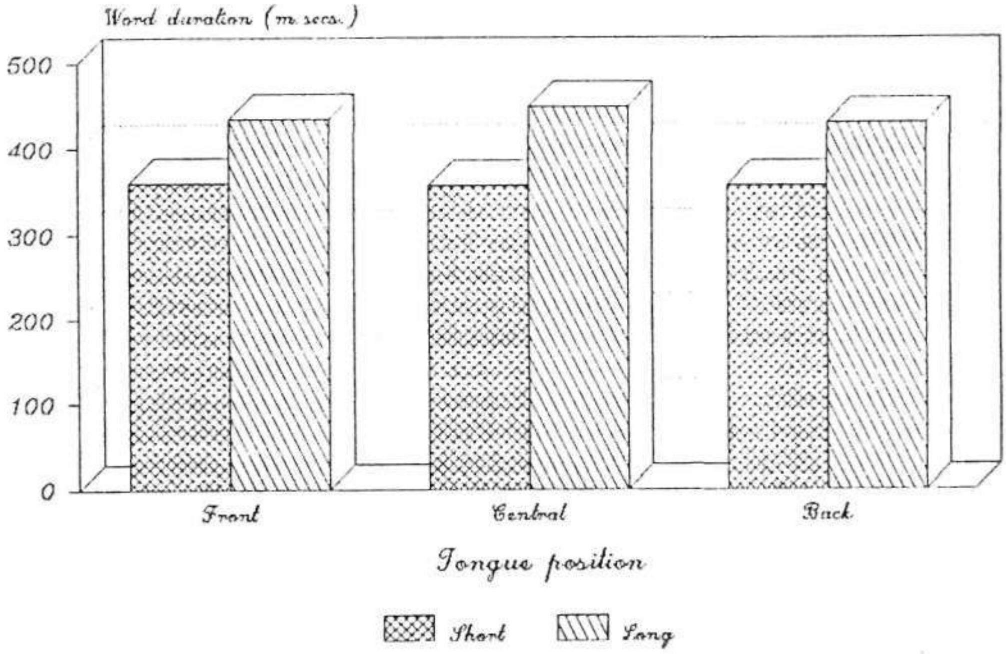
b) Word duration and tongue position:

Table 4.7 shows the mean and S.D. of word duration for front central and back vowels and Graph 4.16 also shows the mean of word duration with respect to front, central and back vowels. Following observations were made from the table and graph.

i) among duration of the words with short (lax) vowels, the words having front vowels had the longest duration (360.64 m. secs.) and the words having central vowels had the shortest duration (357.06 m.secs.).

ii) among the duration the words with long (tense) vowels, the words having central vowels had the longest duration (448.89 m. sees) and the words having back vowels had the shortest duration (430.10 m.secs).

To know the significance of mean difference among front, central and back vowels in terms of word duration repeated measures of ANOVA was conducted. The results revealed no significant difference in the case of short vowels (F = 1.18, P = 0.3064). Whereas, in the case of long vowels



Graph 4.16: Mean of word duration with respect to tongue position for short and long vowels (in m.secs.).

significant difference among front, central and back vowels in terms of word duration was noticed (F = 9.38, P = 0.0001). To study the individual difference in case of long vowels, Duncan's test was administered and the results showed significant difference between the front & central and central & back vowels, whereas there was no significant difference between the front and back vowels in terms of word duration.

