ANALYSIS OF NASAL CONSONANTS IN MALAYALAM

Reg. No. M 9722

A DISSERTATION SUBMITTED AS PART FULFILLMENT OF FINAL YEAR M.SC, (SPEECH & HEARING) TO THE UNIVERSITY OF MYSORE.

ALL INDIA INSTITUTE OF SPEECH & HEARING
MYSORE - 570 006

MAY 1999

CERTIFICATE

This is to Certify that the dissertation entitled **"ANALYSIS OF NASAL CONSONANTS IN MALAYALAM"** is a bonafide work in part fulfilhnent of Final Year M.Sc, (Speech & Hearing) of the student with Reg. No. M - 9722.

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All India Institute of Speech & Hearing
MYSORE - 570 006

CERTIFICATE

This is to Certify that the Dissertation entitled **"ANALYSIS OF NASAL CONSONANTS IN MALAYALAM"** has been prepared under my supervision and guidance.

MYSORE
MAY 1999

Dr. N.P. NATARAJA
Guide
Professor & Head
Department of Speech Science
All India Institute of Speech & Hearing,
Mysore - 570 006.

DECLARATION

I hereby declare that this dissertation entitled **"ANALYSIS OF NASAL CONSONANTS IN MALAYALAM"** is a result of my own study under guidance of Dr. N.P. Nataraja, Professor & Head of Department of Speech Science, All India Institute of Speech & Hearing, Mysore, has not been submitted to earlier to any University for any other diploma or degree.

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MAY 1999

REG. NO. M - 9722

DEDICATED TO

MY BEST FRIEND

JESUS CHRIST

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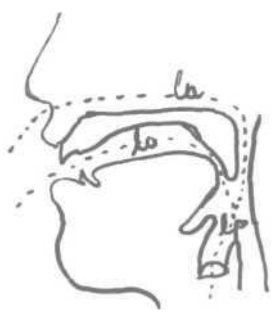
CONTENTS

INTRODUCTION

INTRODUCTION

Studies in speech communication are majorily of 2 types. Production studies and perception studies. Speech production consist of the usage of the speech apparatus, consisting of three major anatomical subsystems: Respiratory, phonatory and articulatory. The various speech sound consists of different acoustic cues. These acoustic cues are cardinal features in helping us to understand a sound as it is. The various manners in which sounds are produced are plosive/stops, fricatives, retroflex, trills, nasals laterals and glides.

The essential articulatory property of a nasal sound is that the velopharyngeal port is open so that sound energy can pass through both the nasal tract and the oral tract (for nasal vowels) or through only the nasal tract (for nasal consonants). This is described in the Fig. 1.



In the case of the nasal vowel, both resonators open to atmosphere. In the case of the nasal consonant, the nasal resonator opens to atmosphere while the oral resonator is closed.

Unlike other oral sounds, nasal formant depends on the length of the cavity extending from the uvula to the nares. These formants have an average spacing of 1400 Hz. The antiformants of the nasal cavity also depends on the length of the nasal cavaity and have an average spacing of 1400 Hz.

When the oral cavity is closed at some point for a nasal consonant, the frequencies of the antiformants are the frequencies at which the mouth cavity short-circuits transmission through the nose. Energy at these frequencies does not pass through the nasal cavity. The nasals |m|, |n̪| and |ŋ| are characterized by low (750 - 1250 Hz), medium (1450 - 2200 Hz) and high (above 3000 Hz) antiformants position respectively. The general rule is that as the place of the oral articulation moves back, the frequency of the antiformant increases. The low frequency formant, the so-called nasal formant, occurs at about 250 - 300 Hz. Higher formants are densely packed, have large band-widths, and vary with place of articulation. To a first approximation, formants occur at about 250, 1000, 2000, 3000 and 4000 Hz.

To understand the speech sounds of a language, it is necessary to learn about the articulatory and acoustic nature of the speech sounds. The speech sounds are perceived by the human being as an acoustic event. These acoustic events are the consequence of articulatory movements. The study of acoustic characteristic of speech sounds will give information about the articulatory nature of the sound and also how these sounds are perceived.

Speech perception is the process where in speech is decoded and interpreted by the listener.

The process of speech perception in human beings is of interest and extensive research has been conducted in the recent past to obtain a knowledge about the processing of speech signals in the auditory pathway.

These experiments use production data or perception data, spectrography has been extensively used to obtain production data, together the details of the parameters of speech sounds which are procured. Thus, the parameters which characterize particular speech sounds are considered to be the cues for the perception of sounds. Hence, before any perception studies a through knowledge about acoustic characteristics of speech sounds is necessary.

Experiments on perception data deal with reconstructing speech sounds form their known spectral and temporal parameters, and presenting them for judgement to the listeners. The advantage of this method lies in the possibility to vary the various parameters individually or in combination, to evaluate their effect on the resulting percept. Some methods employed in this direction include analysis by synthesis[(Halle and Stevens (1939)], articulatory synthesis [Fant 1960] and syntheis by rule [Flanagan et al 1970].

In spite of a many studies done on speech perceptual process in human beings remains an unsolved puzzle. Most of the perception studies deals with one parameter and with nonsense material. The lacuna remains in co-relating all these individual parameters to the overall percept of a sound. The two schools of thought as to the presence or absence of two different process for linguistic and non linguistic stimuli, remains yet involved. Also using the current methods, the process of co-articulation poses a problem in explaining speech perception. Further, the linguistic background seems to influence the perception of speech sounds. In the study of nasal consonants along with all these difficulties, due to its complex spectral variations, acoustic and perceptual studies done are very less.

This necessiates a study to understand important spectral variation and perceptual cues of nasal consonants. In this context the present study was provoked. This study aims finding out the acoustical parameters of nasal sounds in Malayalam (| m |, | n̠ |, | ñ |, | ṇ |, | ŋ |) and also to find out various temporal and spectral cues acting on the perception of these sounds in Malayalam speakers and Hindi speakers.

Hypothesis :

1. There is no difference in murmur frequency between | m |, | n̠ |, | ñ |, | ṇ | and | ŋ |.
2. There is no difference in the murmur duration between | m |, | n̠ |, | ñ |, | ṇ |, and | ŋ |,
3. There is no difference in the preceding vowel transition end point and of vowel steady state frequency between | m |, | n̠ |, | ñ |, | ṇ |, and | ŋ |,
4. There is no difference in the preceding vowel transition duration between | m |, | n̠ |, | ñ |, | ṇ |, and | ŋ |,

5. There is no difference in the following vowel transition beginning and vowel steady state frequency between | m |, | n̠ |, | ñ |, | ṇ |, and | ŋ |,

6. There is no diffrerence in the following vowel transition duration between | m |, | n̠ |, | ñ |, | ṇ |, and | ŋ |,

7. There is no difference in the frequency of the preceding vowel steady state between | m |, | n̠ |, | ñ |, | ṇ |, and | ŋ |,

8. There is no difference in the following vowel steady state frequency between | m |, | n̠ |, | ñ |, | ṇ |, and | ŋ |,

9. Spectral parameters aids in place perception of nasal consonant.

10. Temporal parameters aids in place perception of nasal consonant.

11. There is a change in perception between Hindi speakers and Malayalam speakers.

The aim of the study :

1. to determine the acoustic characteristics of nasals in Malayalam.

2. to determine the major cue in the perception of nasals.

The study consists of acoustical analysis of nasal consonants done through a wide band spectrogram. The spectral and temporal parameters of a inter vocalic nasal consonants were altered by cutting and pasting method. This synthesis stimulus were made to judge by five female Hindi speakers and five female Malayalam speakers. The responses were analysed to find out the important place cue for nasal perception.

This study will give a good understanding of the spectral and temporal characteristics of nasal and will also helpful in enhancing the knowledge about the process of speech perception, which further helps in general understanding of the functions of the various neuroanatomical structures. Also, it aids in the development of proper testing procedures of the functions of various centers in the auditory system. It would furnish information about the cues that could be this could also be used in automatic speech recognition and in constructing synthesizers for speech handicapped. Further, it could be used in text to speech conversion systems and mapping of speech processor in cochlear implant.

Limitation of the study :

- Only five subjects were selected for the analysis.
- For the perception study only ten subjects were taken.
- Anit formance were not analysed in the study.
- The natural speech for used for the study.
- The effect of the transition and murmur on nasal perception was not studied separately.
- The perceptual change in different vowel context was not studied.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Language is a tool of communication. Hence we find language used by both animals and human beings. An example of animal communication is dogs communicating through barks and birds through bird calls. Human beings use; a spoken language system, which makes use of a symbolic system. The symbols used are words, and it is essentially a concrete sign which stands for a relatively abstract idea or meaning. These words are primarily vocal symbols. These vocal symbols consists of streams of sounds produced by the human vocal organs. Thus we can see that language is primarily speech. The symbols used in language are arbitatory. If this arbitatorness is not a property of language and if the symbols used had some logical or necessary connection between the sounds and words used and the meaning expressed by them, then there would have been just one language instead of 100's and 100's of languages.

All languages are characterized by their own specific linguistic system. This linguistic system has syntactic, semantic and phonological component. All these are necessary for use of any language but the way it is used, the components of this sytem varies across languages eg: clicks sound are phonemic in African languages, but not in Indian languages. In some languages such as Hopi (an American Indian Language), distinction is made between three states of water. Thus it shows that depending on the linguistic constraints distinctions are made which may be extremely subtle. Hence, these features components of every language is very important.

These features are distinctive in from each other. Hence we can say that distinctive features are qualities contained in the speech signal itself that are necessary for the speaker-hearer to identify the phonemes of his language. The identification of a particular phoneme is made by picking out concurrent groups of these features and interpreting each group as a particular phoneme. According to phonemic theory, distinctive feature are those features necessary to distinguish each phoneme in a given language from the other phonemes of that language.

Phonemes are significant abstract segments of a particular language. If one assumes that the distinctive features are the elements of phonemes, then this allows for the possibility of having language specific distinctive features, the listener instead of directly interpreting the sound waves that stimulate the ear, the hearer interprets them in terms of complex, abstract linguistic system that constitutes his knowledge of his language.

Discrepancy between the abstract linguistic system and physical speech signal led chomsky and Halle (1968) to propose a different concept of phonology. It is derived from the phonemic theory.

Chomsky and Halle (1968) states that the features are identical with the set of phonetic properties that can be in principle, controlled in speech, representing the phonetic capabilitis of man and therefore the same for all languages. Limiting the distinctive features to phonetic properties that are independently controllable in speech makes the selection of distinctive features emphirical than arbitrary. Hence according to this theory we are able to define the phonemes of a given language.

Jacobson, Fant & Halle (1951): noted 12 distinctive feature, they are :

(1) vocalic / non vocalic :
(2) Consonantal / non consonantal
(3) Intercepted / continuant
(4) Strident / mellow
(6) Voiced Vs Unvoiced
(7) Compact Vs diffuse
(8) Grave Vs acute
(9) Flat Vs plain
(10) Sharp Vs. plain
(11) Tnese Vs lax
(12) Nasal Vs oral.

They noticed that not all languages did not contain all the features. They discussed the speech soundes in terms of presence / absence of a feature.

Miller and Nicely (1955) used a 5 feature system consisting of voicing, duration, affrication, place and nasality.

Halle (1964) described eight features to describe phoneme they are: Vocalic, consonantal, grave, diffuse, strident, nasal, continuant and voiced.

Chomsky and Halle (1968) developed a distinctive feature system consisting of (1) true consonants (2) vowel-vocalic (3) consonants that are more vowel like in nature (sonorant)

All these studies we can find that nasality as an important disinctive feature. Hence, the feature components of every language is very imporant. There are various studies done to find the importance of a feature in a language.

Miller and Nicely (1955) from a study showed that nasality and voicing show greater strength that is greater information transmission than the features duration, frication and place of articulation. When speech is pass through under low pass and high pass filter conditions, nasality, voicing and friction had higher rate of information, while under low pass conditions, features of place of articulation and duration, carry a higher rate of information.

The results by Miller and Nicely .(1955) showed that different features did not hold similar ranks in speech perception. Rank order was; Nasality 62%, voicing 59%, duration 41%, Frication 40%, place of articulation 27%. Singh and Black (1966) did a cross language experiment where speakers of Hindi, English, Arabic and Japanese, were made to a identify a idential set of 26 consonants in contexts of two vowels. Purpose was to establish a common set of parameters or features across the four languages to investigate the universal application of a selected group of consonant features in speech perception. Rank order obtained was (1) Nasality, (2) Place, (3) Liquid, (4) Voicing, (5) Duration, (6) Frication, (7) Aspiration. The results of the study, supported the findings of the previous study. Singh (1970) found a distinct difference between the english consonants perceived by English and Hindi speakers . For both language groups affrication was one of the strongest feature Nasality and frication were one of the weakest features.

Ahamed and Agarwal (1969) investigated the information transmission in 29 consonants in Hindi at the initial position and final position in a CVC syllable. The features nasality and aspiration demonstrated the most pronounced differences between their ranks, both in initial and final positions. Gupta, Agarwal and Ahmed (1969) determined the effects of clipping on the intelligibility of consonants and features and to find out the amount of information given by initial consonants and final consonants and to note differences in consonant perception for these two positions. Analysis revealed that the rank order of features in initial position was from most to least. More susceptible to clipping was found for, place, nasality, liquid and continuancy. In the final position of the syllable the greatest amount of clipping effect was seen for the feature nasality and smallest for affriciates; maximum effect of clipping is seen for the feature frication. Singh (1970) from a study hypothesized that

1. The distinguishing characteristics of the voicing feature improved in noise and deteriorated in quite.
2. Frication improved in quiet and deteriorated in noise.
3. When in competition with other features in quite condition, voicing feature was stable
4. Noise characteristics of frication were easily lost in the experimental noise.
5. Nasals, liquid, glides were minimally affected by filtering and noise conditions.

Gupta, Agarwal and Ahmed (1969) did another study on perception of Hindi consonant, in 'clipped speech'. Effect of peak clipping on intelligibility initial consonants and final consonants and see the difference in perception of the two portions. Results indicated that average effect of clipping on features was as follows. (1) Place of articulation, (2) Nasality, (3) flapped (4) liquids (5) Continuants, (6) Voicing (7) Frication (8) Aspiration (9) affrication.

Somasundaram (1972) did a contrastive analysis of phonology of Tamil, Telegu, Kannada and Malayalam based on distinctive features. 11 distinctive features were necessary to distinguish the phonemes of the four languages, they were (1) Vocalic 2. Consonantal 3. Nasals 4. Continuous 5. Tense. 6. Grave 7. Compact 8. Fait 9. Sharp 10. Diffuse 11. Strident. Based on the analysis it was found that Malayalam had the maximum number of feature distinctions and maximum number of phonemes among the four languages. Features 1 to 8 were common to all languages. Number 11 was phonemic only in Tamil and Malayalam and 9 was phonemic only to Malayalam.

Somasundaram, has stated that "since Malayalam possess all the feature distinctions that are commonly available to all the languages, a native speaker of Malayalam will not find it difficult to identify all the phonemes of other than languages. But native speaker of Tamil or Kannada may fail to distinguish the dental and alveolar dac stops and nasals of Malayalam, because the sharp feature is only allophonic in these languages". He added that "A speech clinician whose native language is Malayalam may tend to over differentiate the sounds when he as to work with the other three languges and under differentiation may be the case when a native speaker of Telugu, Tamil or Kannada therapist tries to teach Malayalam".

From all these studies we can infer that many features that are phonemic in Malayalam language may be allophonic or absent in other languages. One among these feature is nasality. There are 6 nasals in Malayalam, Shyamala Kumari, (1972)

'm' —> Voiced bilabial nasal stop

'n' —> Voiced dental nasal stop

‘ n̲’ → Voiced alveolar nasal stop

‘ṇ → Voiced palatal nasal retroflex

‘ñ → Voiced palatal nasal stop

‘ŋ → Voiced velar nasal stop.

The salient features of nasal consonants and their characteristics are :

(1) Nasal murmur : The articulatory feature of velopharyngal opening accompanied by oral cavity obstruction produces a murmur characteristic. > Nasal murmur has distinct energy regionsN similar to formant patterns of sustained vowel, but unlike vowels, they also possess regions of reduced energy called antiformants, and they possess less over all energy. Formants and antiformants can be described as central frequencies and bandwidths and they usually occur in pairs.

Fujimura (1962) determined that the nasal consonants have three common properties. First, all, of them have a first formant of about 300 Hz that is well separated from higher formants second, the formants tend to be highly damped (i.e., they have wide bandwidths reflecting a rapid rate of absorption of sound energy). Third, there is a high density of formants and the existence of antiformants. According to Delattre (1958), the intensity level of N_1 and the other spectral regions of murmur is around 6dB (NO and 15 dB(N_2 , N_3, N_4 . . . .) lower than for a normal non-nasalized vowel. Demori, Gubrynowicz and Laface (1979); Fant (1962) found N_3 around the value of 2,200 Hz. Fant (1995) reported of antiformant position for |m|, |n| and |ŋ| as low as (750 - 1250 Hz), Medium (1450 - 2200 Hz) and high (above 3000 Hz). He found the (N_1) to occur at about 250 - 300 Hz. Higher formants are densely packed, have large bandwidths, and vary with place of articulation. In general the formants occur at about 250, 1000, 2000, 3000 and 4000 Hz.

Table : The frequency values of murmurs are summarized in a table -1

		Sd		N_2	N_3	N_4	N_z
1.	Dukiewicz (1967)	|m	300-340	850-900	1150-1500	1700-200	-
2.	Fant(1960)		250	800	1000	200	550
3.	Fant(1973)		100-350	875-1300	2000-2500	-	-
4.	Fujimura (1962)		280-290	950-980	1360	1950	750-1250
5.	Jassem (1964)		100-400	800-1200	2150-2500	2800-3000	-
6.	Jassem (1973)		300	750	1300	2000	800
7.	Kacprowski (1963)		300	850	1300	1850	1100
8.	Magdicss (1969)		-	850	2000-2600	-	-
9.	Ramportl (1973)		-	600-800	1300-1900	1800-2900	-

	Reference	Sd		N_2	N_3	N_4	N_z
1.	Dukiewicz (1967)	n I	310-430	900-1000	1500-1800	1900-2350	-
2.	Fant (1960)		250	800	1200	2000	1800
3.	Fant (1973)		100-300	1000-1750	2400-2900	-	-
4..	Fujimura (1962)		300	1000	1450	2000	1450-2700
5.	Jassem (1964)		100-400	1700-2000	2150-2500	2800-3000	-
6.	Jassem (1973)		330	1200	1750	2050	1405

	Reference	Sd	N_1	N_2	N_3	N_4	N_z
7.	Kacprowski (1963)		320	900	1500	2050	1750
8.	Magdicss (1969)		-	1000-1600	2050	-	-
9.	Ramportl (1973)		-	830	1900	2200	-

	Reference	Sd	N_1	N_2	N_3	N_4	
1.	Dukiewicz (1967)	|ñ|	310-430	1000-1200	1500-1600	2000-2300	-
2.	Fant (1960)		250	800	1900	2600	2200
3.	Jassem (1964)		100-400	1100	2200-2500	2800-3000	-
4.	Jassem (1973)		345	1225	2100	2750	2750
5.	Kacprowski (1963)		340	1000	1650	2180	2400
6.	Magdicss (1969)		-	1500-2000	-	-	-
7.	Ramportl (1973)		-	900-1100	2200-2500	2850	-

	Reference	Sd	N_1	N_2	N_3	N_4	N_z
1.	Dukiewicz (1967)	|ŋ|	320-440	900-1300	1500-2200	2000-2550	
2.	Fant (1960)		300	1000	2200	2900	2200
3.	Fant (1973)		100-500	1000-1250	1650-2400	3200-4000	
4.	Fujimura (1962)		250-400			2300-3000	Above 3000
5.	Jassem (1964)		100-400	900-1100	2200-2500	2800-3000	-

	Reference	Sd	Ni	N_2	N_3	N_4	N_z
6.	Jassem (1973)		350	1100	1900	2750	Above 3800
7.	Kacprowski (1963)		350	1050	1800	2450	
8.	Magdicss (1969)		—	730-1500	2300-2600	—	—
9.	Ramportl (1973)			800	2000	2600	

This studies shows that formant patterns for |ñ| and |ŋ| are very similar except in the case of N4, which is higher for |ɲ| than for |ñ|; |m| and |ṉ|, present lower formant values, those for |m| being even lower than those for [ṉ], Data on frequency values present a succession [ɲ] > [ñ] > {ṉ} > [m} Data on N_z value gave an arrangement of [n] > [ñ] > [ṉ] > [m].

Nasal consonants, like others consonants, are associated with formant transitions when they are produced in sequence with other sounds. Following is a table summarizing the frequency values in (Hz) corresponding to F2 - F3 transitions in nasals in post vocalic position.

	Phoneme	End points		Ranges		Directions	
	|m|	f_2	f_3	F_2	F_3	F_2	F_3
1.	Dukiewicz (1967)	1000	2850	-50	+50	-	-
2.	Jassem (1962, 1964	1100	3050	-250	+100	-	-
3.	Magdics (1969)	1650	1695	-380	-500	-	-
4.	Fant(1960)	800	2150	-500	-50	-	-
5.	Vagges e tal(1978)	1200	2340	-200	-140	-	-

	Refeences	[ṉ]	F_2	F_3	F_2	F_3	F_2	F_3
1.	Dukiewicz (1967)		1250	2800	+ 50	-150	+	-
2.	Jassem (1962, 1964)		1500	2900	+200	+200	+	+

	Refeences	[n]	F_2	F_3	F_2	F_3	F_2	F_3
3.	Magdics (1969)		1650	1650	+220	-540		-
4.	Fant(1960)		1400-1500	2250	0	-50	-	-
5.	Vagges et al (1978)		1425	2665	+55	+40	+	+
6.	Ferrero et al 1979		1450-1500	2650	+50	-50	+	-

	References	[ñ]	F_2	F_3	F_2	F_3	F_2	F_3
1.	Dukiewicz (1967)		1900	2500	+500	-450	+	-/+
2.	Jassem (1962, 1964		2300	3150	+1000	+500	+	+
3.	Magdics (1969)		1970	2032	+495	-195	+	-
4.	Fant(1960)		2050	2850	+550-650	+550	+	+
5.	Vdgges et al (1978)		2140	2990	+825	+475	+	+
6.	Ferrero et al 1979		2200	3200	+ 650	+ 350	+	+

	References	[ŋ]	F_2	F_3	F_2	F_3	F_2	F_3
1.	Dukiewicz (1967)		900-1400	2900-3200	-50 -200	-100 +600	-	-/+
2.	Jassem (1962, 1964		-	-	-	-	-/+	-
3.	Magdics (1969)		-	-	-	-	-/+	-

Analysis of results shows that, F_2 for [n] does not overlap with other categories and shows a constant positive transition direction. Infact a 250Hz seperation minimum between F_2 values for [n̪] and [ñ] is a good indication of high F_2 distinctiveness for [ñ], such a difference was also found for czech and Russian by Romportl (1973) i.e. (ñ): 1100 - 1300 Hz. [ñ] 1600 - 1800 Hz, Recasen (1982). The properties for the nasal vowel syllable are the murmur, transition and vowel steady state.

Speech pereception:

Speech perception is the process where in speech is decoded and interpreted by the listeners.

The speech signals are carried as electrical impulses, through auditory nerve to higher centers. There are various temporal and spectral analysis that take place at lower centers, but processing the specific speech parameters and other complex acoustic features of natural speech stimuli, begins only at the level of medial - geniculate body (MGB), which is located in thalamus. At the higher centers of the cortex, the linguistic components are added to the already analyzed signal to reconstruct the percept as intended by the speaker.

Theories of speech perception :

Two broad classifications are -

Active theories and passive theories.

Theories of variance and invariance.

Active theories include the motor theory of 'speech perception by Liberman (1978) and the theory of analysis-by-synthesis by Halle and Stevens (1959).

Motor theory of speech perception: Principle view of these theorists is that speech perception takes place on the basis of the articulatory knowledge of the listener. The phonemic gestures of the speakers are represented as invarient motor commands in the brain of the listeners, which call for the movements of the articulator to identify the phonetic gesture. The experimental works leading to this theory reveal the importance of relative cues, context and the importance of linguistic and articulatory knowledge of perception.

Analysis-by-synthesis theory: This is similar to the motor theory, in that, the listener refers to perception. However, the reference is assumed to be more acoustic and less articulatory. Halle and Stevens (1959) theorizes that the listener has an auditory model of his production which he uses for analysis of the input auditory stimuli. Thus, the listener can apply his knowledge of phonological rules when performing the rudimentary synthesis and thus normalize variations caused by fast speaking rate and other distortions (Borden and Harris, 1980).

Passive theories :

Fant (1960) emphasizes on a sensory filtering machanism of the listener. The role of speech production is relegated to a miinor place and is considered to be used only in difficult circumstances.

Quantal theory :

This was proposed by Stevens (1972). he believes that there is adiscontinuity between changes in the articulatory positioning and the resultant changes in the acoustic output, i.e., there are regions in the vocal tract, in which small continuous difference in articulatory position cause little or no difference in the acoustic output, while there are regions in which small articulatory changes result in large acoustic differences, thus causing a quantal leap in terms of the sound change. Thus the human auditory system is especially sensitive to the acoustic changes that the articulatory systems produce.

Of these, the analysis - by - synthesis theory is termed the theory of in-variance and the others are called as the theories of variance.

Speech perception is a area that needs more research. There is not much research done in the area of nasal perception due to its spectral difference from other sounds. This warrants a research in this area.

Important cues for Nasal perception :

There are certain spectral characteristics of nasal murmur mark nasal consonants as a class, independent of place of articulation and the adjacent nasalized vowels Delattre (1958, 1968); Fant, (1960); Fujimura (1962); Fujimura and Lindqvist (1970); Hattori, Yamamoto and Fujimura (1958); Mattingly 1968;

As mentioned previously Delattre (1958) has reported that intensity level of N_1 and the other spectral regions of murmur was around 6dB(Ni) and 15dB (N_2, N_3, N_4) lower than for a normal non-nasalized vowel. This seemed to be the most important class cue for nasal consonants, in contrast with negligible perceptual role of the frequencies of higher nasal formants (Delattre 1968).House (1957) assigned the murmur to have an intensity 8dB lower than that appropriate for |I|. Concentration of formants (N_2, N3 , N4 -) between 300 - 4000 Hz, with large band width (BW) were found. The small perceptual significance of those formants seems to result not only from their low intensity level with respect to N_1 (especially N_2, often absent as reported by Fant 1962, Weinstien, Candless, Mondshein and Zue (1975) but also from their spectral variability.

Data is availabgle on optimal formant bandwidth values for consonantal nasality. Martony (1964) has stressed the perceptual relevance of an N_2 bandwidth value around 250Hz given an optimal NI value at around 100-150 Hz. Such an N_2 bandwidth was close to frequencies chosen as the most favourable for nasal perception by Nakata (1959) (N_2 : 200H_z; N_1 : 300H_z and pickett (1965) (N_1 N_2 N_3 : 180 H_z; N_4 : 300 H_2

Takeuchi, Kasuya, and Kido (1975) have shown that an uninterrupted pole excursion between vowel and nasal consonant, with the addition of some nasality parameter that represents the amount of spectral difference between nasal and vowel spectra, can be regarded as a valid cue for detection of nasals as a class. A continuity between vowel formants and nasal poles (F_1 - N_1, F_2 -

N_3, F_3 - N_4 . . . .) was found by Fant 1960 and Recasens (1982). Nasalized releases following the nasal murmur, different from non-nasal stop realeases in presenting low-frequency masking (Blumstein and Stevens, 1979). Fi transitions, generally negative but less so than for non-nasal stops. This differential acoustic cue has perceptual relevance for nasals as a class (Fant, 1967; Mattingly, 1968; Miller and Eimas, 1977). Using both synthetic (Garcia 1966, 1967, 1967b); Hecker, (1962); House (1957); Nakata (1959) and with natural speech stimuli (Malecot 1956); Nord (1976) have shown that not only formant transitions but also murmurs and releases were cues to place of articulation for nasal consonants.

Copper, Delattre, Liberman, Borst and Gersstman (1952) emphasized on the polyvalent nature of formant transitions and nasal murmur characteristics in the process of place discimination among nasal consonants. Nakata (1959) Kacprowski and Mikiel (1965) reported that Nj and N_z dynamics could correctly simulate different place percpetion. The perceptual distinction between | |ɲ| | Vs |n̪| could be well cued by high V_s low Ni and absence $V_s$presence of N_z at the central region of the spectrum. Accordingly higher N_1 value for |n̪| 240 Hz than for | m | and |n̪| (180 Hz) was reported to help perceptual place identification (Haskins laboratories GPR H,1954) Nz's being above 4000 Hz or absent in the case of |ŋ| was consistent with Ohala's (1975) observation that its perceptual effectiveness was presumably severely attinuated because of that high frequency location.

Malecot (1956) found that in experiments with natural english speech, released murmur segments for | m | were categorized quite accurately (80% - 100%) whether in isolation or for or following without formant transition.

Henderson (1978) found for the overall vocalic set a higher accuracy in place identification for [m] without transition or release (about 75%) than for [n̪]; [ŋ] (65% - 75%); following [a], in the absence of formant transitions the [m] murmur identification was always higher than 90%, independently of in isolation with natural speech (65% - 85%) (House, 1957, Nakata, 1959). Moreover, Manreque de, Gurlekain, and Massone (1980). report in experiments with natural Argentinian Spanish speech that not only isolated [n̪] murmurs give a higher percentage of [m] than [n̪] identifications. The syllable [an], with no transitions or release, was identified 50% - 60% of the time Henderson (1978); with release, the average rise to 97% in Henderson's experiment but not Malecot's (50%). Both naturally-spoken Malecot (1956) and synthetic House, (1957); Nakata, (1959) [n̪] murmur presented in isolation give the same 50% - 60% effect [m] as in manrique de et al(1980). Dukiewicz (1967) has shown that | ŋ | murmur presented in isolation to polish speakers elicit no | ñ | judgement. Correct recognition of | ñ | improved 30% when murmur was presented with its corresponding onset. Repp (1986) reported that murmurs and transition onset were important in identification of place of articulation.

Melecot, (1956); House, (1957); Nakata, (1959); observed that [ŋ] murmurs are less well identified than those for [n̪] and [m], they tend to be interpreted mainly as [m] but also as [n̪]. Melecot (1956) reported that released ten murmur without transition was very poorly identified and mainly confused with | n |.

Henderson (1978) also found [ŋ] murmur to be a poor indicator with vowel | ∈ | (45%; however for | an | without transitions, responses rose to 74% (unreleased murmur) and 92% (released murmur). "The remarkable importance of released or unreleased |m| murmur in place identification can be related to the particular low N_1 and N_z frequency values. Within an overall low murmur spectrum. This can be considered as an important cue for differentiating |m| from other nasal class", Malecot, (1956); Ramportl, 1973. Demori et al (1979) reported that N_z in |m| was of low frequency about 1000 - 15000 Hz and | n̪ | and | ŋ | was of high frequency 2300 Hz by Delattre (1958). | ñ |murmur carry very little place information, | ŋ | murmur and |n̪| murmur provide important place information in the unreleased cases and were identified quite consistently when released.

Kurowski & Blumstein (1984) reported that highest performance score for place of articulation were obtained when last portion of murmur and onset of transition was given together.

F_1 transition values were found to help in contributing to place identification. | ñ | transition is extremely negative (Fant, 1960; Vagges, Ferrero, Caldognetto - Magno && Lavangoli, 1978) that for | ɲ | is usually only slightly negative and can even be positive (Dukiewicz 1967). For |a followed by | ñ |, the negativity is due to an important increase of back cavity size and noticeable increase of vocal tract constriction (Delattre, 195ft Fant 1960). The slightly negative F_1 excursion between |a| and | ɲ | is related to a smaller increase in pharynx cavity size. According to Henderson (1978) sequece of |a| followed by a nasal consonant, without nasal murmur and with or without final release, gave 60% of [m] responses when presented with [m] transitions and 80% of [n] response with [n] transitions but only 15% - 30% of [rj] responses with [n] transitions in favour of a majority of [anj judgements. Dukiewicz (1967) found that for [an] transitions compensated for the negligible place information conveyed by murmur. Recasens (1982) found that transitions were powerful cues in identification of [ñ] and [n̠]. [ŋ] murmur contributed more to place identification than other murmurs.

Derkach et al (1970) found that a strongly negative F[transition to be a relevant palatalization cue. Duration of formant transitions were found to differ among place categories. (Hecker, (1962); Mattingly, (1968); Nakata, (1959) has considered longer transitions for [n], storter transition for [m] and [n] in synthesis. Miller & Eimas (1977) reported that in nasals place and manner were not processed independently. The analysis of place was influenced by variations in manner and similarly the mechanisms responsible for extracting manner information was from a particular value of place of articulation. Repp (1986) found place of articulation information in the murmurs to be somewhat less salient than that in the formant transitions, better identification performance occurred when both murmur and transition information were presented together. Kurowski and Blumstein (1987) found that for labial nasals the perception was from the rapid spectral change with greater change in lower frequency regions than higher frequency region and for alveolar nasals the greater change in high frequencies relative to lower frequencies help in the perception of place.

Repp (1987) found the importance of spectral changes between murmur and transitions as having an important perceptual role in place identification in nasals.

Repp and Svastikula (1988) reported that in CV syllables, the abrupt spectral change from the murmur to the vowel provides important additional place of articulation information but for VC syllables formant transitions of the vowel and murmur spectrum functioned as independent cues.

From these review we understand that perception studies done on nasals are limited and is very complex. The researchers contradicts themselves regarding the importance of murmur (Nakata 1959, Kasprowski & Mikiel (1965) and transitions Henderson (1978); (Recasens (1982) as the cue for place perception. Most of the researchers, Delattre (1958); Fant (I960); Fujimura (1962); Hattori, Yamamoto and Fujimura (1958); Mattingly (1968) have shown that manner cue is mostly from the murmurs. A combined infraction of transition and murmur for identification of nasals is putforth by other researches Repp (1986, 1987) Kurowski and Blumstein (1987).

Most of these studies are done in English language were only nasals present are |m| |n̪| and | ŋ |. This warrents the study to be done in a Indian Language like Malayalam where, there are '6' nasals present.

Need for the study :

Most of the studies on nasals are done in English language were only nasal preseent are |m|, and |n̪|. This warrants the study to be done in Indian languages like Malayalam where, there are '6' nasals present.

Purpose of the study is to find out the :

1. acoustical parameters of nasal sounds in Malayalam [m, n, ñ, ṇ ŋ]
2. To find out various temporal and spectral cues acting on the perception of nasals in Malayalam speakers and Hindi speakers.

Implication of the study :

This study will give a good understanding about the spectral charactereistics of nasals. It will help in enhancing the knowledge about the process of speech perception which will further help in understanding of the various neuroanatomical structure, it will aid in the development of proper testing procedure of the functions of various centers in the auditory system. It would furnish information about the cues that could be used with speech and language handicapped. The informatioan obtained from this could also be used in automatic speech recognition and in constructing synthesizers for speech handicapped, further it could be used in text to speech conversion systems and mapping of speech processor in cochlear implant.

METHODOLOGY

METHODOLOGY

1. The present study was carried out to analyse the spectral and temporal parameters of nasal consonants.
2. To find out important temporal and spectral cue for perception of nasal consonants in Malayalam.

The methodology is dvided into two:

(1) that which is used for acoustic analysis

(2) and for finding out the important cues for nasal perception.

I. Acoustic Analysis :

(a) Acoustic Measures : Formant frequencies

(1) fi f_2 and f_3 for pre murmur vocalic steady state and post murmur vocalic steady state.

(2) Spectral frequency of nasal murmur (N_1 N_2 N_3)

(3) Frequency of pre and post vocalic transitions.

Temporal Cues :

Murmur duration :

Pre murmur and post murmur transition duration.

3. Subjects :

1 male and 4 female normal Malayalam speakers in the age range of 18 - 23 years participated in the study. They all had normal hearing, no neurological improvement, and no history of any other problem related to speech and hearing.

Speech material: The speech material used was 5 meaningful Malayalam words in a V_1, C_1, V_2 or C_1 V_1 C_2 V_2 combination. All these five words are frequently used in the language. The words were.

(1) a:ma (2) a: n̲a (3) Pan̄a (4) a: ṇṇa (5) maɲa

$V_1C_1,V_1,$ $V_1C_1V_1$ $C_1V_1C_2V_2$ $V_1C_1V_2$ $C_1V_1C_2$ V_2

In Malayalam there are 6 nasals, they are :-

|m| → Voiced bilabial, nasal stop. The lips comes to form closure and then there is a sudden release of air.

| n̪ | → Voiced dental nasal stop consonant. The tip of the tongue touches the back of the upper front teeth blocking the airway.

| n̲ | → Voiced alveolar nasal stop. The tip of the tongue firmly touches the alveolar ridge to stop the air passage, followed by a release.

|ñ| → Voiced palatal nasal stop consonant mid part of the tongue touches the hard palate closing the air flow.

|ṇ| → Voiced palatal nasal reteroflex consonant The tongue tip curls back and it touches the hard palate thereby making a closure of the air passage.

|ŋ| Voiced velar nasal stop consonant. The mouth is completely blocked by raising the back of the tongue to touch the front part of the soft palate.

Out of this, dental nasal stop was not considered for the study because of its occurrance only in the initial position of a word. As the words selected were VCV combination 'n̪' was not taken for the study.

Meaningful words having inter vocalic nasals were used for the study.

Data collection:

All the speakers were first familiarized with the material. The words were usually presented one at a time and the subjects were instructed to produce them clearly at comfortable rate and laidness.

The recording was done through SSL record 1 programme. Microphone (H - Legend) was kept approximately 10 cm. away from the speakers mouth. These recordings were used for analysis.

Analysis of the data :

Equipments used :

(1) Antialiasing filter (LPF having cut-off frequency at 7.5 kHz).

(2) A-D/D-A Converter (sampling frequency rate of 16 kHz, 12 bits)

(3) PC (At intel 80386) microprocessor 80837 numerical data processor.

(4) Software developed by voice-speech system,. Bangalore.

(5) Amplifier head phones.

Procedure adopted for the analysis :

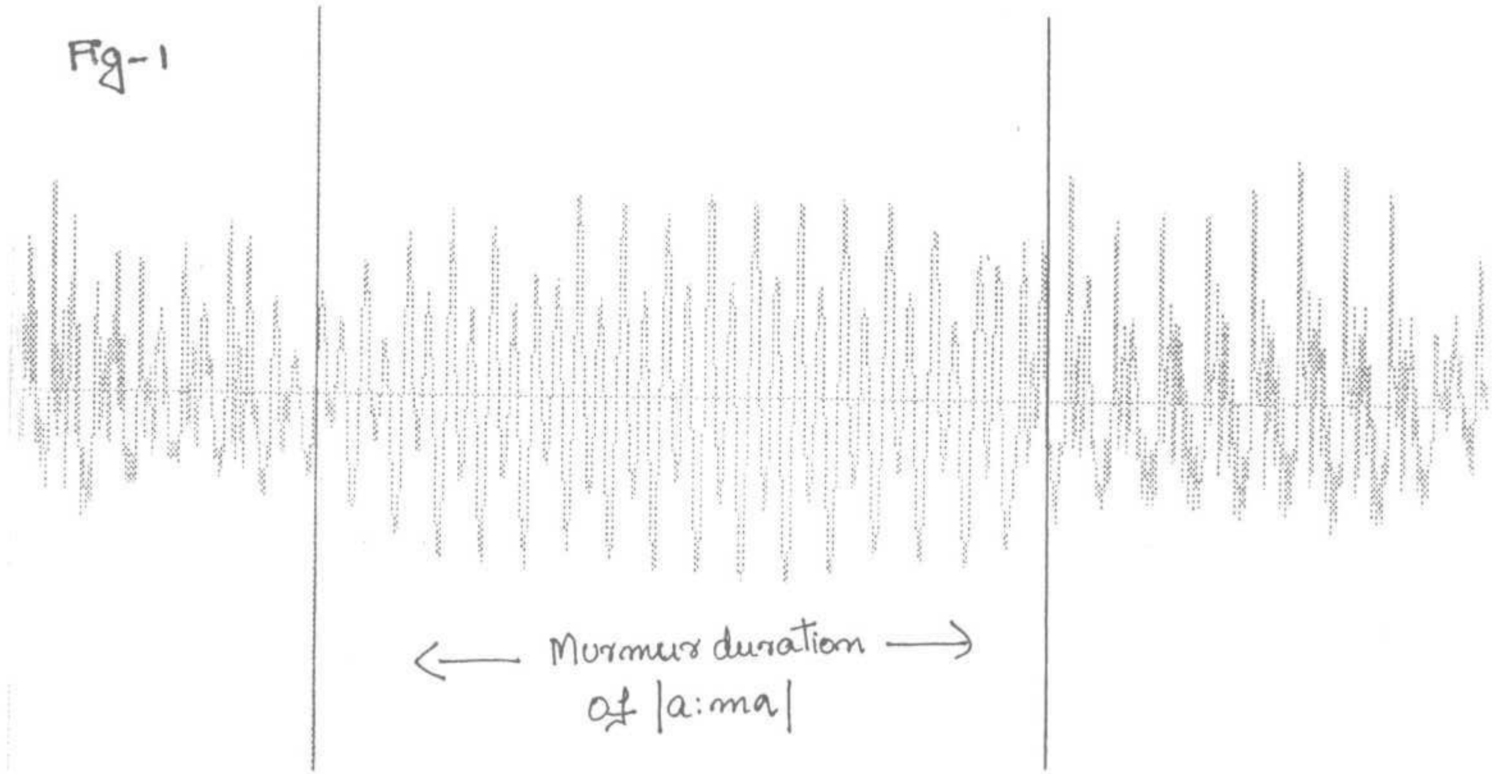
The program spectrogram was used to obtain a wide band spectrogram (300 Hz filter) display. The recorded speech sample was digitized using 16 kHz bits. The digitized samples were used for the analysis. The level indicator of speech interface unit was used to monitor the intensity level of the signal to avoid any distortion while digitizing the signal, using the spectrographic analysis spectral and temporal parameters were analyzed.

Temporal analysis:

Murmur duration:

During the production of a nasal sound there is a bifurcation of resonating system. Hence, air passes through both the oral cavity as well as nasal cavity. The velopharyngeal opening accompanied by oral cavity obstruction is linked to an acoustic feature of nasal murmur. The murmur is the acoustic segment associated with an exclusively nasal radiation of sound energy. Duration of nasal murmur in a inter vocalic condition was analyzed by moving the cursor on the terminal point of the precedingvowel to the onset of the following vowel. The time value thus obtained was the consonant murmur duration of that consonant. The figure 1 shows the murmur duration for |a:ma|.

Fig-1



Preceding vowel transition duration :

Transition duration is the time taken to transit from vowel to consonant or from consonant to vowel, it will vary depending on the consonant vowel environment. The duration of precedingvowel transition was determined by keeping cursor at the point where transition begins to point of transition off set. The vowel environment was |a|.

Following vowel transition duration :

The duration of following vowel transition was determined by keeping the cursor at the point where transition begins to the point where post vocalic steady state begins.

Spectral parameters :

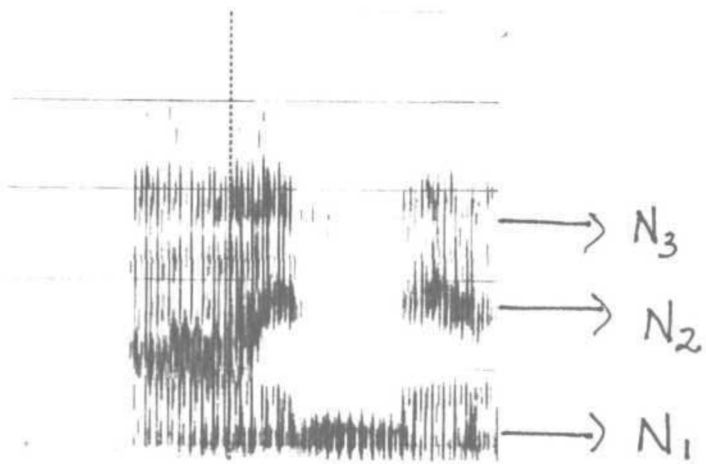
Murmur frequency :

For extracting the murmur frequency the cursor was place din the middle of the murmur, and the murmur frequency was determined, by using the sectioning method, through the use of linear preductive coding (LPC). This was done with 18 LPC co-efficients. The frequencies at the peaks representing the murmur were noted using the cursor. Through this frequency value of (N_1 N_2 N_3) was found out. The figure 2 shows spectrograph of |ɑ:n̠a| with N_1, N_2, N_3 marked.

Preceding vowel transition end point frequency :

For finding out the transition frequency the cursor was kept in the end point of the transition and frequency value was noted down. Again the cursor was kept at the vocalic steady state and the frequency was noted down. This method was carried out for finding F_1, F_2, F_3 transition end point. Difference in the frequency of precedingvowel steady state and transition end point were calculated to get the extend of frequency variation.

Fig- 2.



SPECTROGRAPH OF /a:ṉa/

Following vowel transition beginning frequency :

The procedure is similar to that used for finding out precedingvowel transition frequency. The cursor is kept at beginning of the following vowel transitions and the frequency is noted down. The frequency opf the vowel steady state was noted down. This method was carried out for finding F_1, F_2, F_3 transition end point. Difference in the frequency of following vowel steady state and transition beginning were calculated to get the extend of frequency variation.

Frequency of preceding vowel steady state :

To extract the vowel formant frequencies (f_1 f_2 f3) the cursor was placed in the middle of the vowel portion and the formant frequencies were determined by using the sectioning method through the use of linear predictive coding (LPC). A LPC with co-efficient 18 was used. The frequencies at the peaks representing the formants were noted using the cursor.

Frequency of following vowel steady state :

The procedure carried out is similar to that used for finding out the frequency of precedingvowel steady state. Formant frequencies were determined by keeping the cursor in the middle of the vowel portion and 18 co=efficient LPC was used to find out formant frequencies.

Analysis :

A average value was found out on all these parameters.

Methodology used for perception study

The aim of this study was to out the important temporal and spectral cue for perception of nasal consonant.

The study consist of five conditions :

1. Interchanging the murmur with different words.
2. Inter changing the precedingvowel steady state and transition with different words.

3. Interchanging the following vowel steady state and transition with different words.
4. Inter changing both the precedingand following vowel steady state and transition with different words.
5. Inter changing the duration of murmur.

Speech Material:

The materialused for acoustic analysis was used for the perception steady also.Five meaningful Malayalam words which are frequently used in language were taken for the study.

(1) a:ma	(2) a: n̠a	(3) Pañã	(4) a: ṇṇa	(5) maŋa
$V_1C_1V_1$	$V_1C_1V_1$	$C_1V_1C_2V_2$	$V_1C_1V_2$	$C_1V_1\ C_2V_2$

Subject and data collection :

1 male speaker aged 23 years were instructed to produce the words one after the other as clearly as possible at comfortable rate and loudness.

The recording was done through SSL record 1 programme. Microphone (H - Legend) was kept approximately 10 cm. away from the speakers mouth.

This material was used for waveform editing.

Equipment used :

Similar to that used for acoustic analysis.

Procedure:

The program display in SSL was used to give the display of the digitized wave form. Using the 'Edit' program in 'SSL', appropriate splicing and pasting was done. The procedure involved is described in detail for each experiment.

Experiment I:

Aim: To interchange the nasal murmur between words, so as to find out the importance of murmur as a place cue.

Stimulus preparation:

Results obtained through acoustic analysis on murmur duration is used to find out the exact location of murmur beginning and murmur.

The fig. 3 shows the point where the cut is beginning and ending for | a:ma | respectively. The murmur portion of all the words were cutout and was stored in hard disk memory.

In the words whose murmurs were cut in the place of original murmur of that particular word the murmur of some other word was inserted. The insert program under edit session was used for this.

Using this procedure 20 tokens were produced.

eg. ama with murmur of ana, panflt , anna, maw,

These stimuli were randomized, converted toanalog signal and audio recorded. The Fig.4 . |a:ma| with |pana|'s murmur.

Experiment No.II:

Aim : To interchange the precedingvowel and transition across different words, so as to find out the importance of precedingvowel and transition as a place cue for nasal perception.