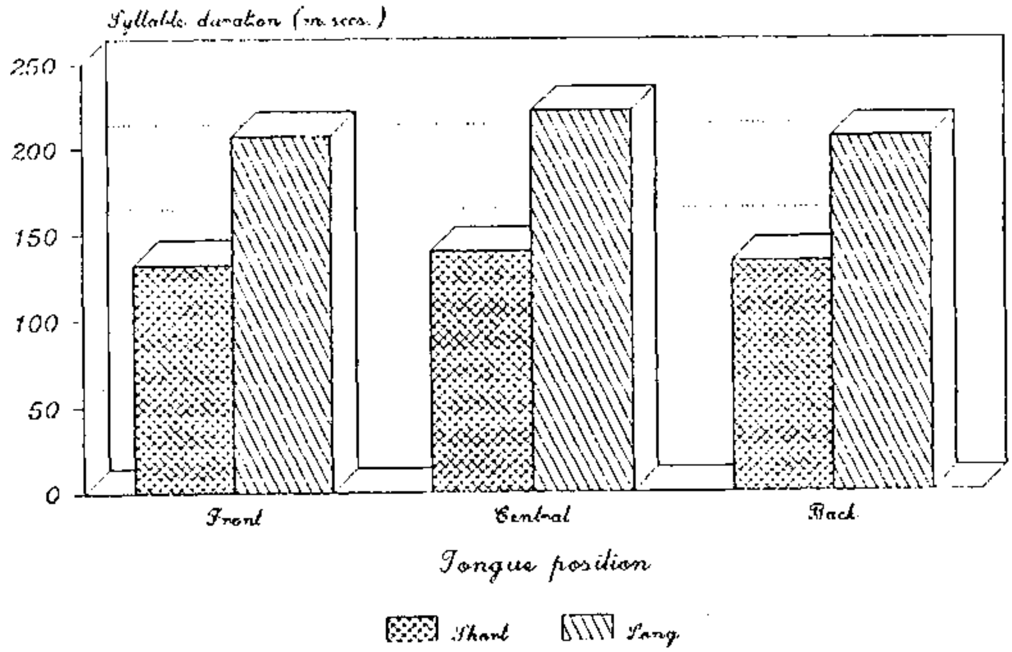
c) Syllable duration and tongue position:

The mean and S.D of syllable duration for front, central and back vowels are presented in Table 4.7 and Graph 4.17 shows the mean of syllable duration for front, central and back vowels. The following observations were made from the table and graph:

i) among the syllables with short (lax) vowels, syllables having central vowels had the longest duration (139.35 m.secs.) and syllables having front vowels had the shortest duration (132.16 m.secs.).

ii) among the syllables having long (tense) vowels, syllables having central vowels had the longest duration (221.84 m. secs.) and syllables having back vowels had the shortest duration (206.20 m.secs.).

Repeated measures of ANOVA was conducted to know the significance of mean difference among front, central and back vowels in terms of syllable duration. The results showed significant difference among front, central and back vowels in terms of syllable duration for both short and long vowels ($F = 4.59$, $P = 0.0103$ and $F = 28.22$, $P = 0.0$ respectively). Further to verify the individual differences among short and long vowels Duncan's test was carried out and the results revealed that in case of both long and short vowels there