Stimulus preparation:

Using the results obtained through the acoustic analysis of words, the exact duration of preceeding, vowel steady state and transitions were found out. using this durational measure the waveform was cut from the beginning of the signal tothe end of the transition. The Fig. 5 shows cutting point for precedingvowel of|ama|

For all the words the precedingvowel, along with transitions were cut and stored in the hard disk of the computer. On the words pana and mana, to maintain the homogenety of $V_1C_1V_2$, instead of $V_1C_1C_2V_2$ the initial portion of signal contributing for |P| or |m| was cut in 10 milli sec. steps until the

Fig- 3.

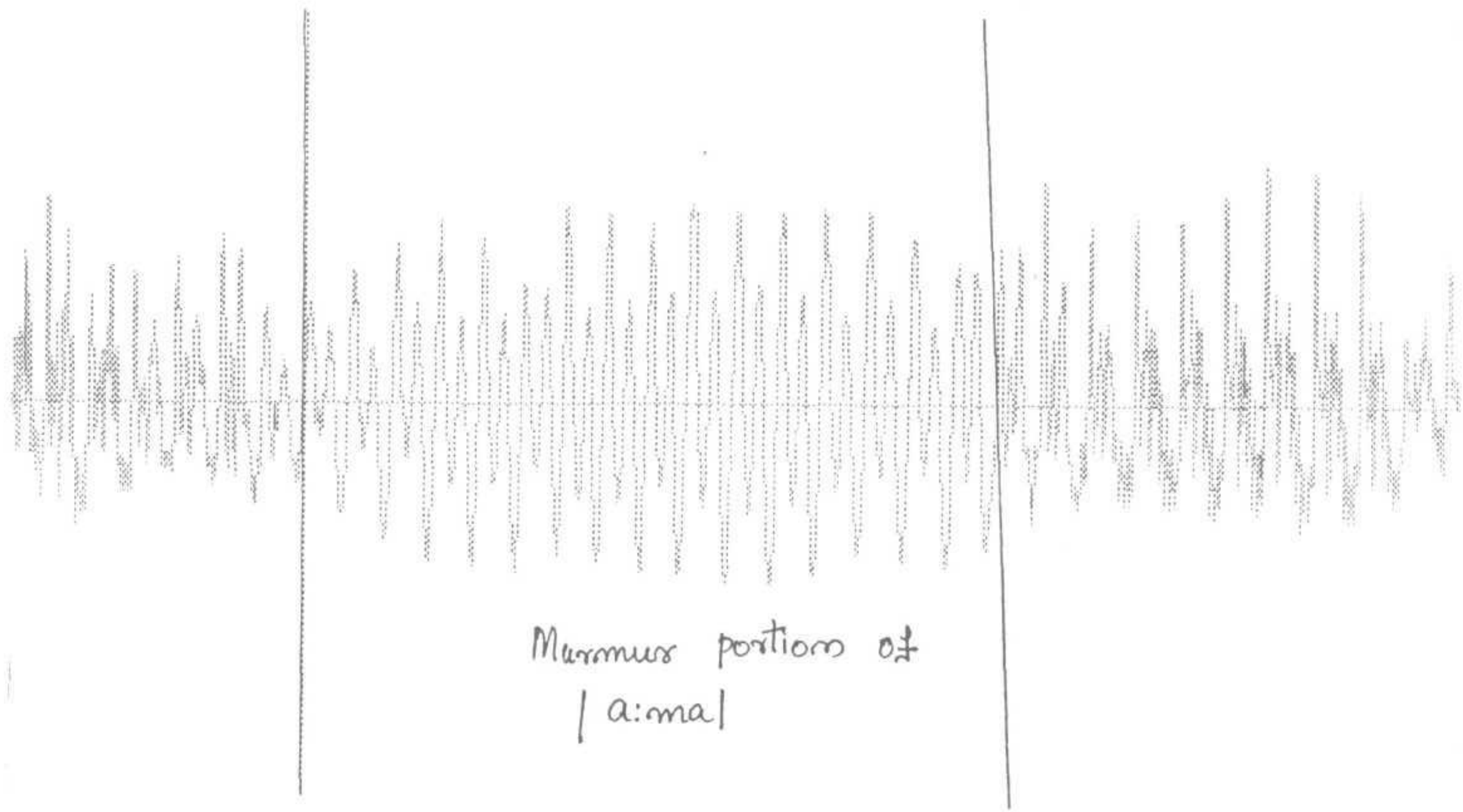
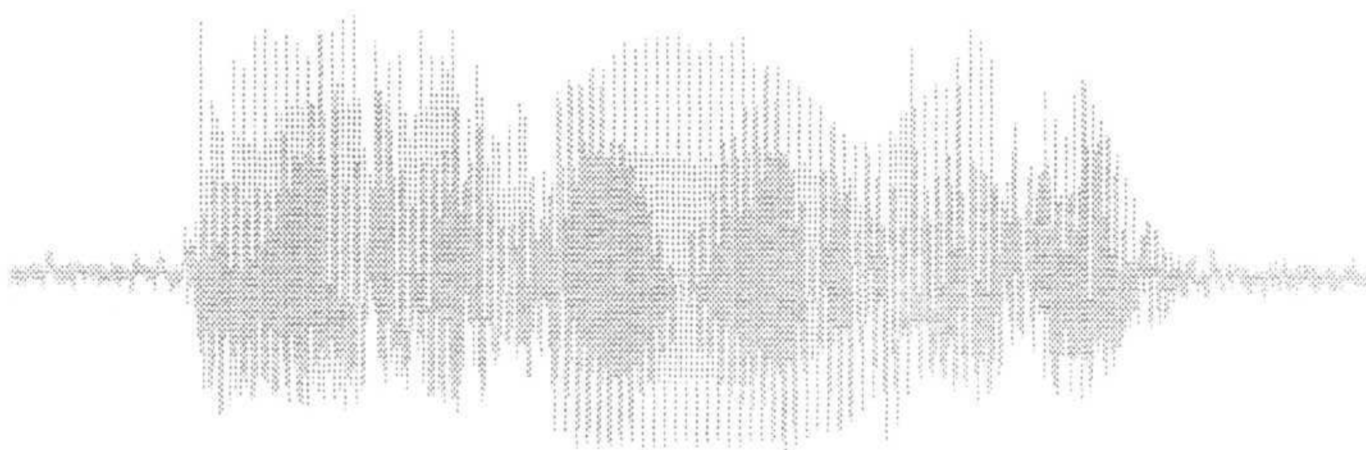
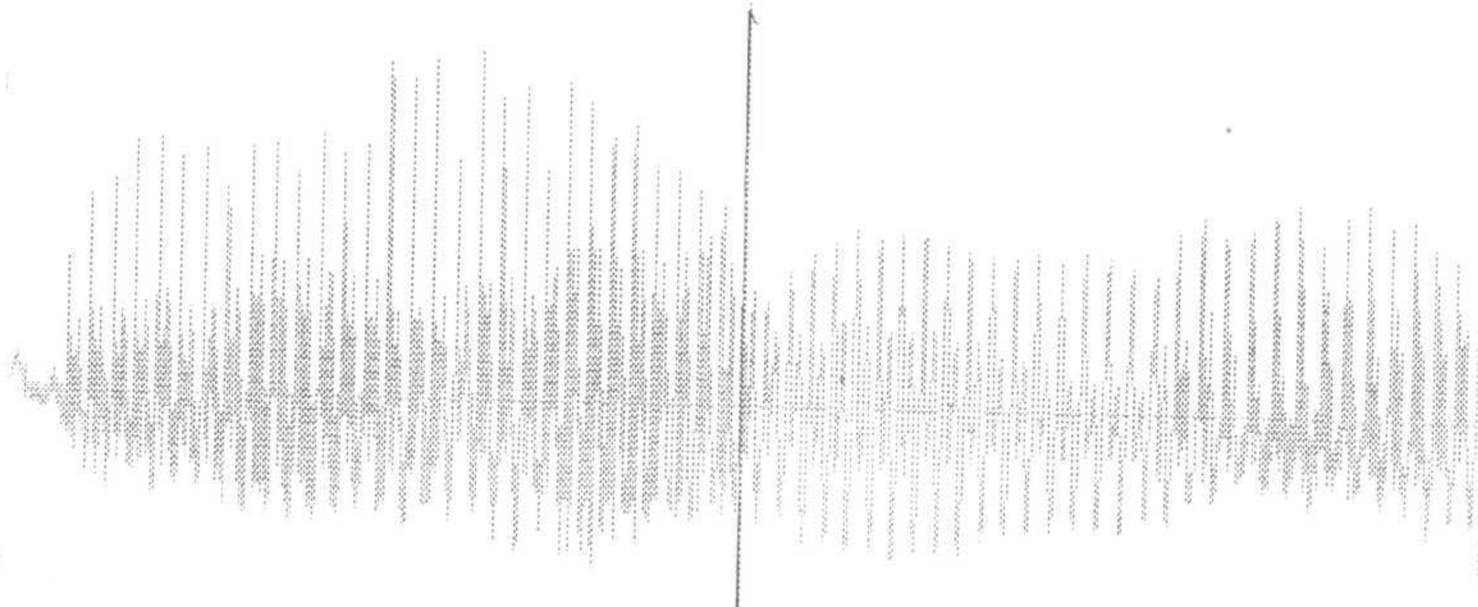


Fig - (4)



|a:ma| with murmur of |Paña|

Fig - 5.



The fig showing the cutting
Point of the preceeding vowel.

perception of 'p' and 'm' was nullified to get a V_1 C_1 V_2 signal. In the signals with murmur and post murmur vowel in the place of original precedingvowel, the precedingvowel segment of some other word was inserted using the insert programme under edit session.

Thus 20 tokens were produced this procedure. These stimuli were randomized, converted to analog signal and were audiorecorded.

Experiment No. Ill:

Aim: To interchange the following vowel transition across different words, so as to find out the importance of following vowel transition as a place cue for nasal perception.

Stimulus preparation:

Using the results obtained through the acoustic analysis of the words, the duration of following vowel transition and steady state was found out. Keeping this durational measure as a reference, the wave form was cut from the beginning of following transition to the end of the signal.

For all the words the following vowel along with transitions were cut and stored in the hard disk of the computer. In the signal with following vowel cut, in the place of original signal the following vowel and transition of some other signal were inserted using the insert programme in the edit session. The Fig. 6 shows the following vowel with transition of | paña |

Using this procedure 20 tokens were produced, these stimuli were randomized, converted to analog signal and audiorecorded.

Experiment No. IV :

Aim : To interchange both the precedingand following vowel steady state and transition to find out how the perception affects by changing these parameters, which inturn will give a idea about the cues used for place perception.

Fig-6

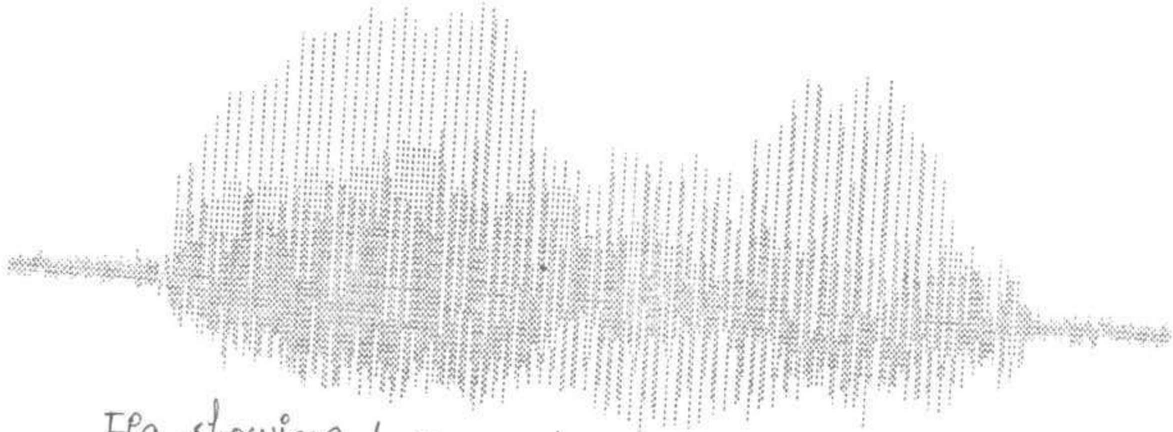


Fig showing | a:ŋ̣ŋ̣a | with following vowel of | Pana |

Stimulus preparation :

It is similar to procedure used in experiment No.II and experiment No.III. The combination is used in this procedure, here using cutting and inserting method under edit session a signal havring the the precedingvowel transition, murmur and following vowel transition of three different words were synthesized. The Fig. 7 shows the signal with precedingvowel of | a:ṉa |, murmur of | m | and foallowing vowel of | a:ṇṇa |.

60 tokens were produced using this procedure. These stimuli were randomized, converted to analog signal and was audiorecorded.

Experiment No.V:

Aim: To change the duration of the murmur of each word, so as to see whether murmur duration affects the nasal perception.

Stimulus preparation:

Duration of different murmur vocalic context (|a|) was obtained through acoustic analysis mentioned previously. In the display program, the middle portion of the murmur was found out and by keeping error at exact zero crossing a portion was either cut or was reinserted using the cut program or insert program under edit session.

This way the same murmur portion was increased or decreased in murmur duration. Transitions portion were not used for cutting and inserting fig. 8 | a:ma |'s duration increased to match with |pana| .

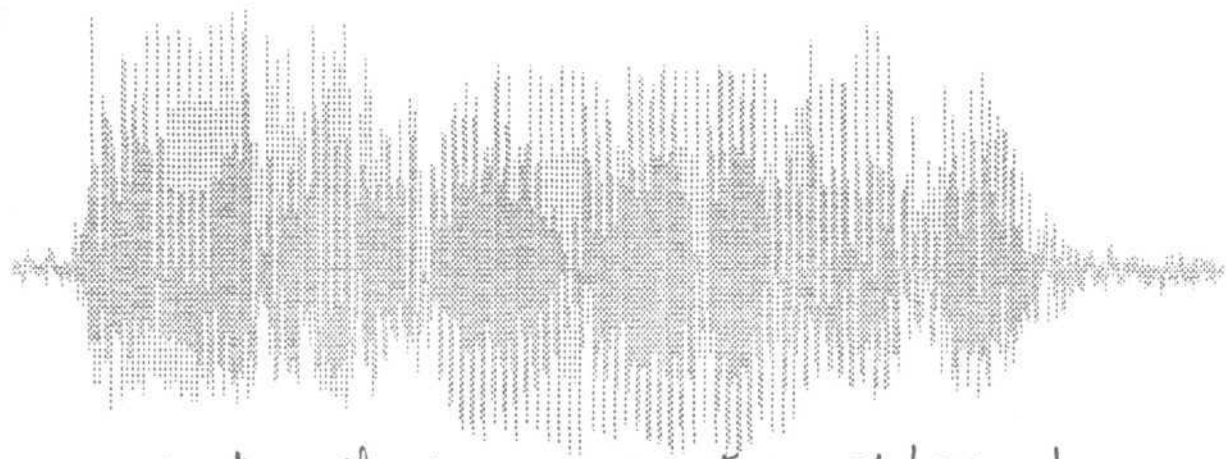
Using this procedure 20 tokens were made.

These stimuli were randomized converted to analog signal and was audiorecorded. Appendix No. I shows stimulus changes for each experiments.

Fig -7

The Fig, showing the signal with preceeding vowel of |a:ma|, murmur of |a:ma| and following vowel of |a:ma|

Fig-8.



The fig, showing the duration of /a:ma/ increased to match with duration of /paña/

Test environment:

The stimuli were audio presented to the subjects at comfortable listening levels through a Sony Deck with preamplifier (Sonodyne) inb perception lab, so that all the subjects could participate at a time.

Subjects :

Five native female Malayalam speakers and five native female Hindi speakers served as the subject. They all had normal hearing no neurological improvement and no history of any other problem related to speech and hearing.

Procedure :

The subjects were instructed to listen to the audio-stimulus and indicate their responses by marking (+) under the appropriate percepts on the response sheets provided. Close chance of 3 percept were given on the response sheet (Viz. similar, some what similar, and different). (The response sheet is given in the appendix). The responses obtained was analyzed to know the differential cues provided by each parameter.

RESULTS AID DISCUSSION

ACOUSTIC ANALYSIS OF THE NASAL SOUNDS

Aim of the present study was to find out the temporal and spectral characteristics of nasal consonants.

Nasal sounds are characterized by various formats and antiformats at different frequency regions. In the production of nasal consonants, at the region of murmur (nasal format/pole), the energy is effectively radiated outside through the nasal cavity. Whereas at the region of anti-format (zeros) the energy is prevented from radiation through the nasal cavity. Therefore energy is trapped into the oral cavity which creates regions of diminished energy called antiformants (zeros).

In the present study three nasal formats were analyzed, they were N_1 N_2 and N_3 Nasal sounds analyzed were /m/, /n̠/, /ñ/ /ṇ/ and /ŋ/. Nasal sounds were in a intervocalic position, with /a/ as the vowel. The words thus formed were /a:ma/, /a:n̠a/ /paña/ /a:ṇṇa/ and /maŋa/.

/ ml - is a voiced bilabial nasal stop consonant with recognizable N_1 N_2 and N_3 frequencies. Fig. 1 shows the spectrogram of a:ma. as produced by a male speaker. In the present study three nasal formats were analyzed, they were N_1 N_2 and N_3 The analysis results shows that N_1 is located around 250 Hz. Similar findings were obtained by Fant (1960) ; Jassem (1964) ; magdics (1969) ; Fant (1973) : Recasens. They found N_1 at around 250 Hz. The reduced resonant frequency may be due to large internal cavity size (pharynx and nasal subsystems) behind the lip closure, because of nasal coupling (Recasen (1982).

N_2 In the present study found was found around 1110 Hz. Similar finding has been reported by Jassem (1964) ; Fant (1973) Recasen (1982).

They found N_2 in the range of 800 to 1300 Hz. The value of N_2 is largely dependent upon the size of the narrow velar passage to the nasal cavity (Bjuggren and Fant, 1964). As there is a increase in the size of velar passage the frequency decreases. On the contrary, Fant (1960) ; Fujimura (1962) ; Kaprowski (1969) : Ramport (1973) found N, around 800-900 Hz. This may be due to linguistic variability or speaker variability.

N_3 for nasal / *ml* was found at around 1420 Hz in the present study. This finding has been supported by Fujimura (1962) ; Kaprowski (1963) ; Ramport (1973) ; Jassem (1973) ; Recasen (1982. They found N_3 in the range of 1300-1900 Hz. This reduction in the resonant frequency can be again attributed to the large internal cavity size (pharynx and nasal subsystems) behind the lip closure (Recasens (1982). As bilabials have an anterior constriction there are more chances for it to have larger cavity size resulting in a reduced N_3 Therefore bilabials have reduced N_3 than alveolars, palatal and velar nasals. In contrary Magdics (1969) ; Jassem (1964) Fant (1973) found N_3 having higher frequency value is 2000-2500 Hz. This may be due to speaker variability. Female speakers shows larger resonant frequency (Peterson and Barney (1952).

/n/ is a voiced alveolar nasal stop. It is characterized by poles (murmurs) and zeros (anti formats). On analyzing the nasal formats of /n/, it was found that /N_1/was around 310 Hz. Similar reports have been made by Fant (1960); Fujimura (1962); Kacprowski (1963); Jassem (1964); Fant (1973); Jassem (1973); Recasen (1982); They found N_1 for /n/, at around 100-400 Hz. The reduction in the resonant frequency can be attributed to wider pharyngeal and nasal cavity (Recasen (1982). N_3 value found for *INI* was higher than /N_1/

value for /m/ .This can be attributed to the decrease in the internal cavitv size as the tongue moves backward, from /m/ to /n/.

N, frequency of *Inl* was found, at around 1200 Hz. This was supported by Dukiewicz (1967) ; Fant (1973) ; Fujimura (1962) Jassem (1964) ; Jassem (1973) : magdics (1969) ; Recasen (1982). They found N_1 ranging from 1000 to 2000 Hz. The value of N, is largely dependent upon the size of the narrow velar passage to the nasal cavity (Bjuggren and Fant 1964). As the cavity size decrease, more high frequency resonance will be seen. Therefore, *Inl,* because of the more posterior placement of the tongue of the higher resonant frequency than in bilabial /m/. Similar findings has been noticed by Fant (1960); Kacprowski (1963); Ramport (1973); obtained much reduced value as N_7, ie in the range of 800-1000 Hz.

N, value for *Inl* was found at around 2230 Hz. This was supported by Fant (1973), Jassem (1964) ; Magdics (1969). N_3 resonance is reported to be a characteristic of pharyngeal cavity (Fant 1960) ; Fujimura (1962). In *Inl* because of more posterior tongue placement than for /m/. the pharyngeal cavity size decreases and subsequently there is an increase in the resonant frequency. Therefore /n̲/ has higher N_3 resonant frequency than for /m/. On the contrary Dukiewicz (1967); Fant (1960); Fujimura (1962); Jassem (1973); Kacprowski (1963); Ramport (1973) found N_3 values in the region of 1200-1900 Hz.

/nl voiced palatal nasal stop. It possess poles and zeros at different frequency regions.

N_1 for n was found to be around 350 Hz. Dukiewicz (1967); Fant (1960); Jassem (1964); Jassem (1973); Kaprowski (1963), found N_1 ranging from 250 to 400 Hz. The lower resonant frequency can be attributed to large pharyngeal and nasal cavity size. The N_1 frequency found was more than for */ml* and /n̲/, because of more posterior placement of the tongue during the production of /ñ/ decreasing the pharyngeal cavity size, there by increasing the N_1 frequency.

/N_2/ for |ñ| was obtained at a frequency range of 1130 Hz. This result is similar to one reported by Dukiewicz (1967); Jassem (1964): Jassem (1973): Kacprowski (1963): Ramport (1973). They found N, in the range of 1000 to 1200 Hz. N_2 value can be largely attributed to the size of the narrow velar passage to the nasal cavity. Bjuggren and Fant (1964), as the size of the velar passage is small during the production of /ñ/ than /m/ and /n̲/ the N_2 frequency value is found higher for /ñ/ than for / *ml* or /n̲/. In contrast Fant (1960) obtained the N, frequency value at low frequency ie around 800 Hz.

Analysis of N, revealed, greater energy concentration for N, around 2230 Hz. Similar N_3 value for /ñ/ was seen in studies done by Jassem (1964); Ramport (1973) ; Jassem (1973) ; Recasen (1982). During the production of palatal sound the tongue can compress the pharyngeal cavity more than it does for the labials and dentals. This reduction in the pharyngeal cavity size increases the resonance of N_3 for /ñ/, compaired to */ml-* and /n̲/. On the contrary Dukiewicz (1967) ; Fant (1960) ; Kaprowski (1963) found N_3 being in the range of 1500-1900 Hz.

/ṇ/ is a Voiced palatal nasal retroflex. The nasal /ṇ/ is characterized by poles and zeros.

On analysing /ṇ/, it was found that N,, occurred, around 370 Hz. As there are only few languages which have /ṇ/ as a phoneme, there seems to be no reports on the murmur characteristics of /n/. In malayalam N for /n/ was of lower frequency due to an increased pharyngeal or nasal cavity size.

N, was found around 1260 Hz, this low frequency energy can be explained by the narrow velar passage to the nasal cavity. During retroflex production back of the tongue is placed posteriorly creating a smaller pharyngeal cavity and which has lead to a high frequency resonance. Therefore compared to /m/, /n̠/, /ñ/, /ṇ/ has N_2 is in a slightly higher frequency region. But /n_2/ of /ṇ/ is lesser than for /ŋ/ because of the velar placement for /ŋ/ production.

N_3 was found around 2495 H_z. This is again higher than /m/, /n̠/ and /ñ/. N_3 majorly depended on the size of the pharyngeal cavity (Fant 1960; Fujimura (1962). During the production of /ṇ/, due to the posterior placement of the tongue, the pharyngeal cavity size decreases, resulting in an increased resonant frequency. Thus /n/ is found to have N_3 value more than /m/. /n̠/. /ñ/ but less than /ŋ/.

/ŋ/ is a Velar nasal stop. It is characterised by poles and zeros.

In the present study Nj for /ŋ/ was found at 390 Hz. This result is similar to the reportes made by Dukiewicz (1967); Fant (1973) Fujimura (1962); Jassem (1964); Jassem (1973); Kacprowski (1963), they obtained N, value for /ŋ/ in a wide range of frequencies, ie. from 100 - 400 H . 1^ value depended on the size of the pharyngeal and nasal cavities (Recasens(1982).