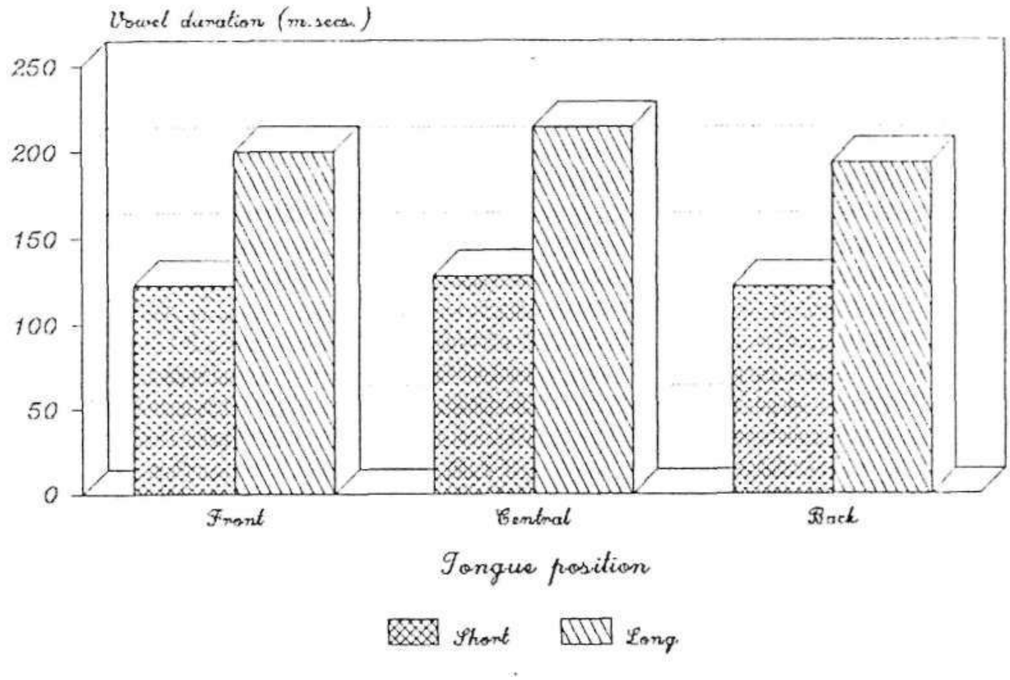


Graph 4.17: Mean of syllable duration with respect to tongue position for short and long vowels (in m.secs.).

was significant difference between central & front vowels and central & back vowels in terms of syllable duration, whereas there was no significant difference between front and back vowels.

d) Vowel duration and tongue position:

From the study of Table 4.7 showing mean and S.D of vowel duration for front, central and back vowels and Graph 4.18 showing vowel duration for front, central and back vowels, it can be stated that in case of both short and long vowels, the central vowels had the longest vowel duration



Graph 4.18: Mean of vowel duration with respect to tongue position for short and long vowels (in m.secs.).

(128.37 m.secs. and 214.35 m.secs respectively) and the back vowels had the shortest vowel duration (121.85 m.secs and 193.34 m.secs. respectively).

To measure the significance of difference in vowel duration with respect to tongue position, repeated measures of ANOVA was conducted. ANOVA test results showed a significant difference between the front, central and back vowels in terms of vowel duration for short and long vowels ($F = 4.58$, $P = 0.0104$ and $F = 37.41$, $P = 0.0$ respectively). Duncan's test was carried out to know the individual differences and the results revealed that in case of short vowels significant difference was observed between central & back and central & front vowels in terms of vowel duration and no significant difference was noticed between the front and back vowels. Whereas, in case of long vowels significant difference in vowel duration was noticed between all the vowel positions.

From the above results it can be concluded that, in case of short vowels there is no significant difference between front, central and back vowels in terms of sentence and word duration. Whereas there is significant difference in terms of syllable and vowel duration. In case of long vowels, there is no significant difference between front, central and back vowels in terms of sentence duration, whereas there is significant difference in terms of word duration, syllable duration and vowel duration.

7) Segmental durations and vowel length:

The sentence duration, word duration, syllable duration and vowel duration were grouped according to the vowel length (short and long) of the test vowel. Table 4.8 shows the mean and S.D. of sentence duration, word duration, syllable duration and vowel duration for the short and long vowels.

a) Sentence duration and vowel length:

Table 4.8 shows the mean and S.D. of sentence duration for short and long vowels. The study of the above table revealed that the duration of sentences having long vowels were longer by approximately 80 m.secs., than sentences having short vowels. Statistical analysis was carried out using paired test and the results showed that the difference between the durations of sentences having short and long vowels was significant (t = - 21.95, P = 0.0).

Table 4.8: Mean and S.D. of sentence duration, word duration, syllable duration and vowel duration for short and long vowels (in m.secs.).

Segmental duration	Vowel length	Mean	S.D.
Sentence duration	Short	1387.67	160.04
	Long	1468.20	165.30
Word duration	Short	358.50	42.16
	Long	435.89	50.69
Syllable duration	Short	134.03	34.62
	Long	209.77	26.18
Vowel duration	Short	123.49	31.65
	Long	200.44	29.06

b) Word duration and vowel length

Table 4.8 shows the mean and S.D of word duration for short and long vowels. The study of the above table revealed that the duration of words having long vowels were longer by approximately 80 m.secs., than words having short vowels.

Statistical analysis was carried out using paired 't' test to determine whether there is any significant word duration between the short and long vowel group. The results revealed that they were significantly different ($t = -69.01$ $P = 0.0$).

c) Syllable duration and vowel length:

Table 4.8 shows the mean and S.D. of syllable duration for short and long vowels. It was observed from the above table that the duration of syllables having long vowels were longer by approximately 80 m.secs, than the syllables having short vowels. Statistical analysis was carried out using paired 't' test and the results revealed a significant difference in syllable duration with respect to vowel length ($t = -126.60$ $P = 0.0$).

d) Vowel duration and vowel length:

Table 4.8 shows the mean and S.D. of vowel duration for short and long vowel. From the study of the table it was observed that the long (tense) vowels had longer duration than the short (lax) vowels. Statistical analysis was carried out using paired 't' test and the results revealed a significant difference in vowel duration with respect to vowel length (t = 133.42, P = 0.0).

Based on the results it can be concluded that the long vowels were longer by approximately 80 m.secs., than the short vowels. This result was in agreement with the results obtained by House (1961); Sharf (1964); Nooteboom (1972); Lindblom (1973); Velayudhan (1975); Balasubramanian (1981) Rajapurohit (1982); Ganesan, et. al., (1985); Lindau - Webb (1985); Nagamma Reddy (1988); Savithri (1989); Maddieson (1993); Mc Donough, Ladefoged & George (1993); Shalev, Ladefoged & Bhaskara Rao (1993); Engstrand & Krull (1994) and Venkatesh (1995), with reference to vowels in various languages. It can be concluded that the sentence duration, word duration, syllable duration and vowel duration showed significant difference between short and long vowels.

8) Ratio of vowel length:

The short and long vowel ratio in terms of duration was found to be 1 : 1.89. The ratio of duration of the short and long vowels in the initial and medial position of the word were 1 : 1.85 and 1 : 1.93 respectively. The durational ratios of short and long vowels, for different vowels are given in Table 4.9.

Table 4.9: The short and long vowel ratios for different vowels.

Vowel	Short and long vowel ratios
a/a:	1 : 1.905
i/i:	1 : 2.058
u/u:	1 : 1.905
e/e:	1 : 1.776
o/o:	1 : 1.817

The ratio of the short and long vowels (i.e., 1: 1.89) is similar to the observations of Velayudhan (1975), Savithri (1986) and Venkatesh (1995). It is also in agreement with the report made by ancient Kannada Grammarian Keshiraja (Twentieth century) who stated that the duration of long vowel is twice the duration of the short vowel.

9) Relationship between short and long vowels:

Linear regression analysis was carried out and the following relation was established between short and long vowels. The equation to relate the short and long vowel in terms of duration was:

VD (short) = 0.555.4 VD (long) - 2.64

10) Relationship between vowel duration and sentence duration:

Linear regression analysis was carried out and the following relation was established between the vowel duration and sentence duration. The equation to relate the duration of short and long vowels and sentence duration was

VD (short) = 0.3613 STD + 73.35

VO (long) = 0.0553 STD + 119.766

11) Relationship between vowel duration and word duration:

To find the relationship between word duration and vowel duration linear regression analysis was carried out for all the subjects. The relationship between the duration of the word and duration of the short and long vowels are:

VD (short) = 0.3364 WD + 2.847

i

VD (long) = 0.3502 WD + 47.7674

12) Relationship between vowel duration and syllable duration:

To find the relationship between vowel duration and syllable duration, linear regression analysis was carried out for all the subjects. The relationship between duration of syllable and duration of the short and long vowels were;

VD (short) = 0.8514 SD + 9.3684

VD (long) = 0.9656 SD + 2.124

In Malayalam, each vowel had it's own intrinsic duration. The vowel duration varied with the height of the tongue. High vowels had shortest duration and low vowels had longest duration. Opennes and closeness of vowels also affected the duration of the vowel. The long (tense) vowels had approximately twice the duration of short (lax) vowels. The duration of the vowel had different relationships with sentence duration, word duration and syllable duration.