During the production of /ŋ/ due to the posterior placement of the tongue, the pharyngeal cavity size reduces, this will create an increase in resonant frequency. Thus /ŋ/ has n_1 greater than in /m/, /n̠/ /n̥/ and /ñ/. In contrast a study done by Fant (1960) showed N_1 value around 250 Hz

N, value for /ŋ/ in the present study was found around 1400 Hz. Dukiewicz (1967); Fant (1960); Fant (1973); Jaseem (1964); Jaseem (1973); Kacprowski (1963) Magdics(1969), obtained n, value around 1000 to 1500 Hz. N_2 depends on the narrow velar passage to the nasal cavity (Bjuggren & Fant 1964). In the production of /ŋ/, the posterior placement of the back of the tongue narrows the velar passage to the nasal cavity increasing the frequency. (Bjuggren & Fant 1964).

This can be expanded as:

$V = rW$	V = Volume
$V = r \times 2\pi\upsilon$	r = Radius
$\upsilon = \dfrac{v}{r \times 2\pi}$	υ = Frequency

Therefore as the size of the opening decreases frequency increases. It is found /ŋ/ has N_2 at high frequency region than /m/, /n̪/, /ñ/ and /ṇ/. On the contrary Ramport (1973) found N_2 in a much lower frequency is around 900 Hz.

N, for /ŋ/ was found in the range of 2650 Hz. This was supported by Dukiewicz (1967); Fant (1960); Fant (1973); Jassem (1964); Jassem (1973); Kacprowski (1963); Ramport (1973), they found N_r falling in the range of 1500 - 2600. N_3 depends on the pharyngeal cavity size,. As the size decreases the resonant frequency increases. In the production of /n/ the pharyngeal cavity size is considerably reduced due to the posterior placement of the tongue, this creates a higher resonant frequency for /ŋ/. Therefore /ŋ/ has resonant frequency higher than for /m/, /n/, /ṇ/ and /ñ/.

The results of this section can be summarized as follows :

1) The nasal consonants are characterized by poles (formats) and zeros (antiformants) at different frequency region).
2) Frequency of N_1 lies in the region of 200 - 300 Hz.
3) N_2 was found in the frequency region of 1000 to 1500 Hz.
4) N_3, was found in the frequency region of 1500 to 2700 Hz.
5) N_1 value increases as the place of articulation moves from bilabials, alveolars palatal to velars.

   Bilabials < alveolars < palatals < velars.

   Similarly N_2 and N_3 frequency values increase as the place of articulation moves from bilabials to velars.

   Bilabials < alveolar < palatal < velars

Therefore the study rejects the hypothesis that there is no difference in the $N_;$ N,. N_3 between /m/,/n/,/n7,/n/ and **/IJ/.**

TEMPORAL ANALYSIS OF THE NASAL MURMUR

The temporal analysis of nasal murmur was through a wide band spectrogram. By moving the vertical cursor from the beginning to the end of murmur, the duration of nasal murmur was noted down.

The average duration of la:mai found was 122 Hz, /a:na/ 132 Hz., /Pana/ 248 Hz /ama/ 98 Hz and **/maija/** 120 Hz.

Fisher and Jorgensen (1979) reported that as the bulk of actuculators increased the closure duration increased. This can be applied in case of nasal murmur also. The front consonants will be having more murmur duration than back consonants. Therefore /a:ma/ and /a:na/ seem to have more murmur

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duration than /a:n̲a/ and /maɲa/. In case of /pan̄a/ the complete dorsom of the tongue comes in contact with hard palate and therefore the greater bulk of articulators play a role in the production of /n̄/,/ṇ/ and /ŋ/ as they are posteriorly placed sounds, they make use of less bulk of articulators and therefore have reduced duration /n/ being a retroflex has least duration.

The results shows that the hypothesis of there is no difference in the duration of murmur between /m/, /n̲/, /ṇ/, /n̄/ and /ŋ/ is rejected.

Analysis of pre-murmur vocalic steady state and the transition

The acoustic analysis of the vocalic steady state and the transitions were done through a wide band spectrogram. Using LPC program in "spgm" the frequency values were noted down.

In the present study the acoustic analysis of the vowel steady state and transitions revealed F_1 at around 850 Hz and F_1 transition end point at around 796 Hz. The frequency range found for transitions was around 54 Hz. in the negative direction. This was supported by Recasen (1962). The frequency of vocalic steady state can be explained in terms of acoustic theory of speech production (Fant, 1960). The negative transition is due to a complete labial obstruction. (Recasen. 1962) F, was found at a frequency of 1328 Hz. with transition end point at 1248 Hz. The frequency range for transition was 80 Hz in the negative direction. This is supported by Dukiewicz (1967) and Recasen (1983). The reduced F, can be explained in terms of acoustic theory of speech production. (Fant 1960) and negative transition may be due to the change from higher resonant frequency of vowels to the lower resonant frequency of the murmur. A large frequency range (140-500 Hz) were seen in other studies, Magdics (1969) ; Fant (1960) ; Vagges et al.. (1978).

In the present study F_3 was found at around 2737 Hz. F_3 transition end point was seen at around 2692 Hz. The frequency range seen was 45 Hz in the negative direction. F_3 value can be explained by the acoustic theory of speech production (Fant, 1960) and the negative transition may be due to the change from higher resonant of vowels to the lower resonant frequency of the murmur.

In the word /a:n̪a/ pre-murmur vocalic steady state and transition were analyzed. F_1 was found in the range of 796 Hz, with transition end point at around 746 Hz. The frequency range for transition is around 50 Hz in the negative direction. Similar findings were reported by Recassens (1982). The frequency of F_1 can be explained by acoustic theory of speech production (Fant, 1960). The negative transition may due to oral construction. (Recasen 1982).

On analyzing F,, it was found at 1341 Hz and F, transition end point at, around 1571 Hz. The transition frequency range seen was around 230 Hz in the positive direction. This was supported by Racasens (1982). Jassem (1962) : Magdics (1969) ; Fant (1960). Acoustic theory of speech production can be used to explain the increase in F_2 frequency. As the N, resonance of /n̪/ murmur occurred at 1200 Hz, the transition end point of F_2 was found at 1248 Hz, this might have caused a rising transition. Ferrero (1979) ; Nagges et al., (1978) found a lesser range of rising f_2 transition.

F_3 was found around 2537 Hz, with end point at around 2567 Hz. There is a positive transition change to around 30 Hz. This was supported by Recasens (1963) and Nagges et al., (1978). Increase in F_3 transition can be explained by acoustic theory of speech production of Fant (1960). As the N, value of /ṉ/ murmur was around 2230 Hz. The transition of F_3 was found raising. Dukiewicz (1967); Magdics (1969); Ferrero et al.. (1979) found a transition in the negative direction in the range to 50 to 200 Hz.

In /pañа/ the acoustic analyses of vowel steady state and transition revealed F_1 at 814 Hz and transition end point of F_1 at 694 Hz. Direction of transition change was found to be negative in the range of 120 Hz. This was supported by Recasens (1982). The increase in F_1 can be explained by the acoustic theory of speech production. The negative transition for F_1 can be due to complete obstruction of the oral cavity for the production of /ñ/.

F_2 was found at 1360 Hz and transition end point of F_2 was seen at 1785. There was a large increase in the transition frequency. The range of positive transition frequency was found to be 425 Hz. Similar findings were obtained for Dukiewicz (1967) ; Jassem (1962, 1964) Magdics (1969) ; Fant (1960) ; Nagges et al., (1978) and Recasens (1982). Acoustic theory of speech production can be used to explain the frequency of F_2. The rising f_2 transition foi |ñ| might be due to the higher frequency placement of N_2 around (1210).

F_3 was found around 2355 Hz. The F_3 transition end point was seen at 2475 Hz. A positive transition change in the range of 120 Hz was observed. This was supported by Dukiewicz (1967) ; Jassem (1962) ; Fant (1960) ; Nagges et al., (1978) ; Recasens (1982). The increase in F, can be explained by acoustic theory of speech production. The positive direction of transition can be explained by the occurrence of the N_3 resonance at higher frequency region.

In the word /aṇṇa/ the acoustic analysis of the vocal steady state and transitions revealed F_1 at around 856 Hz. The transition end point was seen at 781 Hz. There was a transition in the negative direction, to a range of 75 Hz. This might be due to oral obstruction during the production of retroflex. As there are not many languages with /n/ nasal, there seems to be no reports in the literature regarding the spectral characteristic of nasal vowel.

F_2 was found around 1380 Hz with a rising transition in the range of 245 Hz. The transition endpoint was at 1625 Hz. The frequency characteristic of F, can be explained by acoustic theory of Fant (1960). The rising transition may be due to the resonant frequency of N_2 at a high frequency region.

F_3 was found at around 2785 Hz with a falling transition in the range of 250 Hz. This negative transition marked its end point at 2535 Hz. Acoustic theory of speech production Fant (1960) can be used to explain the spectral characteristic of F_3 The negative transition may be due to the N, found at comparatively lower resonant frequency region. As there are not many languages with /n/ no literature was available regarding the spectral characteristics of /ṇ/

In /maɲa/ the acoustic analysis and vowel steady state revealed F_1 at 802 Hz with a negative transition in the range of 20 Hz. The end point of F_1 transition was seen at around 782 Hz. This is supported by the findings of Duckiwicz (1967). Recasen (1982) was found N_1 in the range of 900-1400 Hz, with a negative transition in the range of -50 Hz. The slight negativity seen in F_1 excursion between /a/ and /ɲ/ murmur is related to a smaller increase in phyangeal cavity size (Recasens, 1982).

F_2 was found around 1349 Hz with transition in the positive direction. The range of rise in transition was around 100 Hz. The transition end point for F_2 was marked at 1449 Hz. The occurrence of F_2 can be explained by acoustic theory of speech production by Fant (1960). The rise in the F_2 can be explained by the resonant frequency of the murmur in the high frequency region. This was supported by Dukiewicz (1967) and Recases (1982). they observed F, frequency in the range of 1400 to 2000 Hz.

F_3 was found at. 2377 Hz. with transitions in the negative "direction. The range of negativity seen in transition is around 94 Hz. The transition end point was marked at 2283 Hz. The spectral characteristic of F_3 can be explained by acoustic theory of speech production Fant (1960). The negativity seen can be explained by the resonant frequency of the nasal murmur in the low frequency region. This was supported by the reports of Dukiewicz (1967) and Recasens (1982). They found F_3 value in the range of 2300 to 2800 Hz.

The results shows that the frequency of the preceding transition end point range from (F_1 746-796, $F_2$1248-1785, F, 2283-2692). The F_1. F_2 F_3 trasition was found to be falling for /a:ma/. Four /a:n̠a/ F_1 was falling F_2.and F_3 raising. For /paña/ F_1 was found falling, F_2,and F_3 raising. For /a:ṇṇa/ F_1 was found falling. F_2 raising, F_3 falling. For /maɲa/ F_1 was found falling. F_2 raising, F, falling. The preceding vowel steady state was found in the range of (F_1 796-856. F_2 1328-1380, F_3 2355-2785) for /a:ma/. /a:n̠a/, /paña/, /a:ṇṇa/, /maɲa/.

This results rejects the hypothesis that there is no difference in the frequency of pre murmur vocalic study state and transition between /m/,/n̠/,/ñ/, /ṇ/ and /ɲ/.

Temporal analysis of the pre-murmur vowel transition :

Duration of the pre-murmur vowel transition was found using a wide band spectrogram. The vertical cursor was moved from the beginning of the transition to the end of the transition to find out the transition duration. The duration of vowel to murmur transition was found to be around 20 msec for /a:ma/, 60 msec of /a:n̠a/, 70 msec for /pañа/ and 80 msec for /a:ṇṇa/ and 45 msec for /maɲa/. Recasens (1982) found the transition duration of n to be around 70 msec, /n/ to be 50 msec and /n/ to be 35 msec, which are similar to the present results.

Through the temporal analysis, it is clear that /n/ has the maximum transition duration followed by /ñ/ and /n̠/, /ɲ/ and /m/.

The results rejects the hypothesis that there is no difference in the duration of pre murmur vowel transitions between /a:ma/, /a:n̠a/, /pañа/, /a:ṇṇa/, /maɲa/.

Analysis of results of post murmur transition and vowel steady **state** :

The acoustic analysis of the post murmur vocalic steady state and the transitions were done through a wide band spectogram. Using LPC program in spgm the frequency values were noted down.

The acoustic analysis of the /a:ma/ post murmur transition and vowel steady state revealed F_1 transition in the positive direction. The transition beginning was seen at 632 Hz and the frequency of vocalic steady state at around 707 Hz. The rise in the frequency was by around 75 Hz. This rise in the transition may be due to a preceding complete oral construction.

F_2 transition was also found in the positive direction. The transition beginning was at 1181 Hz and vocalic steady state was found around 1281 Hz. There is a rise in frequency from transition to vocalic steady state by around 100 Hz. The rise in F_2 may be due to the preceding complete oral construction. The frequency of vocalic steady can be explained by acoustic theory of speech production (Fant (1960).

Transition of F_3 was found raising, in the range of 50 Hz. The transition beginning frequency for F_3 was found around 2518 Hz and the frequency of vocalic steady state was around 2568 Hz. The frequency of vocalic steady state can be explained by the acoustic theory of speech production (Fant. 1960). The rise in the transition frequency can be attributed to the change from low frequency murmur to high frequency vowel format. This view has been supported by Jassem (1962, 1964). He obtained F_3 transition rise in the range of +100 Hz.

In the word /a:na/ the acoustic analysis of post murmur transition and vowel steady state revealed $F_{(}$ transition in the positive direction. The transition beginning was seen at 712Hz, and the frequency of vocalic steady state was found at around 787 Hz. The rise in the frequency was by around 75Hz. This rise in the frequency may be due to the change from low frequency murmur to high frequency vowel formants.

F_2 transition was found in the negative direction. The transition beginning was found at 1725 Hz and the vocalic steady state was found at 1475 Hz. There was a reduction in frequency from transition to vocalic steady state by around 250Hz. This negativity might be due to change from high frequency nasal murmur to low frequency vowel steady state.

F_3, transition was found falling. The transition beginning for F_3 was found at 2623Hz, and the frequency of vocalic steady state was at around 2548 Hz. The frequency of vocalic steady state can be explained by the acoustic theory of speech production (Fant, 1960). The reduction in the transition frequency can be attributed to the change from high frequency murmur to low frequency vowel formant.

The acoustic analysis of /pan̄a/ for the post murmur transition and vowel steady state revealed F_1 transition in the positive direction. The transition beginning was seen at 696Hz and the frequency of vocalic steady state was found around 796 Hz. The rise in frequency was by l00Hz. This rise in the transition may be due to change from low frequency murmur to high frequency vowel formant.

F_2 transition was found in the negative direction. The transition beginning was found at 1866 Hz, and vocalic steady state was found at 1416Hz. There is a reduction in frequency by around 450Hz. This reduction in F_2 may be because of the change from high frequency murmur to a low frequency vowel steady state. The frequency at vowel steady state can be explained by the acoustic theory of speech production (Fant. 1960).

In the word /a:ṇṇa/ the F_1 transition was seen to be in positive 'direction. The transition beginning was seen at 776Hz and the frequency of vocalic steady state was found at 851Hz. The rise in the frequency was a 75Hz. The rise in the transition may be due to change from low frequency murmur to high frequency vowel steady state. The occurance of this frequency of vowel steady state can be explained by acoustic theory of speech production (Fant. 1960).

F_2 transition was found in a negative direction. The transition beginning was around 1754Hz and the vocalic steady state at 1479Hz. The reduction in the frequency is by 275Hz. This reduction in frequency might be due to change from high frequency murmur to a low frequency vowel steady state.

The frequency of vowel steady state can be explained by acoustic theory of speech production (Fant, 1960).

F_3 transition was found raising, the transition beginning frequency for F_3 was 2481 Hz, and the frequency of vocalic steady state was at around 2706Hz. The frequency of vocalic steady state can be explained by the acoustic theory of speech production (Fant, 1960). The rise in the transition frequency can be attributed to the change from loco frequency murmur to high frequency vowel steady state. F_3 transition rise was in the range of 225Hz.

In the word /maɲa/ the acoustic analysis of the post murmur transition and vowel steady state revealed F_1 transition in the positive direction. The transition beginning was seen at 769Hz. The rise in the frequency was by 24Hz. The frequency of vocalic steady state was found at 793Hz. This raise in the transition may be due to change from low frequency murmur to high frequency in the vowel steady state.

F, transition was found in the negative direction. The transition beginning was at 1420Hz and the vowel steady state was found at. 1295Hz. The rise in the frequency was in the range of 125Hz. This rise in frequency may be because of the change from high frequency murmur to low frequency vowel steady state. The frequency of vowel steady state acoustic theory of speech production.

F_3, transition of the word /maɲa/ was found raising, in the range of 125Hz. The transition beginning was found at 2598Hz and the vowel steady state was found at 2723Hz. This increase in the frequency may be due to change from low frequency murmur to high frequency vowel steady state.

The results shows that the frequency of the following transition beginning, range from (F_1 -> 632 to 776, F_2 -> 1181 to 1866 and F_3 -> 2486 to 2628). F_1 F_2 and F_3 transition were found to be raising for /a:ma/. For / /a:na/ F_1 was found rising, F_2 and F_3 were found falling. For ,/pañ F_1 was found rising, F_2 and F_3 were found falling. For /a:nna/ F_1 was rising, F_2 was falling and F_3 was found rising. For /maɲ F_1 was rising, F_2 was falling and F_3 was found rising. The following vowel steady state was found to be in the range of (F_1 -> 707 to 793, F_2 -> 1281 to 1479 and F_3 -> 2548 to 2723). Therefore the hypothesis that there is no difference in the spectral characteristic of post murmur transition and vowel steady state between /a:ma/, /a:n̠a/, / /pañа/, /a:ṇṇa/ and /maɲa/ was rejected.

Temporal analysis of the post murmur vowel transition

Duration of the post-murmur vowel transition was found using a wide band spectrogram. The vertical cursor was moved from beginning of the transition to the end of the transition to find out the transition duration. The duration of post murmur vowel transition to vowel steady state was found to be around 30msec for /a:ma/, 75msec for /a:n̠a/ 90msec for ,/pañа/ 110 msec for /a:ṇṇa/ 60msec f /oмaɲa/. Through the temporal analysis, it is clear that /ṇ/ has the maximum transition duration followed by /ñ/, /n̠/, /ɲ / and /m/. Therefore the hypothesis that there is no difference in the duration of post murmur vowel transition between /a:ma/, /a:n̠a/, /pañа/, /a:ṇṇa/ and /maɲa/ was rejected.

Aim of this study was to find out the place cues for the perception of nasal consonants in Malayalam.

Experiment No. **1**

PERCEPTUAL ROLE OF MURMUR

Stimulus were prepared by cutting and pasting murmur across different nasal consonants. This was done through a waveform editing as already explained in the previous chapter. The results of the perception analysis has been presented here.

Murmur portion of /a:ma/ was substituted by, murmur of /a:na/. /pana/, /a:nna/ and /mana/. The perception of /a:ma/ was not affected for malayalam speakers and Hindi speakers when /a:ma/ was substituted by /n/, /n/ and /n/ murmur. This shows that the murmur of /m/ in the intervocalic position, with vowel being /a/ did not had a significant role in place perception.

Malecot (1956) reported that the perceptual role played by a murmur was small and varied across different places of articulation. Recasens (1983) reported that place judgement for nasal consonant cannot be obtained on the basis of appropriate murmur structure alone. Delattre 1958, 1968: Fant 1960; Fujimura (1962); Fujimura and Lindquist (1970); Hattori. Yamamoto and Fujimura (1958); Mattingly (1968), have reported nasal murmur as a spectral characteristic which mark nasal consonants as a class; independent of place of articulation and the adjacent nasalized vowel. House (1957) assigned the murmur to have an intensity 8dB lower than that appropriate for /i/. Concentration of formants (N_2, N_3 N_4) between 300-4000Hz, with large - band width were found. The small perceptual significance of those formants seems to result not only from their low intensity level with respect to N_1

(especially N, often absent as reported by Fant (1962); Winstein Candless. Mondshein and Zue (1975)) but also from their spectra variability..

Repp (1986) found that mismatched murmur did not lead to a performance decrement in /a/ and /u/ syllables, which confirmed the prediction of an auditory adaptation hypothesis, which is enhanced by peripheral auditory system. On the contrary Garcia (1966, 1967, 1967b); Hecker (1962); House (195); Nakata (1959); Nord (1976); Copper Delattre, Lerberman, Borst and Gerstman (1952); Kurowski and Blumstein (1984, 1987) Repp (1986, 1987) through various experimental paradigms have shown that spectral relation of murmur with that of formant transition aids in place perception of nasals. Nakata (1959); Kacprowski and Mikiel (1965) reported that *N*- and $N_{/}$ dynamics could correctly simulate different place perception.

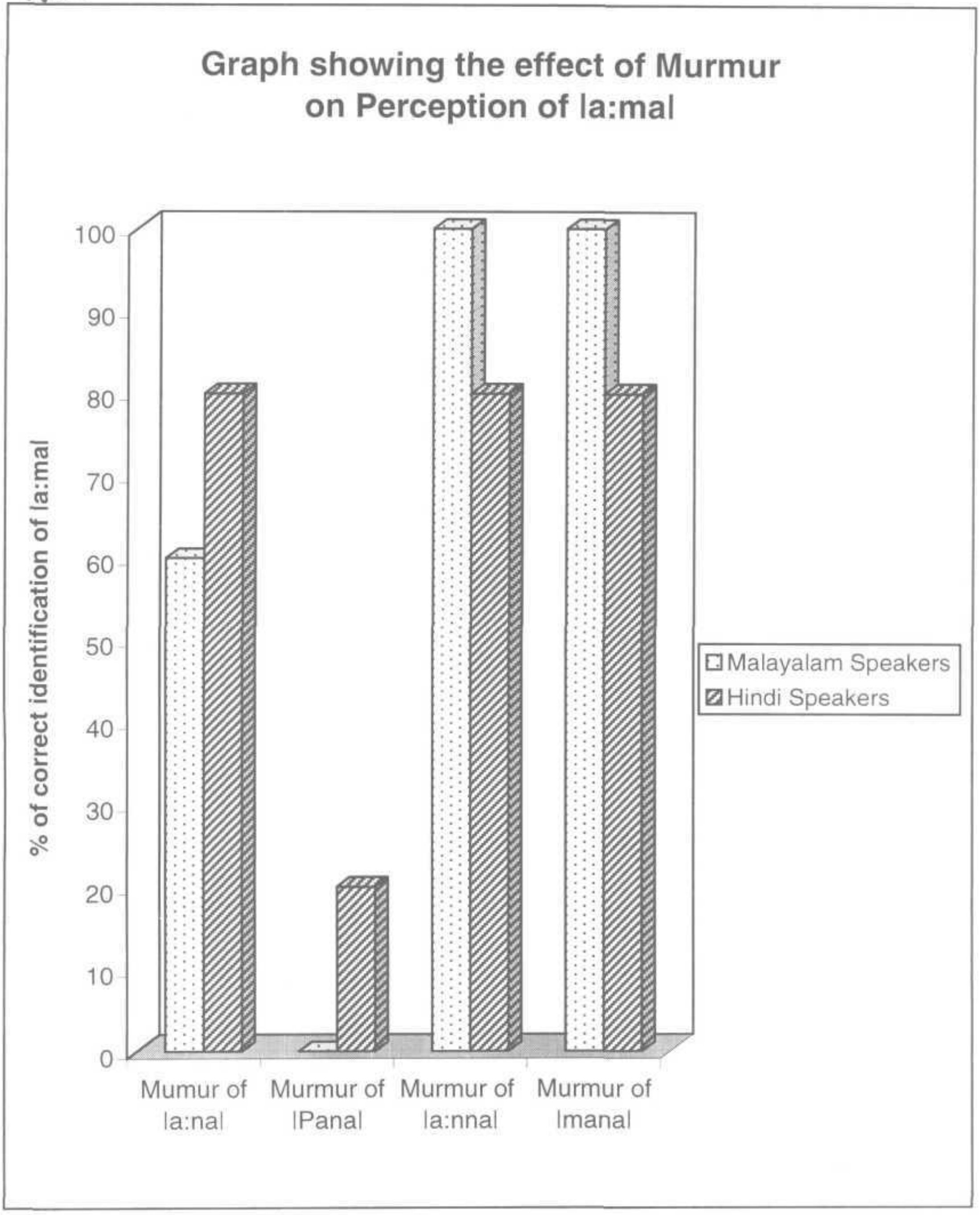
When the murmur portion of a:ma was substituted by murmur of / pana/, the perception of /a:ma/ was affected to an intermediate degree for Malayalam speakers and Hindi speakers. This might be due to the artificiality introduced by increased signal duration. The average murmur duration of / a:ma/ was increased by 126 msec when the murmur of panjya was introduced. Repp (1986) analyzed the effect of natural variation in murmur duration, he found that the intelligibility of truly steady state isolated murmur decreased as their duration was increased.

From this experiment, it can be seen that :

1. Murmur of *I ml* did not provide much of place cue, in the /a/ context.
2. Abnormal increase in murmur duration can affect the perception.
3. There was not much of difference between hindi speakers and malayalam speakers in terms of perception.

Graph 1 shows effect of murmur on perception of /a:ma/.

No:1



Graph showing the effect of Murmur
on Perception of /a:ma/
% of correct identification of /a:ma/
100
90
80
70
60
50
40
30
20
10
0
Mumur of /a:na/
Murmur of /Pana/
Murmur of /a:nna/
Murmur of /mana/
Malayalam Speakers
Hindi Speakers

The murmur portion of /a:na/ was substituted by murmur of /a:ma/, /pana/, /a:nna/ and /mana/. The perception of /a:na/ was affected to an intermediate degree for Hindi speakers and Malayalam speakers when the murmur of /a:na/ was substituted by murmur of /a:ma/, but in the previous experiment, when the murmur of /a:ma/ was substituted by murmur of /a:na/, there was no change in perception of /a:ma/. This shows that murmur acts as a place cue in the perception of alveolar nasal and consonant. This was supported by Kuro'wski and Blumstein (1984). They reported of a difference in perceptual cue provided by murmur for different place of articulation. Garcia (1966, 1967, 1967b); Hecker (1962); House (1957); Nakata (1959); Nord (1976); Delattre, Liberman, Borst and Gerstman (1952); Kurowski and Blumstein (1984, 1987); Repp (1986, 1987) through various experimental paradigms have shown that, spectral relation of murmur with that of formant transition aids in place perception of nasals. Nakata (1959); Kacprowski of Mikiel (1965) reported that N_1 and N_2 dynamics could correctly simulate different place perception.

Malecot (1956): Recasens (1983) Delattre 1958. (1968): Fant (1960); Fujimura (1962): Fujimura and Lindquest (1970); Hattori, Yamamoto and Fujimura (1958): Mattingly (1968); House (1957) reported of a minimal perceptual clue provided by the nasal murmur.

The perception of /a:na/ with the murmur of /pana/ was affected to a intermediate degree for Hindi speakers and malayalam speakers this might be due to the artificiality introduced by increased signal duration. (Repp, 1986): or by the inherit property of the alveolar nasals to use the spectral information from murmur as a clue for place perception.

By introducing the murmur of /n/ and /n/ in /a:na/ there was no change in perception of /a:na/ for Hindi speakers and malayalam speakers. This can be explained by spectral similarity of /n/ murmur with /n/ and /y/ in terms of N_3 and N_2 N_3 was placed in a range of 2230 to 2650 for the /n/, /n/ and /n/ murmur. When compared to /m/, the N_3 and N_2, placements of n. n, n and n are in higher frequency. The spectral similarity seen for /n/. /n/ and /n/ does not seem to produce any change in the perception when /n/ was substituted by /n/ and /n/.

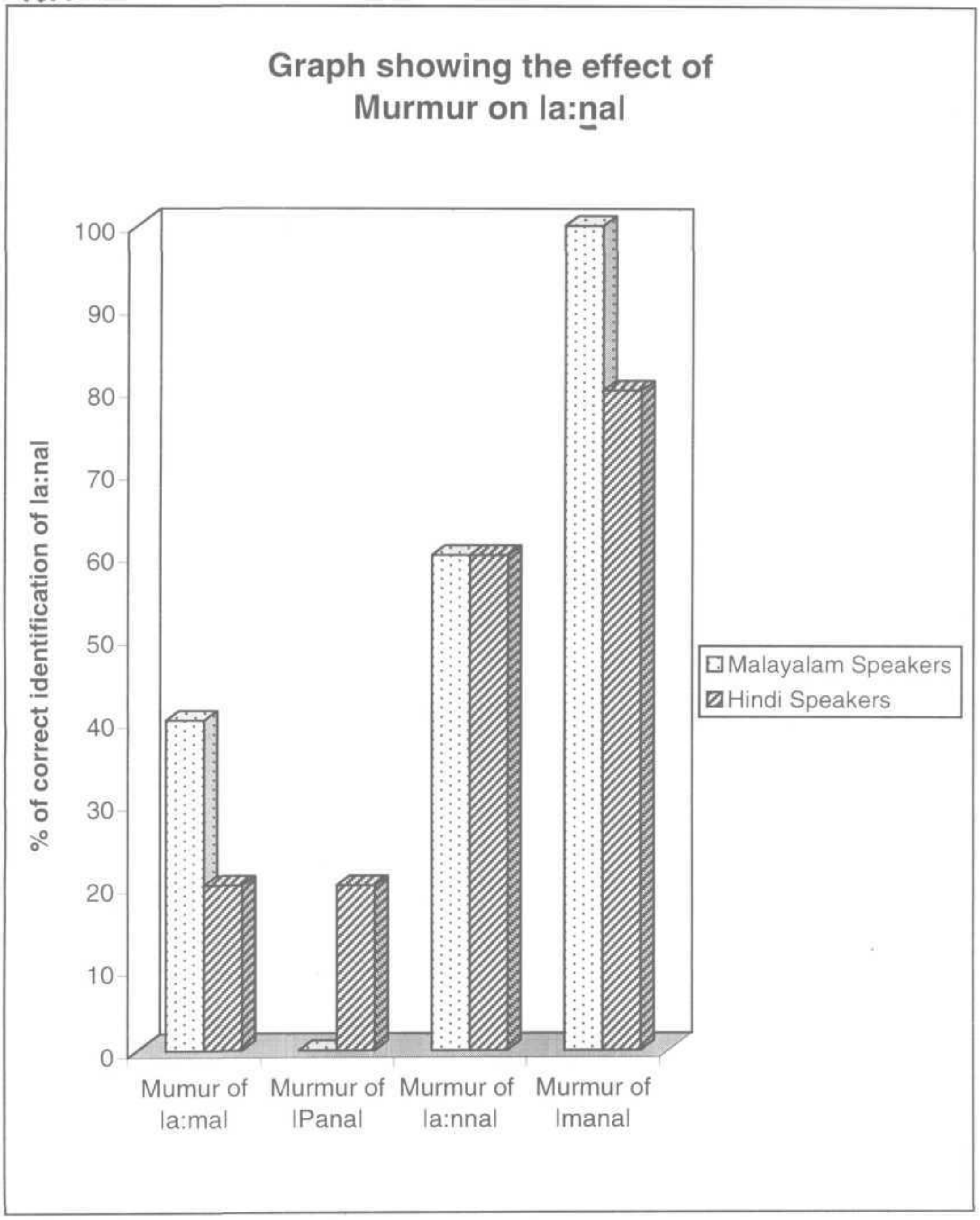
Therefore it can be stated that the murmur of alveolar nasal consonant provides spectral cues for place perception. Garcia (1966, 1967. 1967b); Hecker (1962); House (1957); Nakata (1959); Nord (1976); Copper, Delattre. Liberman Borst and Grestman (1952); Kurowski and Blumstein (1984, 1987) Repp (1986, 1987) have shown that spectral relation of murmur with that of formant transition aids in place perception of nasals. Nakuta (1959) Kacprowski and Mikiel (1965) reported that N_1 and N_3 dynamics could correctly simulate different place perception. On the contrarory Malecot (1956); Recasens (1983); Delattre (1958, 1968); Fant (1960); Fujimura (1962); Fujimura and Lindquist (1970); Hattori, Yamamoto and Fujimura (1958); Mattingly (1968); House (1957) Repp (1986) reported of a minimal perceptual clue provided by the nasal murmur.

This experiment shows that :

1. For alveolar nasals, the murmur and transition acts as a place cue.
2. Abnormal increase in duration negatively affects the perception.
3. There was no change in perception between native hindi speakers and malayalam speakers.
4. As the results on perceptual cue provided by nasals are inconclusive, further studies are warranted.

The graph 2 shows the effect of murmur on the perception of nasal consonants.

No: 2



Graph showing the effect of
Murmur on la:nal
% of correct identification of la:nal
100
90
80
70
60
50
40
30
20
10
0
Mumur of la:mal
Murmur of lPanal
Murmur of la:nnal
Murmur of lmanal
Malayalam Speakers
Hindi Speakers

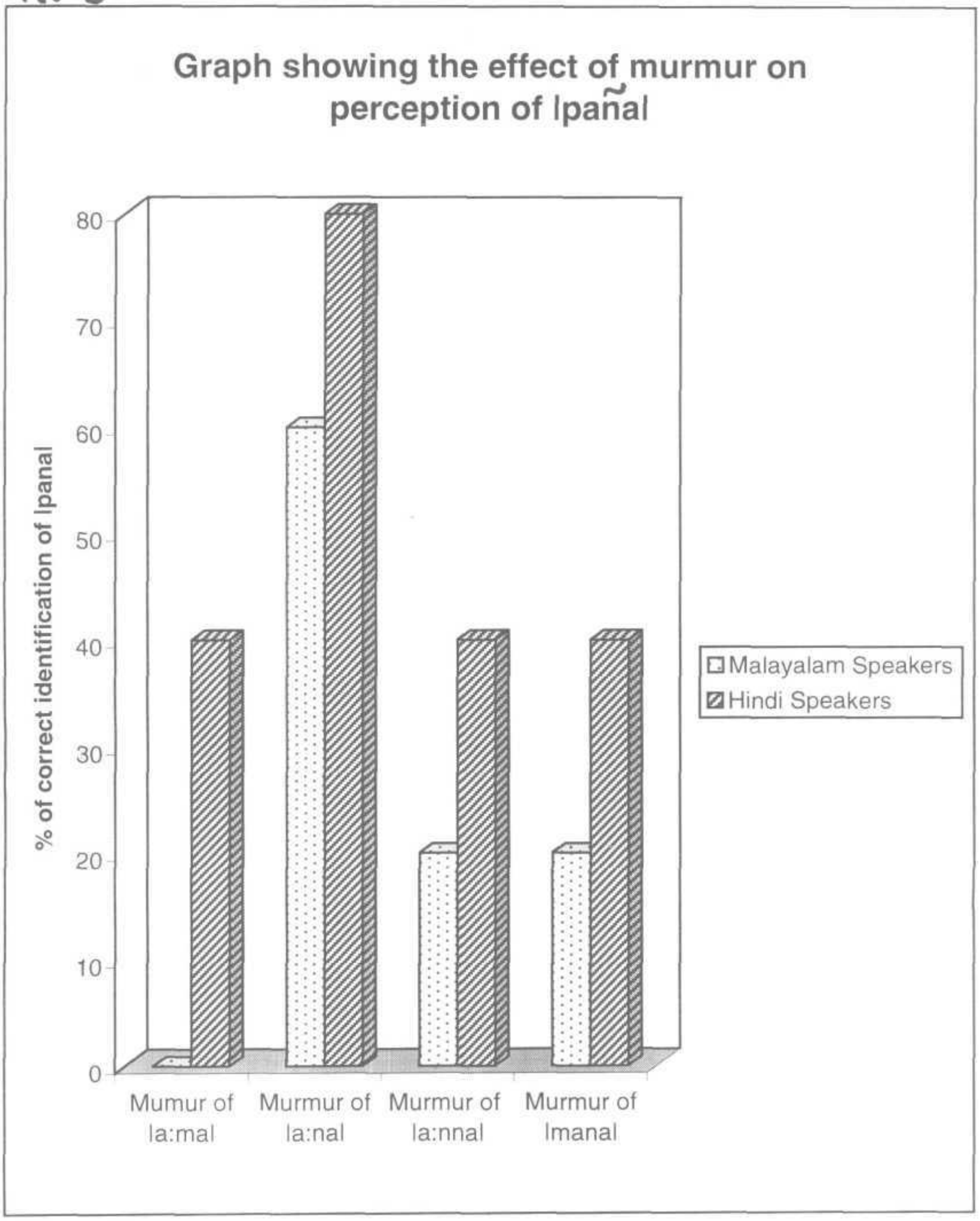
Murmur portion of /pana/ was substituted by murmur of /a:ma/. /a:na/, /anna/ and /mana/. Perception of /pana/ was affected to a intermediate degree for Hindi speakers and Malayalam speakers in all the conditions except where murmur of /n/ was substituted for /n/. The perception affected to an intermediate degree with the murmur of /m/, /n/ and /n/. This can be explained by the durational changes. From an average duration of 248 msec, the tokens were made of /pana/ having the duration of 122msec (/m/ murmur's duration) 98 msec (/n/ murmur's duration) and 120msec (/n/ murmur's duration). This drastic reduction in the duration might have created an artificiality in the perception of synthesized /pana/.

When the duration of murmur decreases the short term adaptation created by the murmur decreases, there by increasing the perceptual errors (Repp. 1987). Physiological studies have shown that auditory adaptation in animals increases with adapter duration upto about 100msec on identification of murmur - vowel stimuti.

When the murmur of /pana/ was substituted by /a:na/. there was no change in perception for both the groups. This might be because, the murmur of /a:na/ was found to have longer duration that /m/, /n/ and *Inl* murmur. Murmur duration of *Inl* was longer than /n/, */m/* and /n/ by around 15msec. This longer duration seen for the murmur of /a:na/ helps in correct identification of /pana/. These result are not conclusive of the place information provided by the nasal murmur, but it can be concluded that abnormal .reduction in murmur duration increases the perception error. For every nasal consonants, there is an optimal duration that is necessary for perception. Similar kind of perception was seen for Hindi speakers and Malayalam speakers.

The graph 3 shows the effect of murmur on perception of /pana/.

NO:3



Graph showing the effect of murmur on perception of /pañal/
% of correct identification of /panal/
80
70
60
50
40
30
20
10
0
Mumur of /a:mal/
Murmur of /a:nal/
Murmur of /a:nnal/
Murmur of /manal/
Malayalam Speakers
Hindi Speakers

Murmur portion of /a:nna/ was substituted by murmur of /a:ma/, /a:na/, /pana/ and /mana/. When murmur of /m/ was substituted for /n/ murmur in /a:nna/, the perception was affected to an intermediate degree. This might be because of the spectral difference between /a:ma/ and /a:nna/. /a:nna/ which has a higher low frequency concentration N_1, N_2, and N_3 where as /a:nna/ has a greater high frequency concentration. N_3 values for /anna/ were around 860 Hz higher than for /a:ma/. This spectral difference might have contributed in place perception. Therefore in /a:nna/ murmur and transition acts as a place cue. Kurowski and Blumstein (1984), have reported of a difference in perceptual cue provided by murmur for different place of articulation. Other studies by Garcia (1966, 1967. 1967b): Hecker (1962); House (1957); Nakata (1959); Nord (1976); Delattre. Leberman. Borst and Gerstman (1952); Kurowski and Blumstein (1984, 1987); Repp (1986. 1987) have shown that spectral relation of murmur with that of formant transition aids in place perception of nasals. Nakata (1959); Kaeprowski and Mikiel (1965) reported that N_1 and N_z dynamics could correctly simulate different place perception. In contrast Malecot (1956); Recasens (1983); Delattre (1958, 1968); Fant (1960): Fujimura (1962); Fujimura and Lindquist (1970). Hattori. Yamamoto and Fujimura (1958); Mattingly (1968); House (1957): Repp (1986) reported of a minimal perceptual cue provided by the nasal murmur.

/a:nna/ with murmur of /n/ and /n/ did not produce any perceptual change. This can be explained by spectral similarity of the *Inl* murmur with /n/, and /n/*l* murmur. It was seen that N_2 of /n/ and /n/ differed only by 60Hz. Similarly N_2 of /n/ differed from /n/ by 140Hz. As there is not much of frequency difference between them in the N_2 range they were not perceived differently eventhough they were cross matched. This again points to the probability of murmur contributing for place perception in /n/. Studies done by Garcia (1966, 1967, 1967b); Hecker (1962); House (1957); Nakata (1959); Nord (1976); Copper. Delattre, Liberman, Borst and Grest man (1952): Kurowski and Blumstein (1984, 1987), Repp (1986. 1987) have shown thai spectral relation of murmur with that of formant transition aids in place perception of nasals. Nakuta (1959), Kacprowski and Mikiel (1965)' reported that N_1 and N_z dynamics could simulate different place perception. On the contrary Malecot (1956); Recasens (1983); Delattre (1958, 1968); Fant (1960). Fujimura (1962); Fujimura and Lindquist (1970); Hattori. Yamamoto and Fujimura (1958); Mattingly (1968); House (1957); Repp (1986) reported of a minimal perceptual clue provided by the nasal murmur.

When the murmur of /a:nna/ was substituted by murmur of /*n/*. Perception was affected. This may be due to the abnormal increase in the duration of /n/ murmur, when the murmur of /n/ was introduced. Repp (1986) reported of perception getting affected because of artificially introduced by the increased murmur duration. Because of the durational change affecting the perception it is not sure whether there are any additional cues provided by spectral information for place perception. Therefore more studies are necessary in this regard.

From this experiment it can be made out that murmur is an important cue in place perception, but to what extent the murmur helps in place perception is not yet clear. This warrants further research in this area. It was also seen that abnormal increase in duration can alter the place perception due to the artificiality introduced in the signal.

For Hindi speakers /anna/ with murmur of /m/ was not affected *409c* of time, where as for malayalam speakers it was affected 80% of time to an intermediate degree. This difference in perceptual results among Hindi speakers and Malayalam speakers • may be because Malayalam speakers due to their linguistic knowledge were aiming more at accuracy than hindi speakers. Even in this murmur acting as a cue in place perception cannot be ruled out because only 60% of time, the correct identification was made by Hindi speakers, where as malayalam speakers reported of an intermediate perception 80% of the time. Similar to Malayalam speakers. Perception of /a:nna/ with murmur of /n/, *Inl Inl* was affected for hindi speakers. The spectral variability and durational changes can be accounted for this. Garcia (1966; 1967; 1967b); Hecker (1962); House (1957); Nakata (1959); Nord (1976); Copper. Delattre. Liberman Borst and Grestman (1952); Kurowski and Blumstein (1984. 1987) Repp (1986, 1987) have shown that spectral relation of murmur with that of formant transition aids in place perception of nasals. In contrast Malecot (1956); Recasens (1983); Delattre (1958, 1968); Fant (1960); Fujimura (1962); Fujimura and Lindquist (1970); Hattori, Yamamoto and Fujimura (1958); Mattingly (1968); House (1957); Repp (1986) reported of a minimal perceptual clue provided by the nasal murmur. Repp (1986) reports of a reduction in the correct identification of nasal consonant when the murmur duration was increased.

This experiment shows that :

1. For palatal reteoflex nasal consonant the spectral characteristics of the murmur N_2, N_3 and N_2 aids in place perception along with the transition.
2. The abnormal increase in duration negatively affects the perception.
3. There was a change for Hindi speakers and Malayalam speakers in term of perception. Malayalam speakers were aiming more at accuracy.

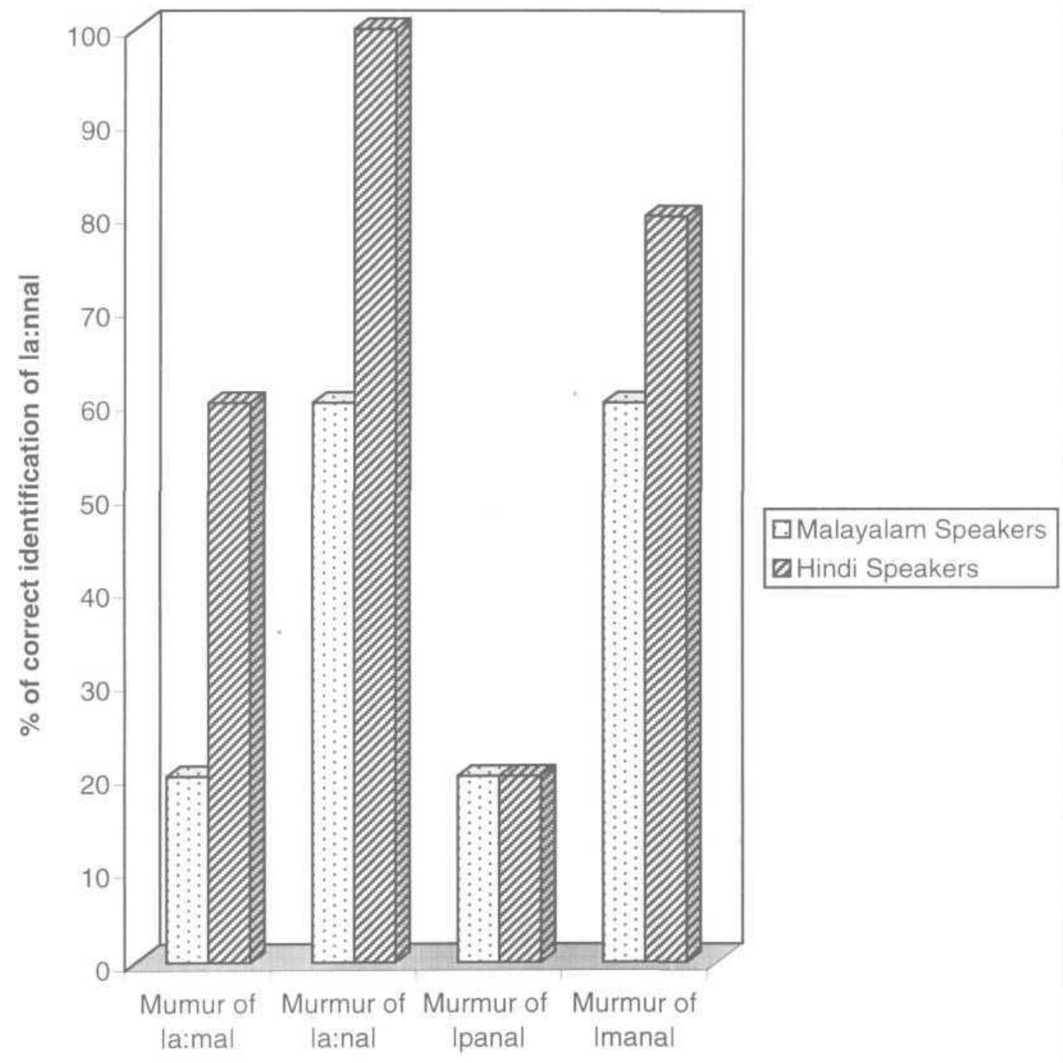
The graph 4 shows that the effect of murmur on the perception of /a:nna/.

Murmur portion of /mana/ was substituted by, murmur of /a:na/. /a:ma/, /pana/, /a:nna/ and /mana/. Perception of /mana/ was affected to a intermediate degree when /*nl* murmur was substituted by /n/ and */ml* murmur. The similar results were found for Malayalam speakers and Hindi speakers. This shows that murmur acts a place cue in the velar nasal consonant. This might be due to the spectral variability of the /n/ and ./ *ml* murmur. N_2 and N, values of *Inl* are placed in the high frequency region compared to *Inl* and /*ml*. Studies by Garcia (1966, 1967, 1967b); Hecker (1962): House (1957); Nakata (1959); Nord (1976); Delattre, Liberman, Borst and Gerstman (1952); Kurowski and Blumstein (1984, 1987) Repp (1986, 1987). Through various experimental paradigms have shown that spectral relation of murmur with that of formant transition aids in place perception of nasals. Kurowski and Blumstein (1984) reported of a difference in perceptual cue provided by murmur for different place of articulation. On the contrary Malecot (1956): Recasens (1983); Delattre (1958, 1968); Fant (1960); Fujimura (1962); Fujimura and Lindquist (1970: Hattori, Yamamoto and Fujimura (1958): Mattingly (1968); House (1957) Repp (1986) reported of a minimal perceptual clue provided by the nasal murmur.