SUMMARY

and

CONCLUSION

SUMMARY AND CONCULSIONS

"Speech is a form of communication in which the transmission of information takes place by means of speech waves which are in the form of acoustic energy. The speech waveforms are the result of interaction of one or more source with the vocal tract filter system" (Fant, 1960).

To understand the speech sounds of a language it is necessary to learn about the articulatory and acoustic nature of the speech sounds. The study of acoustic characteristics of speech sounds will give information about the articulatroy nature of the sound and also how these sounds are perceived (Picket, 1980). Acoustic analysis of speech sounds provides information about the temporal characteristics like, sentence duration, word duration, syllable duration and vowel duration, apart from spectral characteristics.

The speech sounds are mainly classified into vowels and consonants. Vowels are the result of interaction of minimally obstructed vocal-tract and vocal fold vibration. Different vowels are produced by the modulation of laryngeal acoustic energy by various configurations of the vocal tract. The vowels are classified basically in terms of:

a) the relative position of the constriction of the tongue in the oral cavity (front, central and back),

b) the relative height of the tongue (high, mid and low),

c) the relative shape of lips (spread, rounded and unrounded)

d) posiiton of soft palate (nasal and non-nasal) and

e) the phonemic length of the vowel (short and long).

Ladefoged (1975) states that even though the vowels of different languages are perceived as same, there are subtle differences between them. These differences can be studied by the acoustic analysis of speech sounds. Hence, the study of acoustic characteristics of vowel sounds may provide an insight into the structure of language, mainly the phonetic and prosodic system.

The objectives of the present study were to determine the temporal characteristics of vowels of Malayalam language used by normal adults (Peak dialect of Malayalam). The temporal parameters considered for the study were:

a) duration of the vowel (VD),

b) duration of the syllable having the test vowel (SD),

c) duration of the word having the test vowel (WD) and

d) duration of the sentence having the test vowel (STD).

Ten normal adults (five males and five females) having Peak dialect of Malayalam as their mother tongue were chosen for the study. The subjects uttered a randomised list of two hundred and fifty sentences (One hundred sentences with the test vowel in the word initial position, one hundred sentences with the test vowel in the word medial position and fifty sentences with the test vowel in the word final position) in a sound treated room. These sentences had a meaningful, non-emotional Disyllabic test word (/VtV/, PVtV/ and /KVtV/. These words had one of the ten kannada vowels in the initial, medial or final position as the test vowel. The sentences were recorded using a Bony Stereo Cassette Deck (TC -FX 170) and were played, back to the input of the DSP Sonagraph, Model 5500 for spectrographic analysis.

The temporal parameters were extracted from the utterances of all the ten subjects. The obtained data was subjected to statistical analysis using descriptive statistics, ANOVA, paired 't' tests and discriminant analysis and the following conclusions have been drawn.

a) Segmental durations and sex:

i) Segmental durations in females were found to be significantly greater than that in males with the test vowel in the word initial, medial or final positions.

b) Segmental durations and test positions of vowel:

i) In case of long vowels the segmental durations were found to be greater, when the test vowel was in the word initial positon.

ii) In case of short vowels with respect to syllable and vowel durations, the duration was found to be longest when the test vowel was in the word final positions and shortest when the test vowel was in the word medial position.

iii) Sentence duration in case of short vowels was found to be longest, when the test vowel was in the word initial position and shortest, when the test vowel was in the word final position.

iv) Word duration in case of short vowels was found to be longest, when the test vowel was in the word initial position and shortest, when the test vowel was in the word medial position.

c) Segmental duration and vowels:

i) Significant difference **in** segmental durations were observed across the vowels with respect to the test vowel in the word initial, medial and final positions, except that the sentence duration in case of long vowels with the test vowel in the word medial position did not show any significant difference.