When the to murmur of *Inl* was substituted by *Inl* murmur the perception of /mana/ was affected to a intermediate degree, for both hindi speakers and Malayalam speakers. This might be due to the artificiality introduced by increased signal duration (Repp 1986); or by the inherent property of the alveolar nasals to use the spectral information from murmur as a cue for place perception. By introducing the /n/ murmur instead of /*nl* murmur, the perception of /mana/ was not affected. Similar results were found for both Malayalam speakers and Hindi speakers. This can be explained by spectral similarity of /*nl* with /*nl* murmur. N_2 and N_3 of /*nl* and /*nl* are placed in the

NO:4

Graph showing the effect of murmur on perception of la:ṇṇal



Murmur portion of /mana/ was substituted by, murmur of /a:na/. /a:ma/, /pana/. /a:nna/ and /mana/. Perception of /mana/ was affected to a intermediate degree when /n/ murmur was substituted by /n/ and /m/ murmur. The similar results were found for Malayalam speakers and Hindi speakers. This shows that murmur acts a place cue in the velar nasal consonant. This might be due to the spectral variability of the *Inl* and *Ixnl* murmur. N, and N_3 values of *In/* are placed in the high frequency region compared to /n/ and /m/. Studies by Garcia (1966, 1967, 1967b); Hecker (1962): House (1957); Nakata (1959); Nord (1976); Delattre, Liberman, Borst and Gerstman (1952); Kurowski and Blumstein (1984, 1987) Repp (1986. 1987). Through various experimental paradigms have shown that spectral relation of murmur with that of formant transition aids in place perception of nasals. Kurowski and Blumstein (1984) reported of a difference in perceptual cue provided by murmur for different place of articulation. On the contrary Malecot (1956): Recasens (1983); Delattre (1958, 1968); Fant (1960); Fujimura (1962); Fujimura and Lindquist (1970: Hattori. Yamamoto and Fujimura (1958); Mattingly (1968); House (1957) Repp (1986) reported of a minimal perceptual clue provided by the nasal murmur.

When the to murmur of /n/ was substituted by /n/ murmur the perception of /mana/ was affected to a intermediate degree, for both hindi speakers and Malayalam speakers. This might be due to the artificiality introduced by increased signal duration (Repp 1986); or by the inherent property of the alveolar nasals to use the spectral information from murmur as a cue for place perception. By introducing the */nl* murmur instead of */nl* murmur, the perception of /mana/ was not affected. Similar results were found for both Malayalam speakers and Hindi speakers. This can be explained by spectral similarity of /n/ with /n/ murmur. N_2 and N_3 of */nl* and */nl* are placed in the high frequency region. Hence the spectral similarity between them does not seem to produce any change in perception, when they were cross matched.

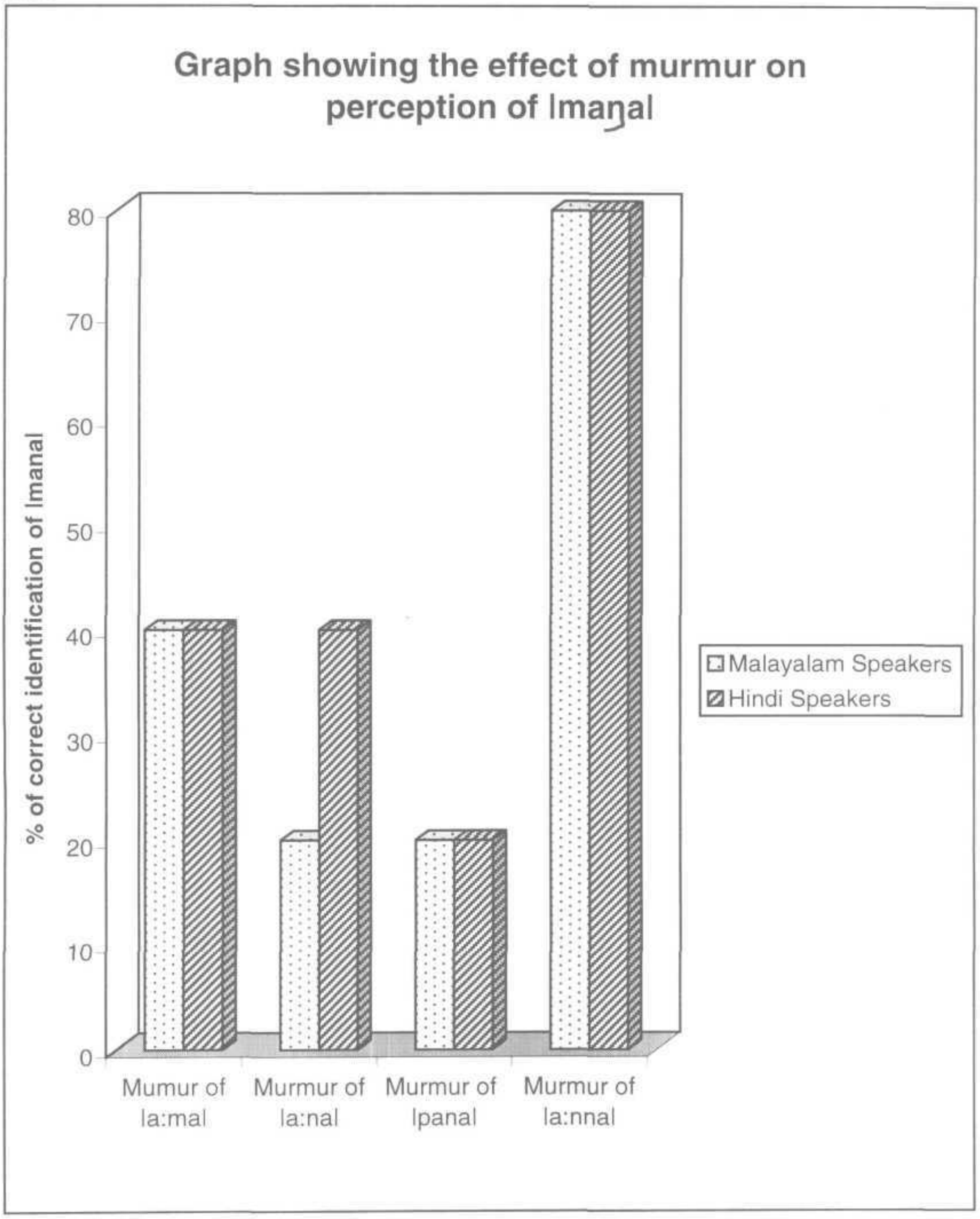
Therefore it can be stated that the murmur of velar nasal consonant provides a spectral cue for place perception. Garcia (1966, 1967. 1967b); Hecker (1962); House (1957); Nakata (1959); Nord (1976); Copper, Delattre. Liberman. Borst and Grestman (1952); Kurowski and Blumstein (1984. 1987); Repp (1986, 1987) have shown that spectral relation of murmur with that of formant transition aids in place perception of nasals. Nakata (1959); Kacprowski and Mikiel (1965) reported that N_1 and N_z dynamics could correctly simulate different place perception. Where as according to Malecot (1956); Recasens (1983); Delattre (1958; 1968); Fant (1960: Fujimura (1962); Fujimura and Lindquist (1970); Hattori, Yamamoto and Fujimura (1958); Mattingly (1968); House (1957) Repp (1986) reported of a minimal perceptual clue provided by the nasal murmur.

This experiment shows that :

1. Murmur and transition acts as a place cue in velar nasal consonant perception.
2. Abnormal increase in duration negatively affects the perception.
3. There was no change in perception between native hindi speakers and malayalam speakers.

The graph 5 shows that the effect of murmur on the perception of /mana/.

No:5



Graph showing the effect of murmur on perception of /maɲa/
% of correct identification of /mana/
0
10
20
30
40
50
60
70
80
Mumur of /a:ma/
Murmur of /a:na/
Murmur of /paɲa/
Murmur of /a:ɳɳa/
Malayalam Speakers
Hindi Speakers

Summary :

For alveolar, velar and palatal retroflex nasal consonants, the transition and murmur together provided the cue for place perception. For palatal nasal consonant the place cue provided by the murmur is inconclusive.

For bilabial nasal consonant the murmur provided only very minimal place cue.

Therefore the hypothesis that spectral parameters provide place perception is accepted. On the whole there was no change seen in the perception of Hindi speakers and Malayalam speakers. This rejects the hypothesis that there is a difference in the perception of nasal consonants between Malayalam speakers and Hindi speakers.

Experiment No. 2

PERCEPTUAL ROLE OF PRE MURMUR VOCALIC STEADY STATE AND TRANSITION

The aim of the present study is to find out the place cues for the perception of nasal consonants in Malayalam.

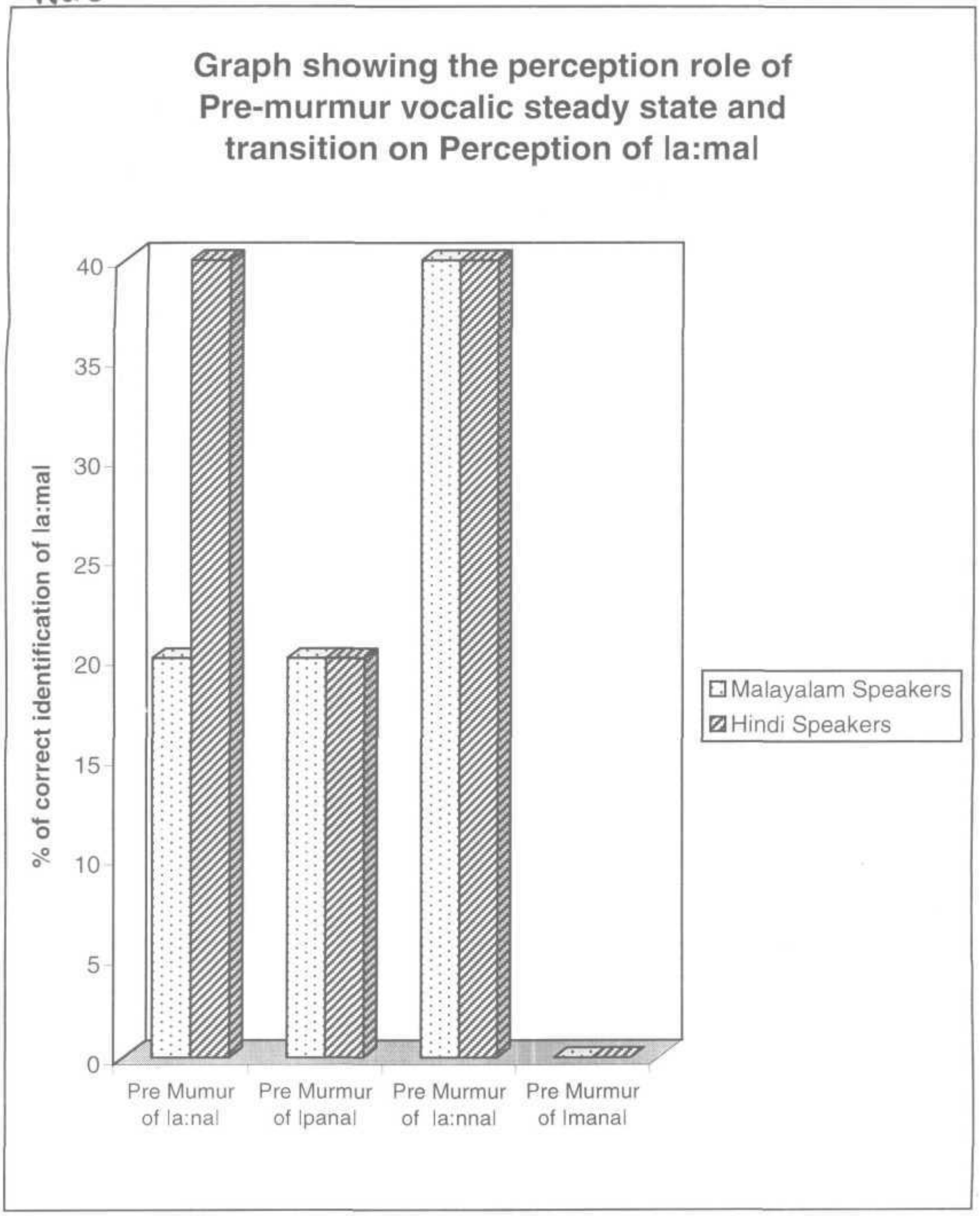
Stimulus were prepared by cutting and pasting pre murmur Vowel with transition across different words. This was done through a wave from editing, as explained in the previous chapter.

Pre murmur portion of /a:ma/ was substituted by pre murmur portion of /a:n̠a/, /pañ̃a/, /a:ṇṇa/ and /maɲa/. The perception was affected to an intermediate degree for both Malayalam speakers and Hindi speakers in all the conditions except, when the pre murmur portion of mana was substituted for pre murmur portion of /a:ma/. With the pre murmur portion of (maɲa) there was a complete change in perception of the word /a : ma/ for Malayalam speakers and Hindi speakers, 80% of time and 60% of time respectively. This shows that pre murmur transitions are important for the perception of the nasal consonant. With the pre murmur, vocalic portion of /maɲa/, the perception of /a : ma/ was completely affected. This shows that more the spectral variability between murmur and transition, the more will be the incorrect perception. Through the acoustic analysis it was clear that transition spectrum of /marja/ had higher value than murmur of /a:ma/. When compared to other words, pre murmur vocalic transition of /maɲa/ is placed at higher frequency-region than /a:ma/. /a:n̠a/, a nd /pañ̃a/. This indirectly shows that spectral variability between murmur and transition is an important place cue. This was supported by Repp (1986); Repp (1987), kurowski and Blumstein (1984). who suggest that acoustic properties may be derived for place of articulation in nasal consonant based on spectral changes in the vicinity of the nasal release. Hence murmur transition are integrated by auditory system into one unitary representation. The present study supports the findings of Malecot (1956) and Recasens (1983) that transitions dominate murmur in the perception of /m/ in the vocalic context of /a/. This was contradicted by Repp and Svastikula (1987). They reported that preceding vowel formants can attenuate the already weak formants of the murmur, and also that a gradual change in the spectrum of vowel to murmur will not give enough place cue. Hence formant transitions in the vowel and the murmur spectrum functioned as independent cues.

The graph 5 shows that the effect of pre murmur vocalic steady state and transition on the perception of /a:ma/.

Pre murmur portion of /a:na/ was substituted by pre murmur portion of /a:ma/ /pañ̄a/, /a:ṇṇa/, and /maŋa/. The perception was affected to an intermediate degree for both Malayalam speakers and Hindi speakers in all the conditions except, with the pre murmur portion of /a:ṇṇa/ and /maŋa/ There was no change in the perception in /a:n̠a/ with pre vocalic portion of /a:ṇṇa/ and maŋa. These results were similar for both the groups. This shows that higher the spectral variability, more the perception affected, here as /a:n̠a/ had a rising F_2 in the range of 230 Hz which is in comparison with /a:ṇṇa/ and /maŋa/. There was no change in perception observed in /a:n̠a/ with pre murmur vocalic portion of. /ṇ/ and /ŋ/. Where as with the pre murmur vocalic portion of /pañ̄a/ the perception was affected to an intermediate degree because /ñ/ had a rising F, around 200 Hz higher than /n̠/ /ṇ/ and /n̄/. Therefore the perception of /a:n̠a/ with pre vocalic portion of /pañ̄a/ was affected to an intermediate degree. The perception of /a:n̠a/ with pre vocalic portion of /a:ma/ was affected because of the spectral variability of the murmur and transition. The vocalic portion of /a:ma/ is at much lower frequency ie; by 200 Hz than the murmur portion of ,/a:n̠a/. This again shows that the spectral

No: 5



Graph showing the perception role of Pre-murmur vocalic steady state and transition on Perception of la:mal
% of correct identification of la:mal
40
35
30
25
20
15
10
5
0
Pre Mumur of la:nal
Pre Murmur of lpanal
Pre Murmur of la:nnal
Pre Murmur of lmanal
Malayalam Speakers
Hindi Speakers

variability between murmur and transition is an important place cue. This supports the findings of Repp (1986); Repp (1987). Kurowski and Blumstein (1984). They suggested that acoustic properties may be derived for place of articulation in nasal consonant based on spectral changes in the vicinity of the nasal release. Repp (1987) suggested that murmur and transition were integrated by auditory system into one unitary representation.

This was contradicted by Repp and svastikula (1987). as they have reported that preceeding vowel formants can attenuate the already weak formants of the murmur and also that a gradual change in the spectrum of vowel to murmur will not give enough place cue. Hence form ant transitions in the vowel and the murmur spectrum functioned as independent cues.

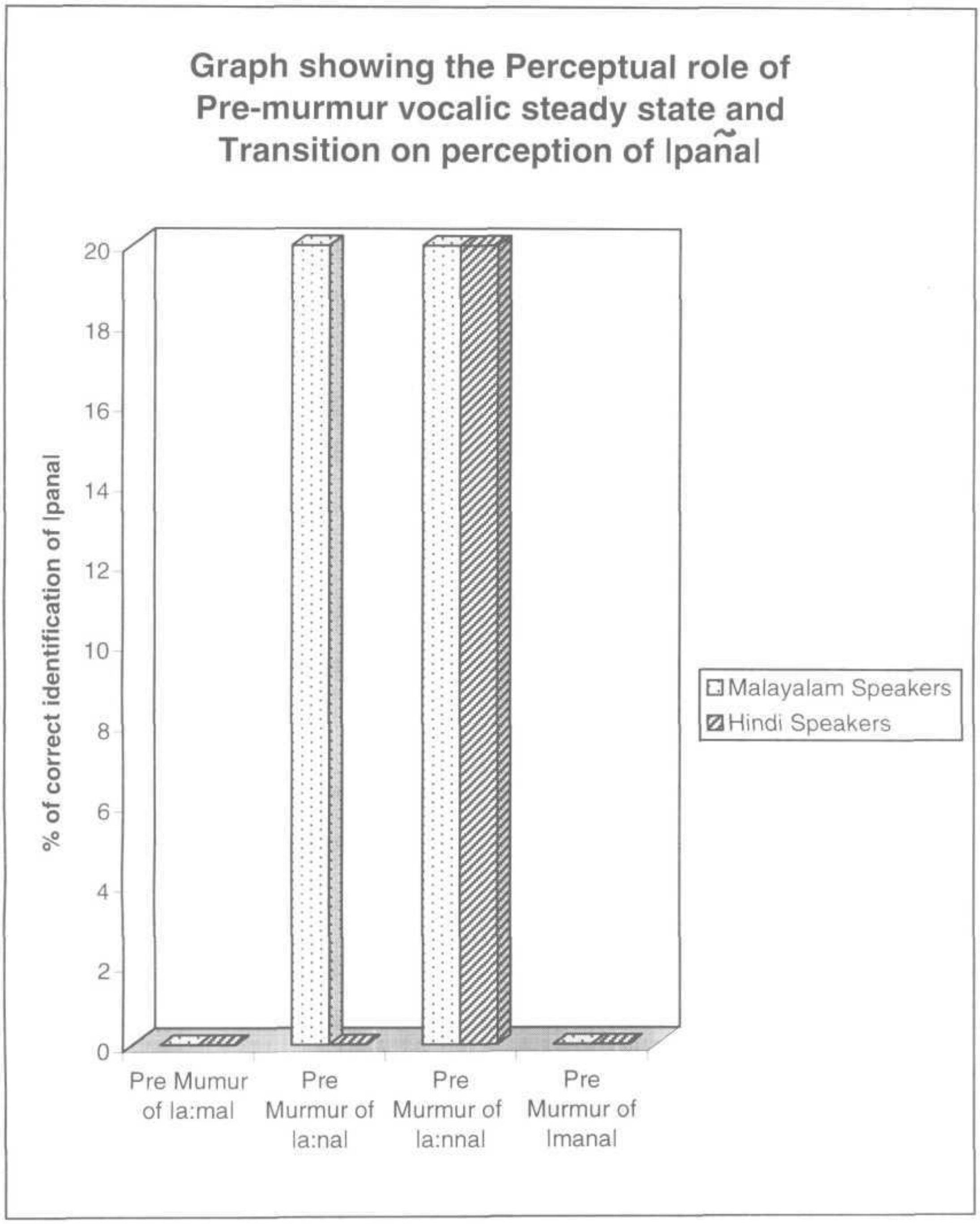
The graph 6 shows that the effect of pre murmur vocalic steady state and transition on the perception /a:n̠a/.

With the pre murmur, vocalic portion of /pañа/, the perception of /a:ma/, /a:n̠a/, /a:ṇṇa/ and /maŋa/ was completely affected in both the groups. This is consistent with the results obtained by Delattre (1958). He found murmur of /ñ/ to carry little place information compared to transition. Therefore in this study when the pre murmur vowel portion of panjya was substituted by pre murmur vowel portion of /a:ma/, /a:n̠a/, /a:ṇṇa/ and /maŋa/, the perception was completely affected. These results also supports the findings of Malecot (1956) and Recasens (1983) that transitions dominated the murmur in place perception.

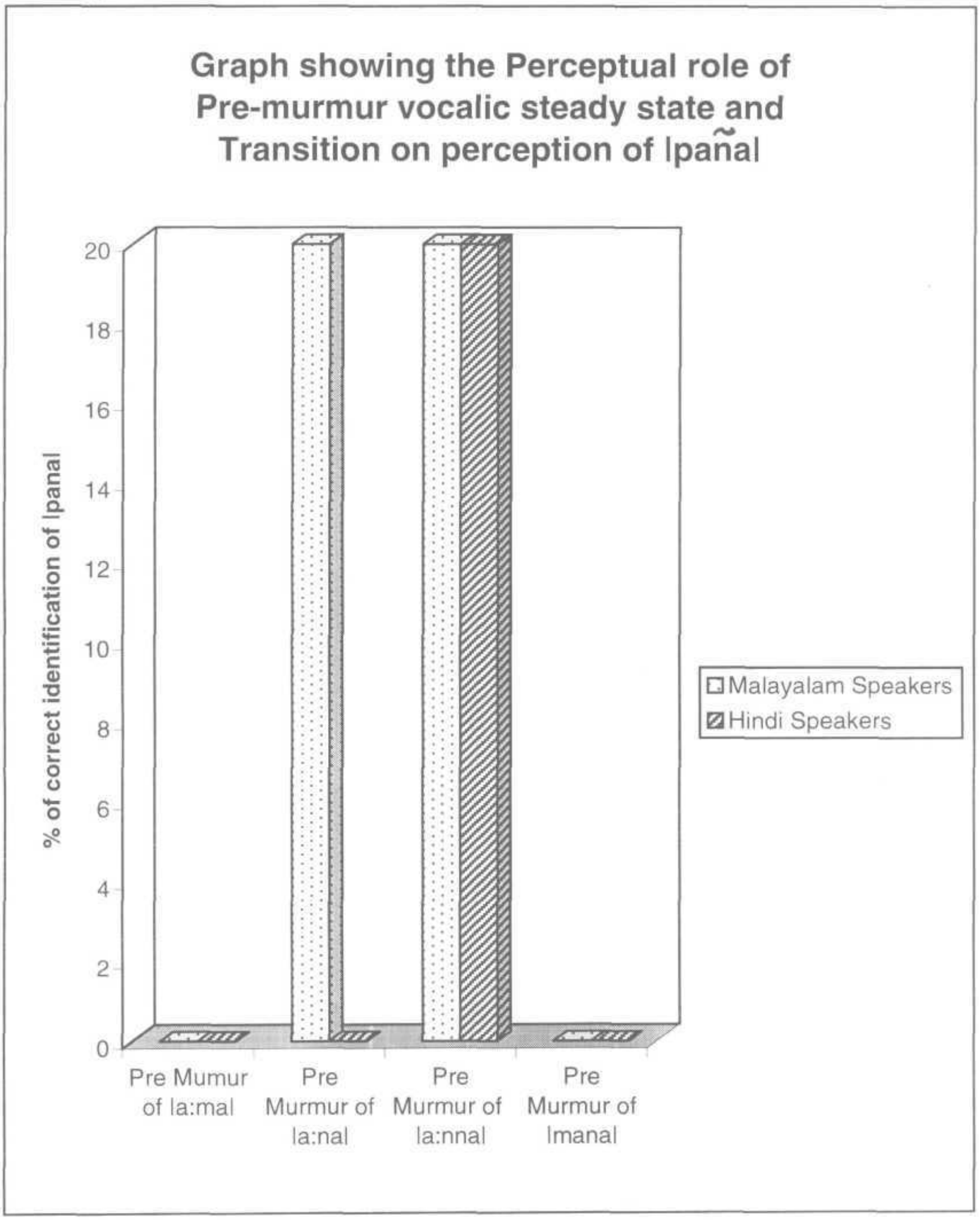
The graph 7 shows that the effect of pre murmur vocalic steady state and transition on the perception /pana/.