d) Segmental durations and tongue height:

i) In the case of long vowel segmental durations were longest among the low vowels and shortest in the case of high and mid vowels.

ii) In the case of short vowels segmental durations were longest among the mid vowels. Both sentence duration and word duration showed shortest durations among the low vowels, whereas duration was found to be shortest among the high vowels with respect to syllable and vowel duration. Openness and closeness of vowels also affected the duration of the vowel.

e) Segmental duration and tongue position among short vowels:

i) The sentence duration and word duration was found to be greatest for the front vowels and shortest in case of central vowels.

ii) The syllable duration was found to be longest in case of central vowels and shortest in case of front vowels.

iii) The vowel duration was found to be longest in case of central vowels and shortest in case of back vowels i.e., the rounded vowels had shorter vowel duration compared to the unrounded vowels.

f) Segmental durations and tongue positions among the long vowels:

i) The sentence duration was found to be greatest in case of front vowels and shortest in case of back vowels.

ii) The word duration, syllable duration and vowel duration was found to be longest in case of central vowels and shortest in case of back vowels ie., the rounded vowels had shorter vowel duration when compared to the unrounded vowels.

g) Segmental durations and vowel length:

i) The segmental durations in case of long vowels were significantly greater than that in the case of short vowels,

ii) The duration of long (tense) vowels were approximately twice the duration of short (lax) vowels.

iii) These short and long vowels had different relationship with their respective sentence duration, word duration and syllable duration.

Limitations:

a) Only some static acoustic parameters have been studied.

b) Only adult males and females have been used as subjects.

c) Only the vowels present in Peak dialect of Malayalam have been studied and

d) The acoustic characteristics of the vowels have been studied only in neutral contexts (/VtV/, /PVtV/ and /KVtV/).

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APPENDIX A

a) List of words with test vowels in the word initial, medial and final positions (Voiceless context).

Word initial	**Word medial**	**Word final**
at̲u അത്	pat̲a പത	kat̲a കത
a:t̲i ആതി	pa:t̲a പാത	kot̲i കൊതി
it̲a ഇത	pit̲a പിത	kot̲u കൊതു
i:t̲u ഈത്	pi:t̲a പീത	kut̲e കുതെ
ut̲u ഉത്	put̲a പുത	kit̲o (NS) കിതൊ
u:t̲i ഊതി	pu:t̲i പൂതി	-
et̲u എത്	pet̲a (NS) പെത	-
e:t̲u ഏത്	pe:t̲a (NS) പേത	-
ot̲a ഒത	pot̲i പൊതി	-
o:t̲i ഓതി	po:t̲u പോത്	-

NS: nonsense words

b) List of sentences with test vowels in the word initial position (Voiceless context).

Carrier Phrase I	Carrier Phrase II
i: va:kku at̲u a:ṇu ഈ വാക്ക് അത് ആണ്	it̲u at̲u en̲n̲aṇu ഇത് അത് എന്നാണ്
i: va:kku a:t̲i a:ṇu ഈ വാക്ക് ആതി ആണ്	it̲u a:t̲i en̲n̲aṇu ഇത് ആതി എന്നാണ്
i: va:kku it̲a: a:ṇu ഈ വാക്ക് ഇതാ ആണ്	it̲u it̲a: en̲n̲aṇu ഇത് ഇതാ എന്നാണ്
i: va:kku i:t̲u a:ṇu ഈ വാക്ക് ഈത് ആണ്	it̲u i:t̲u en̲n̲aṇu ഇത് ഈത് എന്നാണ്
i: va:kku ut̲u a:ṇu ഈ വാക്ക് ഉത് ആണ്	it̲u ut̲u en̲n̲aṇu ഇത് ഉത് എന്നാണ്
i: va:kku u:t̲i a:ṇu ഈ വാക്ക് ഊതി ആണ്	it̲u u:t̲i en̲n̲aṇu ഇത് ഊതി എന്നാണ്
i: va:kku et̲u a:ṇu ഈ വാക്ക് എത് ആണ്	it̲u et̲u en̲n̲aṇu ഇത് എത് എന്നാണ്
i: va:kku e:t̲u a:ṇu ഈ വാക്ക് ഏത് ആണ്	it̲u e:t̲u en̲n̲aṇu ഇത് ഏത് എന്നാണ്
i: va:kku ot̲a a:ṇu ഈ വാക്ക് ഒത ആണ്	it̲u ot̲a en̲n̲aṇu ഇത് ഒത എന്നാണ്
ഈ വാക്ക് ഓതി ആണ് i: va:kku o:t̲i a:ṇu	ഇത് ഓതി എന്നാണ് it̲u o:t̲i en̲n̲aṇu