Pre murmur portion of /a:ṇṇa/ was substituted by pre murmur portion of /a:ma/, /a:n̠a/, /pañа/ and /maŋa/. The perception was affected to an intermediate degree for both malayalam speakers and Hindi speakers in all the conditions.

NO:7


Graph showing the Perceptual role of
Pre-murmur vocalic steady state and
Transition on perception of |pañal
% of correct identification of |panal
20
18
16
14
12
10
8
6
4
2
0
Pre Mumur of |a:mal
Pre Murmur of |a:nal
Pre Murmur of |a:nnal
Pre Murmur of |manal
Malayalam Speakers
Hindi Speakers

NO:7



Graph showing the Perceptual role of Pre-murmur vocalic steady state and Transition on perception of |pañal
% of correct identification of |panal
20
18
16
14
12
10
8
6
4
2
0
Pre Mumur of |a:ma|
Pre Murmur of |a:na|
Pre Murmur of |a:nna|
Pre Murmur of |mana|
Malayalam Speakers
Hindi Speakers

This again shows that transitions are important in place perception than murmur. But as the perception was not completely affected it can be concluded that murmur and transition play a role in /ṇ/ perception.

The graph 8 shows that the effect of pre murmur vocalic steady state and transition on the perception /a:ṇṇa/

The perception of /maŋa/ was found to be affected to an intermediate degree when the pre murmur vocalic portion of /maŋa/ was substituted by pre murmur vocalic portion of /a:ma/, /a:n̲a/, /pañа/ and /a:ŋŋa/. This again shows that transition provides a positive cue in the place perception of velar nasal consonant. As the perception was affected to an intermediate degree in both Hindi : speakers and Malayalam speakers the conclusion about the place cue provided by murmur and transition cannot be drawn. This warrents further research. From this study it was seen that transition and murmur act as cues in place perception of velar nasal consonant. This was supported by Kurowski and Blumstein (1984).

The graph 9 shows that the effect of pre murmur vocalic steady state and transition on the perception ,/maŋa/.

To summarize

From this experiment it can be inferred that for bilabial, palatal nasal consonants, the murmur was found to play a minor role in perception. The major place cue is provided by the transition. Where as for alveolar, palatal (retroflex) and velar nasal consonants the place cue was provided by both transition and murmur.

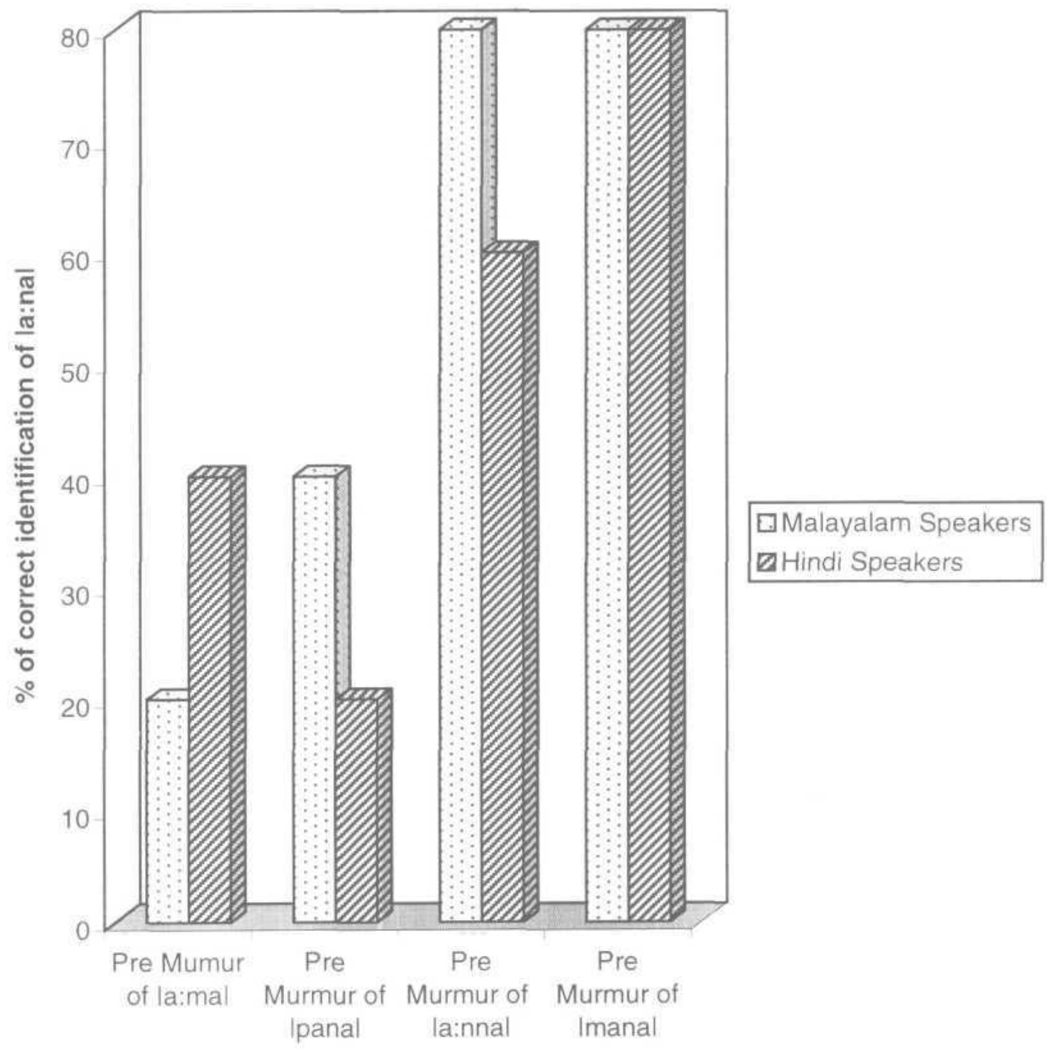
This supports the hypothesis that spectral cues aids in place perception of nasal consonant. There was no difference found in the perception of Hindi speakers and Malayalam speakers. Therefore it rejects the hypothesis that there is a difference in the perception of Hindi speakers and Malayalam speakers.

NO:8

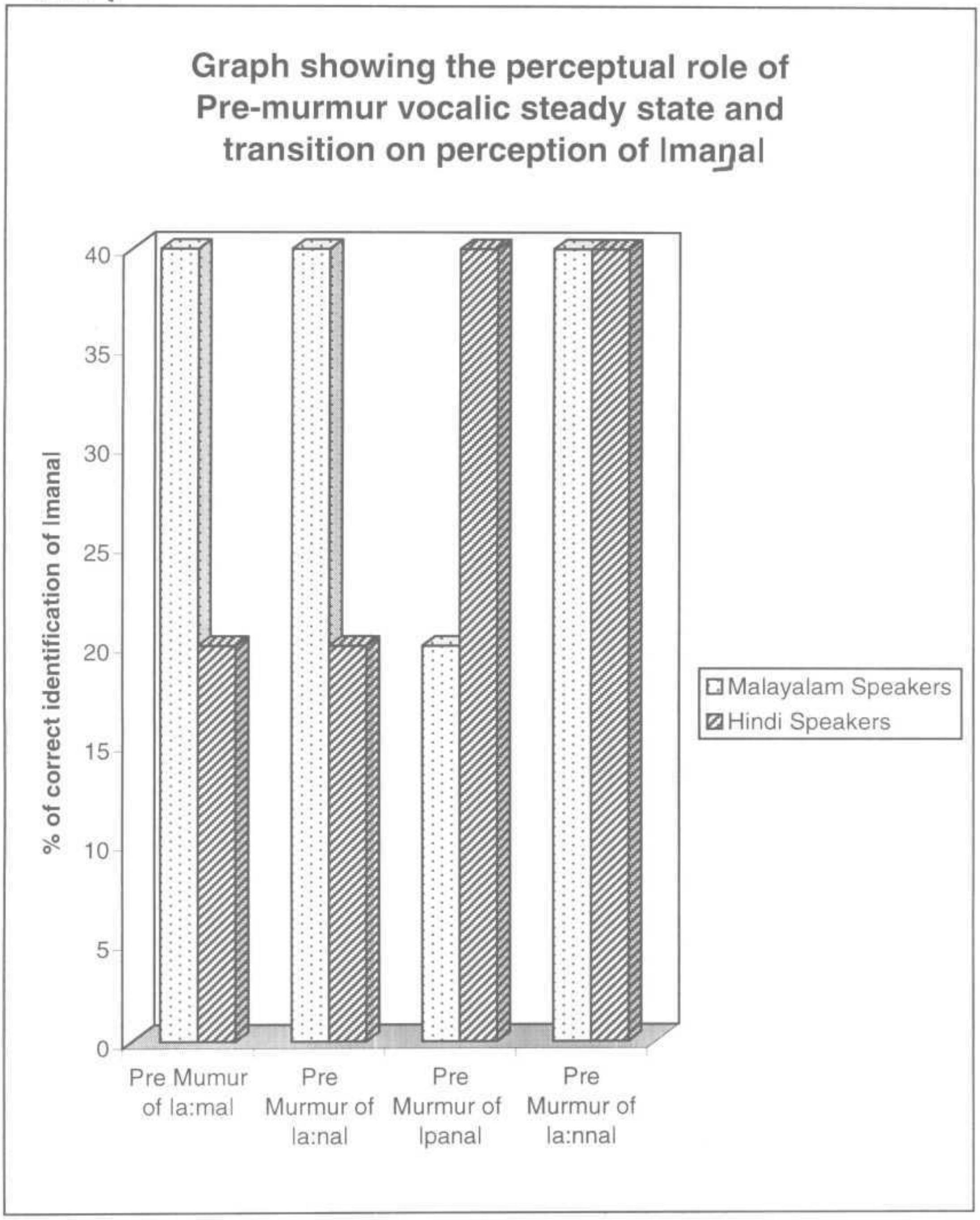
Graph showing the perceptual role of Pre-murmur vocalic steady state and transition on perception of la:ṇṇal

No:6

Graph showing the Perceptual role of pre-murmur vocalic steady state and transition on perception of la:ṉal



NO:9



Graph showing the perceptual role of Pre-murmur vocalic steady state and transition on perception of lmaɲal
% of correct identification of lmanal
0
5
10
15
20
25
30
35
40
Pre Mumur of la:mal
Pre Murmur of la:nal
Pre Murmur of lpanal
Pre Murmur of la:nnal
Malayalam Speakers
Hindi Speakers

Experiment - 3

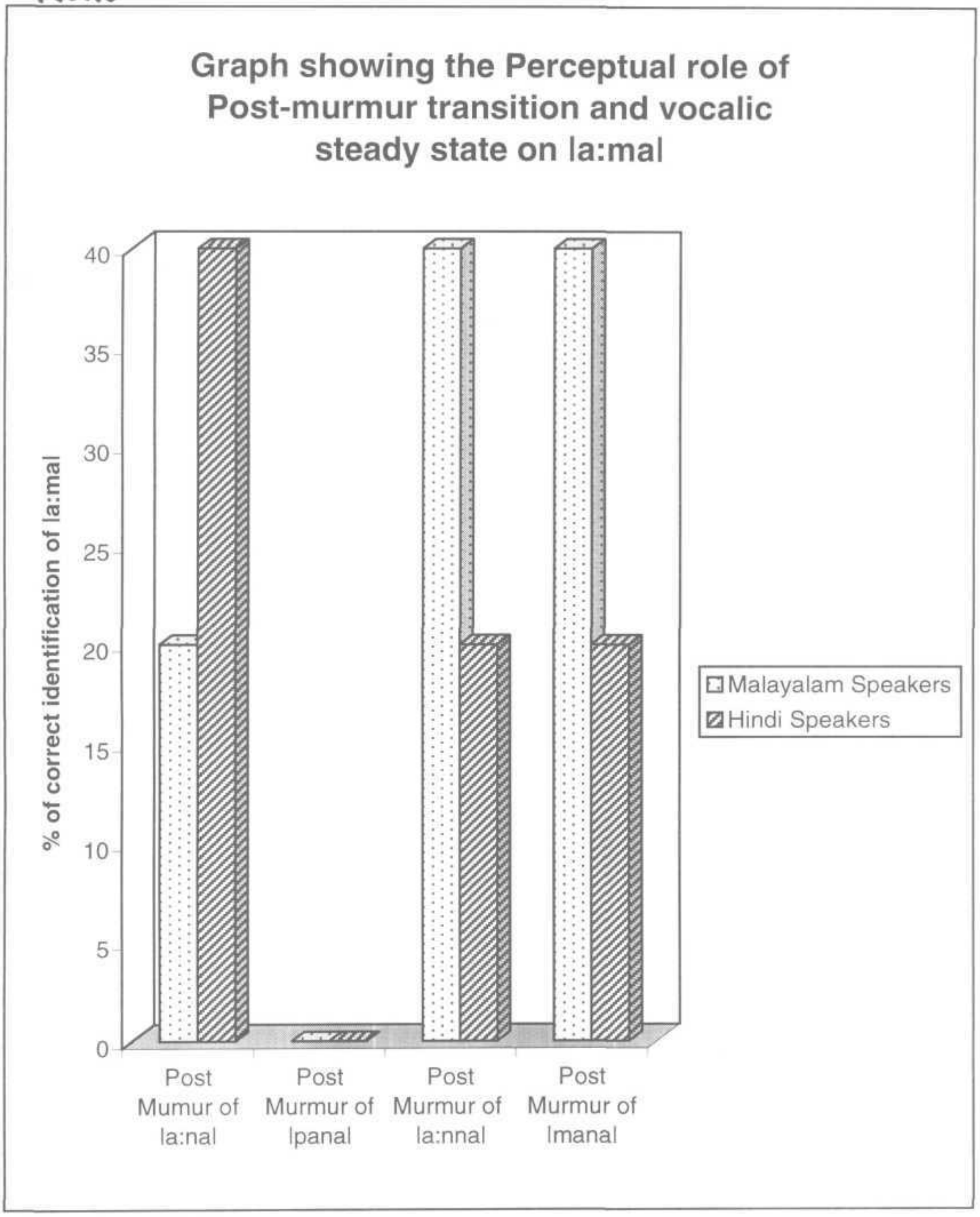
PERCEPTUAL ROLE OF POST - MURMUR TRANSITIONS AND VOCALIC STEADY STATE

As reported previously stimulus were made by cutting and pasting post murmur vowel with transition across different words. This was done through wave form editing.

Post murmur portion of /a:ma/ was substituted by post murmur portion of /a:n̠a/, /pañña/, /a:ṇṇa/ and /maŋŋa/. The perception was affected to an intermediate degree for both Malayalam speakers and Hindi speakers in all conditions, except when the post murmur portion of /pañña/ was substituted for post murmur portion of /a:n̠a/. The perception of /a:ma/ was completely affected by the post murmur portion of /pañña/, in both Hindi speakers and Malayalam speakers. This shows that post murmur transitions are important for the perception of the nasal consonant. There is a spectral variability of more 400Hz between /m/ murmur and /ṇ/ transition. Compared to the post murmur portion of other words, the maximum variability is seen with /ṇ/ transition. Therefore with /ṇ/ transition, the perception of /a:ma/ was completely affected. This shows that the spectral variability is an important place cue. This was supported by Repp (1986) Repp (1987); Kurowski and Blumstein (1984). Further they suggested that acoustic property may be derived for place articulation in the nasal consonant based on the spectral changes in the vicinity of nasal release. Repp (1987) suggested murmur and transitionswere integrated by auditory system into one unitary representation.

The graph 10 shows that the effect of post murmur vocalic steady state and transition on the perception /a:ma/.

No:10



Graph showing the Perceptual role of Post-murmur transition and vocalic steady state on la:mal
% of correct identification of la:mal
40
35
30
25
20
15
10
5
0
Post Mumur of la:nal
Post Murmur of lpanal
Post Murmur of la:nnal
Post Murmur of lmanal
Malayalam Speakers
Hindi Speakers

Post murmur portion of /a:n̪a/ was substituted by post murmur portion of /a:ma/, /pan̑a/, /a:ṇṇa/ and /maŋa/. The perception was affected to a intermediate degree for both Malayalam speakers and Hindi speakers, in all conditions. This shows that transition is a major cue in perception of /a:n̪a/.

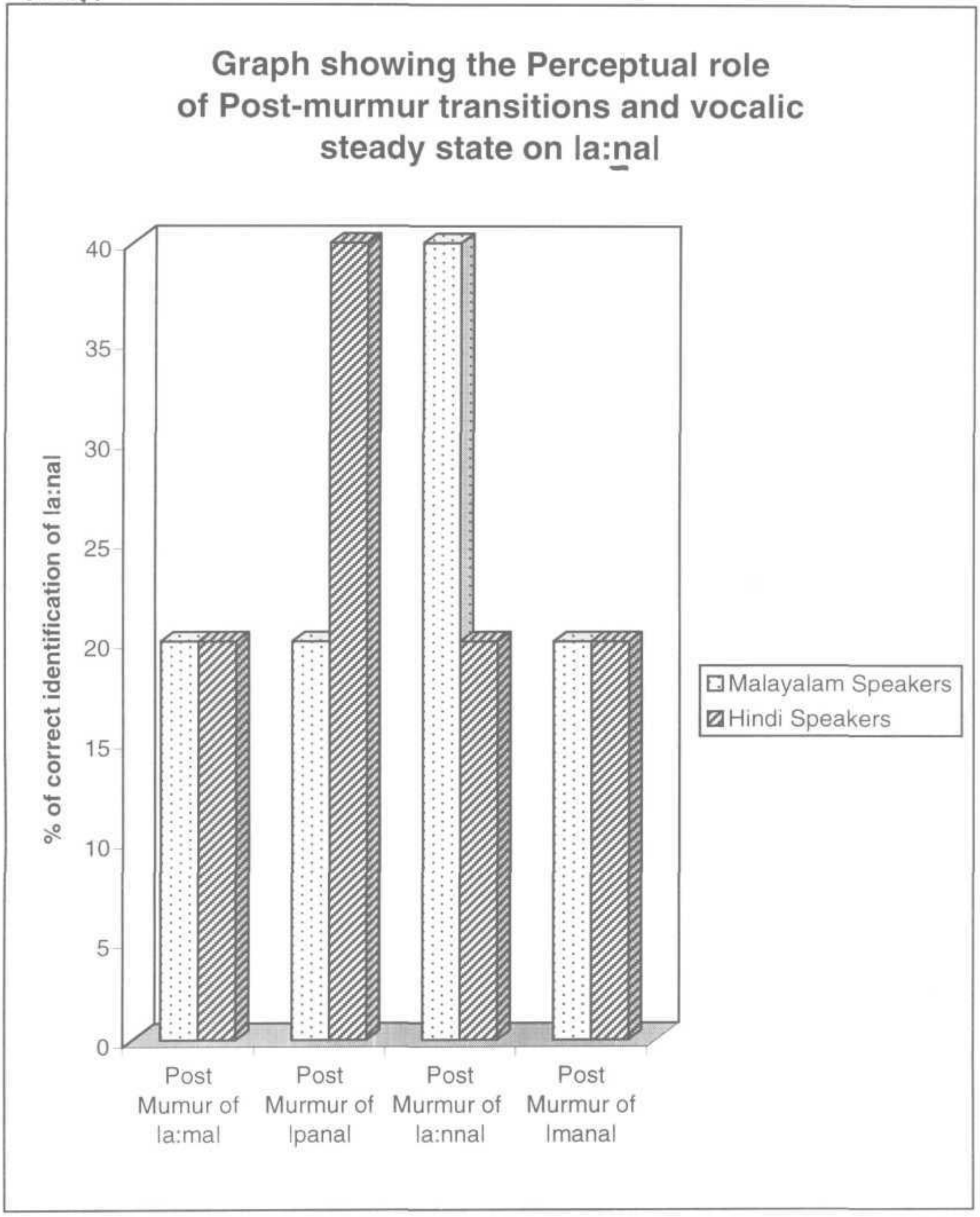
These results also show that post murmur transition have a greater perceptual relevance than pre murmur transition. This was supported by the findings of Repp and Svastikula (1987). They reported that preceeding vowel formants can attenuate the already weak formants of the murmur, and also that a gradual change in the spectrum of vowel to murmur will not give enough place cue. Hence the formant transitions in the vowel and the murmur spectrum functioned as independent cues. Where as the post murmur vowel transitions were found to have large spectral variability and gave much of place cue. (Repp and Svastikula (1987).

The graph 11 shows that the effect of post murmur vocalic steady state and transition on the perception /a:n̪a/.

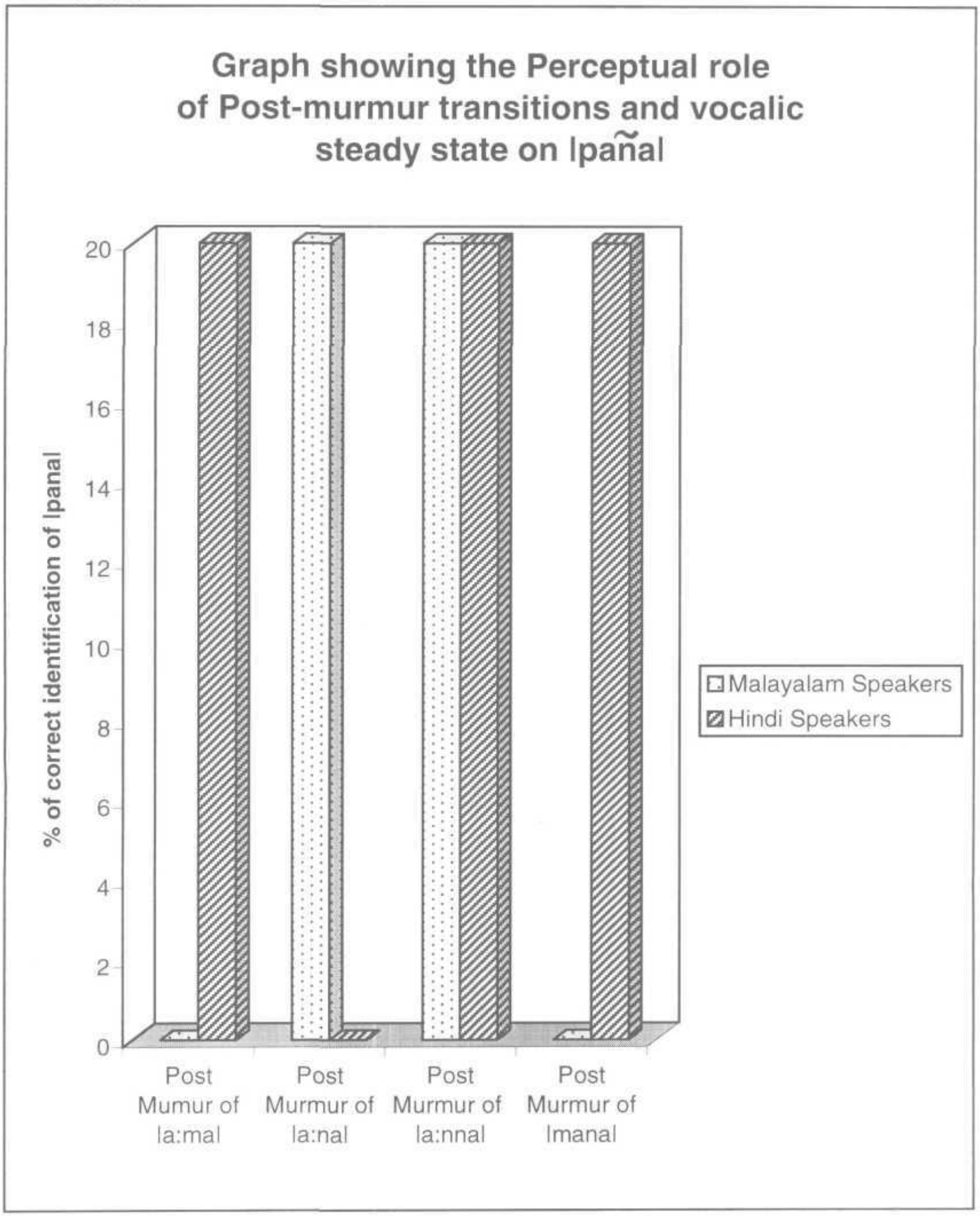
With the post murmur, vocalic portion of /pana/, the perception of /a:ma/, /a:n̪a/, /a:ṇṇa/ and /maŋa/ was completely affected in both the groups. This is consistent with the results obtained by Delattre (1958). He found murmur of /n̑/ to carry little place information, compared to transition. This finding also supports the finding of Malecot (1956) and Recasens (1983) that transitions dominated the murmur in place perception.