&) List of sentences with test vowels in the word medial position (Voiceless context).

Carrier Phrase I				Carrier Phrase II		
i:	va:kku	paṯa	a:ṇu	iṯu	paṯa	eṉṉaṇu
ഈ	വാക്ക്	പത	ആണ്	ഇത്	പത	എന്നാണ്
i:	va:kku	pa:ṯa	a:ṇu	iṯu	pa:ṯa	eṉṉaṇu
ഈ	വാക്ക്	പാത	ആണ്	ഇത്	പാത	എന്നാണ്
i:	va:kku	piṯa	a:ṇu	iṯu	piṯa	eṉṉaṇu
ഈ	വാക്ക്	പിത	ആണ്	ഇത്	പിത	എന്നാണ്
i:	va:kku	pi:ṯa	a:ṇu	iṯu	pi:ṯa	eṉṉaṇu
ഈ	വാക്ക്	പീത	ആണ്	ഇത്	പീത	എന്നാണ്
i:	va:kku	puṯa	a:ṇu	iṯu	puṯa	eṉṉaṇu
ഈ	വാക്ക്	പുത	ആണ്	ഇത്	പുത	എന്നാണ്
i:	va:kku	pu:ṯi	a:ṇu	iṯu	pu:ṯi	eṉṉaṇu
ഈ	വാക്ക്	പൂതി	ആണ്	ഇത്	പൂതി	എന്നാണ്
i:	va:kku	peṯa	a:ṇu	iṯu	peṯa	eṉṉaṇu
ഈ	വാക്ക്	പെത	ആണ്	ഇത്	പെത	എന്നാണ്
i:	va:kku	pe:ṯa	a:ṇu	iṯu	pe:ṯa	eṉṉaṇu
ഈ	വാക്ക്	പേത	ആണ്	ഇത്	പേത	എന്നാണ്
i:	va:kku	poṯi	a:ṇu	iṯu	poṯi	eṉṉaṇu
ഈ	വാക്ക്	പൊതി	ആണ്	ഇത്	പൊതി	എന്നാണ്
ഈ	വാക്ക്	പോത്	ആണ്	ഇത്	പോത്	എന്നാണ്
i:	va:kku	po:ṯu	a:ṇu	iṯu	po:ṯu	eṉṉaṇu

d) List of sentences with test vowels in the word final position (Voiceless context).

Carrier Phrase I	Carrier Phrase II
i: va:kku kaṯa a:ṇu ഈ വാക്ക് കത ആണ്	iṯu kaṯa eṉṉaṇu ഇത് കത എന്നാണ്
i: va:kku koṯi a:ṇu ഈ വാക്ക് കൊതി ആണ്	iṯu koṯi eṉṉaṇu ഇത് കൊതി എന്നാണ്
i: va:kku koṯu a:ṇu ഈ വാക്ക് കൊതു ആണ്	iṯu koṯu eṉṉaṇu ഇത് കൊതു എന്നാണ്.
i: va:kku kuṯe a:ṇu ഈ വാക്ക് കുതെ ആണ്	iṯu kuṯe eṉṉaṇu ഇത് കുതെ എന്നാണ്
ഈ വാക്ക് കിതൊ ആണ് i: va:kku kiṯo a:ṇu	ഇത് കിതൊ എന്നാണ്. iṯu kiṯo eṉṉaṇu