The graph 12 shows that the effect of post murmur vocalic steady state and transition on the perception ,/pan̑a/.

No:11


Graph showing the Perceptual role of Post-murmur transitions and vocalic steady state on la:nal
% of correct identification of la:nal
40
35
30
25
20
15
10
5
0
Post Mumur of la:mal
Post Murmur of lpanal
Post Murmur of la:nnal
Post Murmur of lmanal
Malayalam Speakers
Hindi Speakers

NO:12



Graph showing the Perceptual role of Post-murmur transitions and vocalic steady state on lpãnal
% of correct identification of lpanal
20
18
16
14
12
10
8
6
4
2
0
Post Mumur of la:mal
Post Murmur of la:nal
Post Murmur of la:nnal
Post Murmur of lmanal
Malayalam Speakers
Hindi Speakers

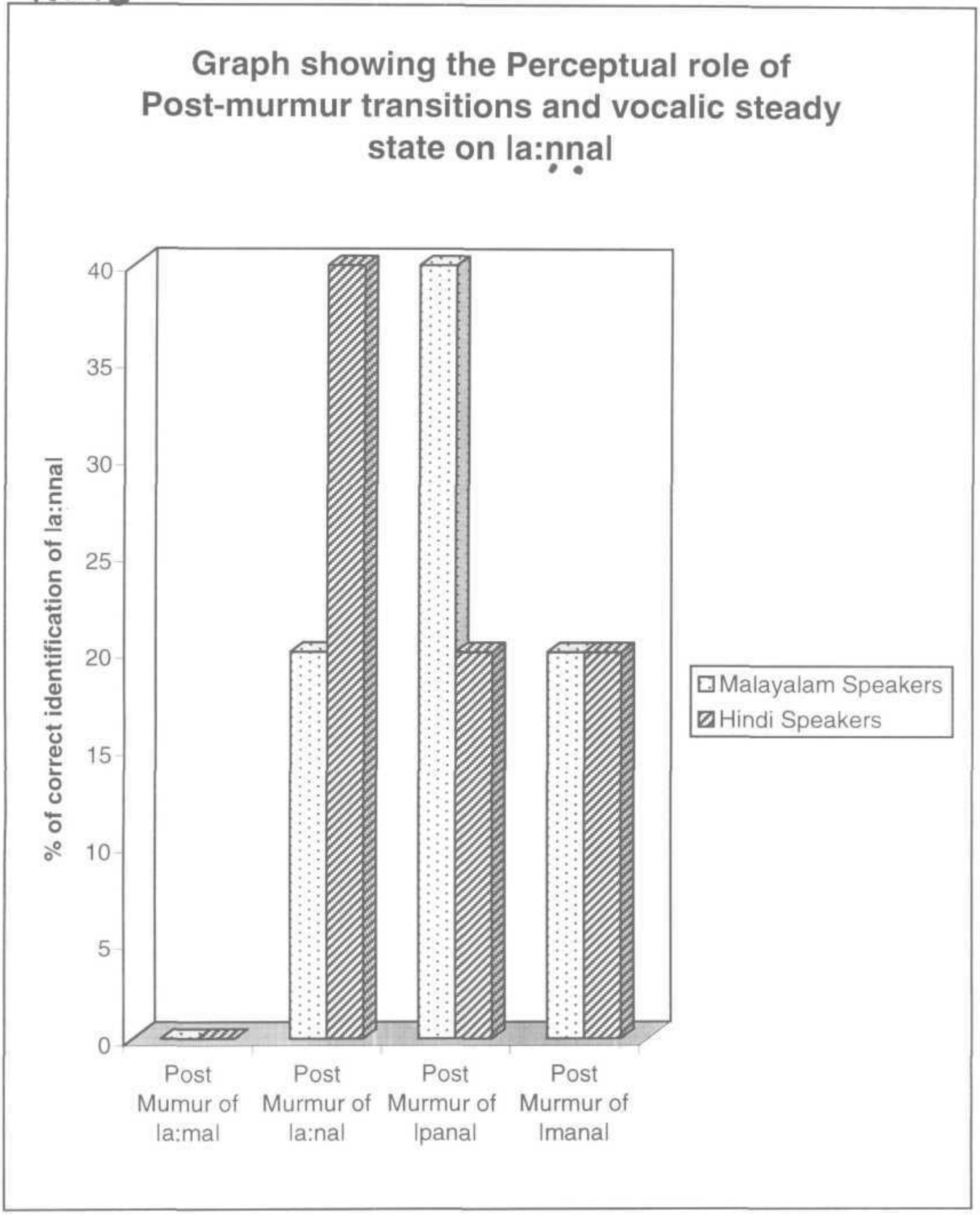
Post murmur portion of /a:ṇṇa/ was substituted by post murmur portion of /a:ma/, /a:n̲a/ /pañа/, and /maŋa/. The perception was affected to an intermediate degree for both Malayalam speakers and Hindi speakers, in all the conditions, except with /a:ma/. When post murmur portion of /a-:ma/ was substituted for the post murmur portion of /a:ṇṇa/. There was a complete change in perception. There was a great spectral variability between the murmur portion of /a:ṇṇa/ and following vowel transition of /a:ṇṇa/. Therefore there was complete change in perception. The spectral variability between murmur and transition was not very much pronounced in other conditions. This shows that murmur and transitions play a role in place perception of the nasal retroflex.

The graph 13 shows that the effect of post murmur vocalic steady state and transition on the perception /a:ṇṇa/.

The perception was found to be affected to an intermediate degree when the post murmur vocalic portion of /marja/ was substituted by post murmur vocalic portion of /a:ma/, /a:n̲a/, /pañа/ and /a:ṇṇa/. This again shows that transitions provide a positive clue in the place perception of velar nasal consonant. As the perception was affected to an intermediate degree in both Hindi speakers and Malayalam speakers a conclusion about the place cue provided by murmur and transition cannot be made. This warrents further research. This study it has shown that transition acts as a major cue in place perception of velar nasal consonant. This was supported by the findings of Malecot (1956) and Repp (1982)

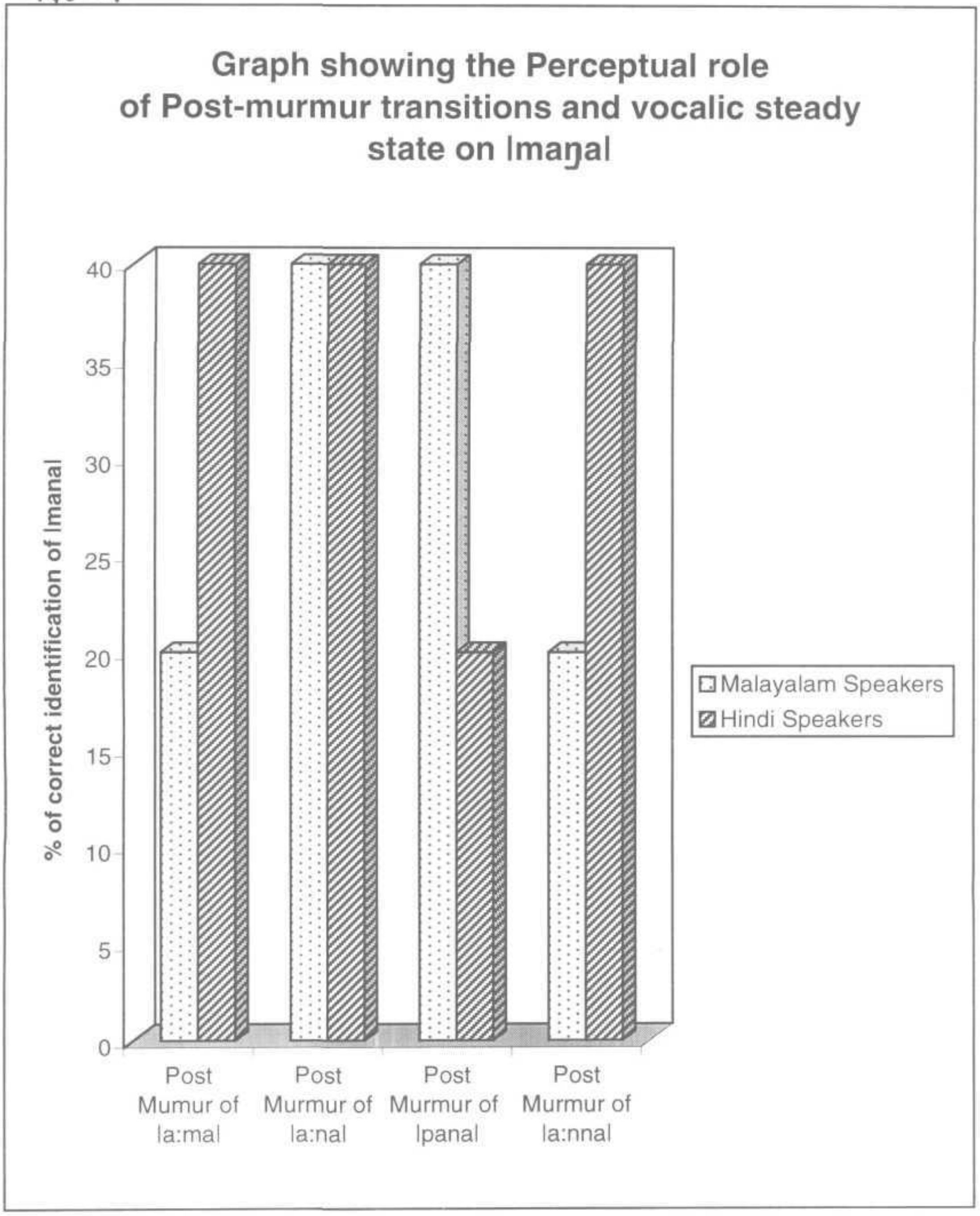
The graph 14 shows that the effect of post murmur vocalic steady state and transition on the perception /maŋa/.

NO:13



Graph showing the Perceptual role of Post-murmur transitions and vocalic steady state on la:ṇṇal
% of correct identification of la:nnal
40
35
30
25
20
15
10
5
0
Post Mumur of la:mal
Post Murmur of la:nal
Post Murmur of lpanal
Post Murmur of lmanal
Malayalam Speakers
Hindi Speakers

NO: 14


Graph showing the Perceptual role
of Post-murmur transitions and vocalic steady
state on lmaŋal
% of correct identification of lmanal
0
5
10
15
20
25
30
35
40
Post
Mumur of
la:mal
Post
Murmur of
la:nal
Post
Murmur of
lpanal
Post
Murmur of
la:nnal
Malayalam Speakers
Hindi Speakers

From his experiment it can be inferred that :

The following vowel transitions were as effective as preceding vowel transitions in cueing the place information.

In /a:na/. the following vowel could cue more place information than the preceding one.

For the perception of /a:ma/ unlike the results found for the 1st experiment and II experiment the transition and murmur was found to give place cue.

For palatal nasal consonants the murmur was found to play a minor role in perception.

For bilabial, alveolar, palatal (retroflex) and velar nasal consonants the place cue was provided by both transition and murmur.

Therefore the hypothesis that spectral cues provide place perception is accepted.

There was no difference found in perception of Hindi speakers and Malayalam speakers, therefore the hypothesis that there is a change perception of Hindi speakers and Malayalam speakers was rejected.

Experiment No. 4

Effect of pre and post transition with vowel an perception

Stimulus were prepared as explained in the previous chapter, by changing the preceding and following transitions and steady state of the vowel. The stimulus were created through wave form editing.

The signal was created by mismatching the preceding vowel with transition, murmur and following vowel with transition for the word /a:ma/. The perception of this word was completely affected in Hindi speakers and Malayalam speakers when the following vowel was of /pana/'s. This confirms the results of the first two experiments that transition of /n/. be it in the final or initial position caused a complete change in the perception in both the groups of listeners. The transition of /a:nna/ in the pre or post murmur position created a complete change in perception. In all other conditions the perception was affected to a intermediate condition. This shows that large spectral variability between murmur and vocalic transition causes the transitions to mask out the effect of place cue provided by the murmur. The response obtained for other conditions show that murmur and the transition together aid as a single integrated cue for the perception of nasals.

Blumstein (1984) Repp (1986) Malecot, Recasen (1982) reported of an integration of murmur and transition as a cue for nasal perception. On the contrary Delattre (1968); Pickett, 1965; Mermelstein, 1977 Ra reported of murmur giving a minor role in place perception.

With reference to the word /a:na/ it can be stated that in all the conditions except for /n/ transition in the pre or post murmur position created an intermediate response. This is consistent with the findings in experiment

No. 3 and 4. Hence it can be concluded that alveolar nasal makes use of both murmur and transition for cueing the place. This supports the views of Kurowski and Blumstein (1984, 1987); Rep (1986); Malecot (1956) Recasen (1982). Delattre (1958). Where as Delattre (1968); Pickett (1965): Mermelstein (1977) reported of murmur giving a minor role in place perception.

In the word ,/pañ a/, the signal was created by mismatching the preceding vowel with transition, **murmur**, and following vowel with transition. The perception was completely affected, this shows that for the perception of palatal nasal consonant transition is a major cue. Similar results were seen in 2,3,4 experiment. This supports by Delattre's (1958) views.

The perception of /a:ṇṇa/ was completely affected in all the conditions except for the intermediate results seen when the following transition was that of /an̪a's/. This intermediate results can be explained by the spectral similarity in the /a:ṇṇa/ and /a:n̪a/. A rising transition may act as a cue in the perception of /ṇ/. As there are not many languages with /ṇ/ as a phoneme, there seems to be no reports in the literature about spectral characteristics of /ṇ/.

The perception of /maɲa/ was found to be affected to an intermediate degree in both the groups, when the pre or post murmur transitions of /mana/ was changed. This again shows that /ɲ/ has maximum place information from the transition and the murmur.

To conclude

1) For the murmur and transition helps in place perception of bilabial nasal consonant, /m/.
2) The transition gives more place information for /n̪/, /ñ/ and /ɲ/.

3) The f, transition along with murmur helps in identification of retroflex and velar nasal consonant.

4) There was no difference found in the perception of Hindi speakers and Malayalam speakers.

Therefore the hypothesis that spectral cues helps in place perception was accepted. The hypothesis that there was a difference in the perception of Hindi speakers and Malayalam speakers was rejected

Experiment No. 5

Effect of duration of Murmur on perception

A explained in previous chapter stimulus were prepared by cutting or pasting the murmur portion, so as to make the stimuluses that match in murmur duration with the nasal murmur of other words.

The signal was created of /a:ma/ with /a:n̪a/'s murmur duration, /pañ̃a/'s murmur duration, /a:ɳɳa/'s murmur duration and /maŋa/'s murmur duration. Perceptual results show that none of these conditions, made any change in perception of the word /a:ma/ for both the groups. This shows that duration of murmur is not an important cue in perception of nasals. This results supports the findings of Repp (1987).

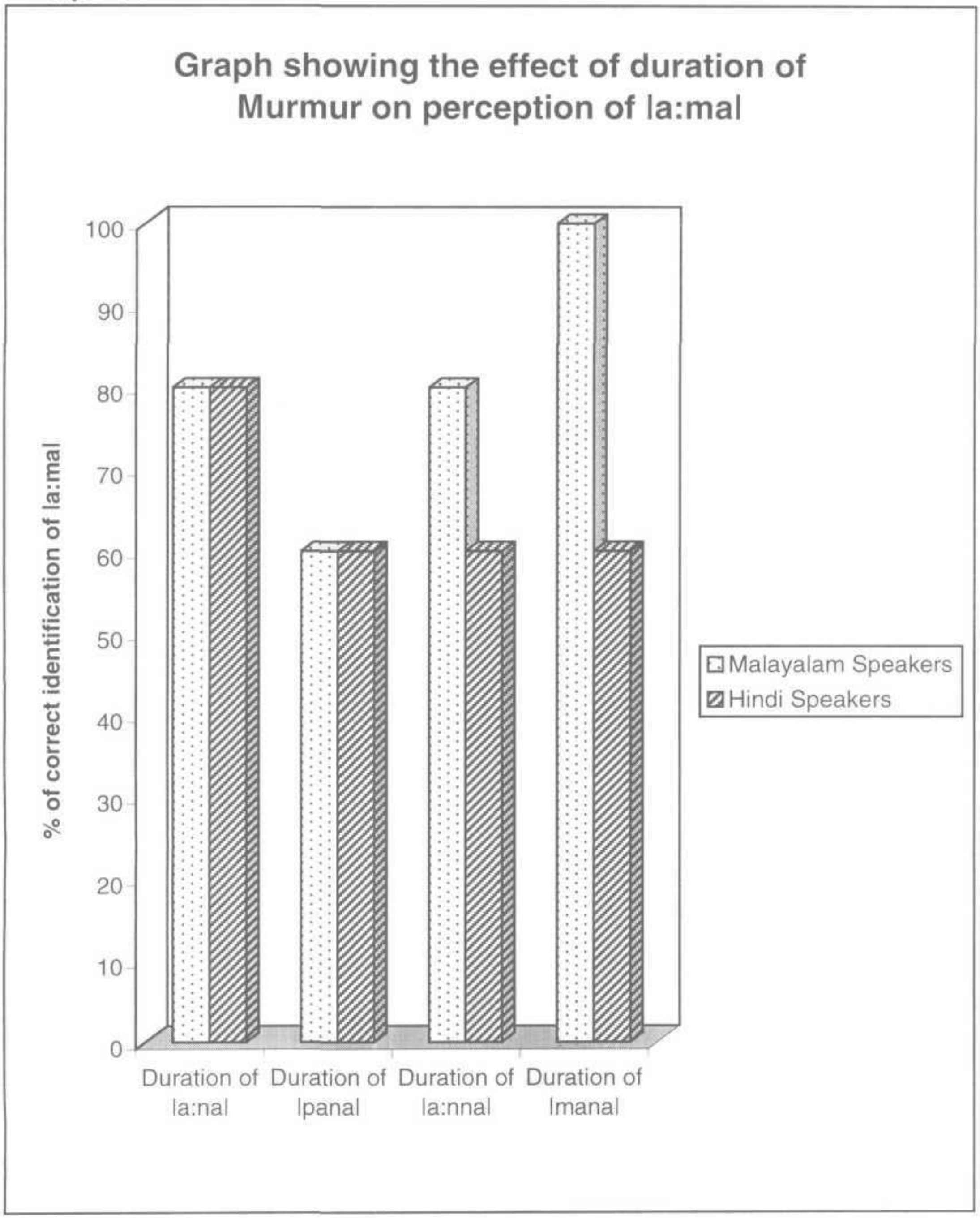
The graph 16 shows the effect of duration of murmur on perception of /a:ma/.

For the word ,/a:n̪a/ with the murmur duration of /pañ̃a/ the perception was affected to intermediate degree in both the groups. This might be because of the artificiality created by abnormal increase in duration (by around 116 Hz). This supports the findings of Repp (1986) who had analyzed the natural variation in murmur duration and found that the intelligibility of truly steady state isolated murmur decreased as their duration was increased.

The graph 17 shows the effect of duration on the perception of /a:n̪a/

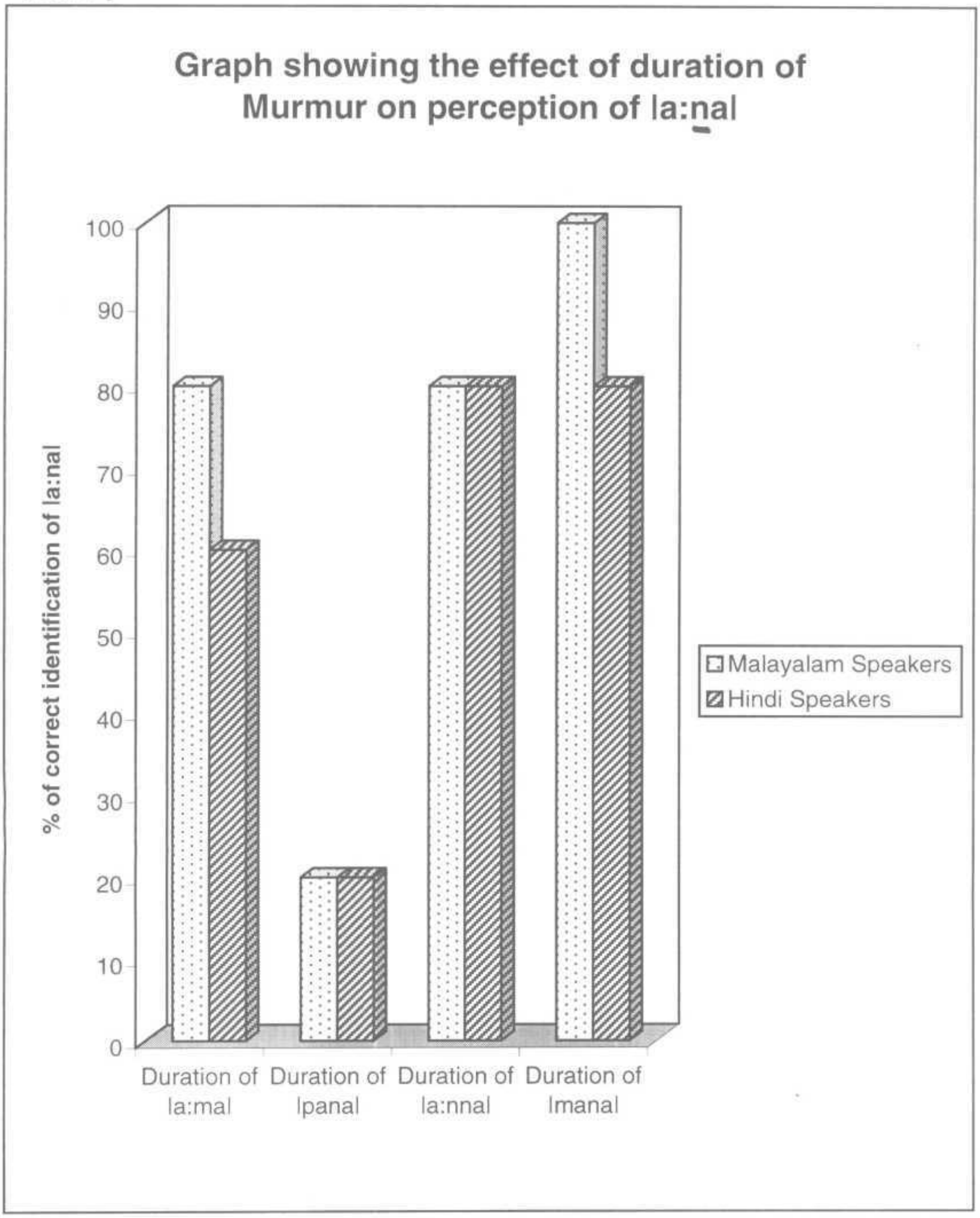
In the case of /pañ̃a/ perception was affected to an intermediate degree in all the conditions except, with the murmur duration of /a:n̪a/. There was only a difference of 116 msec between /a:n̪a/ and ,/pañ̃a/. This result shows that a reductuion in murmur duration did not show pronounced effect and as

No:16



Graph showing the effect of duration of Murmur on perception of la:mal
% of correct identification of la:mal
100
90
80
70
60
50
40
30
20
10
0
Duration of la:nal
Duration of lpanal
Duration of la:nnal
Duration of lmanal
Malayalam Speakers
Hindi Speakers

No: 17



Graph showing the effect of duration of
Murmur on perception of /a:na/
% of correct identification of /a:na/
100
90
80
70
60
50
40
30
20
10
0
Duration of /a:ma/
Duration of /pana/
Duration of /a:nna/
Duration of /mana/
Malayalam Speakers
Hindi Speakers

the increase in murmur duration and that every murmur has an optimum duration at which it is perceived appropriately.

The graph 18 shows the effect of duration of murmur on the perception of /paña/.

Except with the duration of /paña/, the perception of /a:ṇṇa/ was not affected. With the duration of /paña/, the perception of /a:ṇṇa/ was affected to a intermediate degree. This again shows that abnormal increase in duration decreases the intelligibility. This supports the report by Repp (1986).

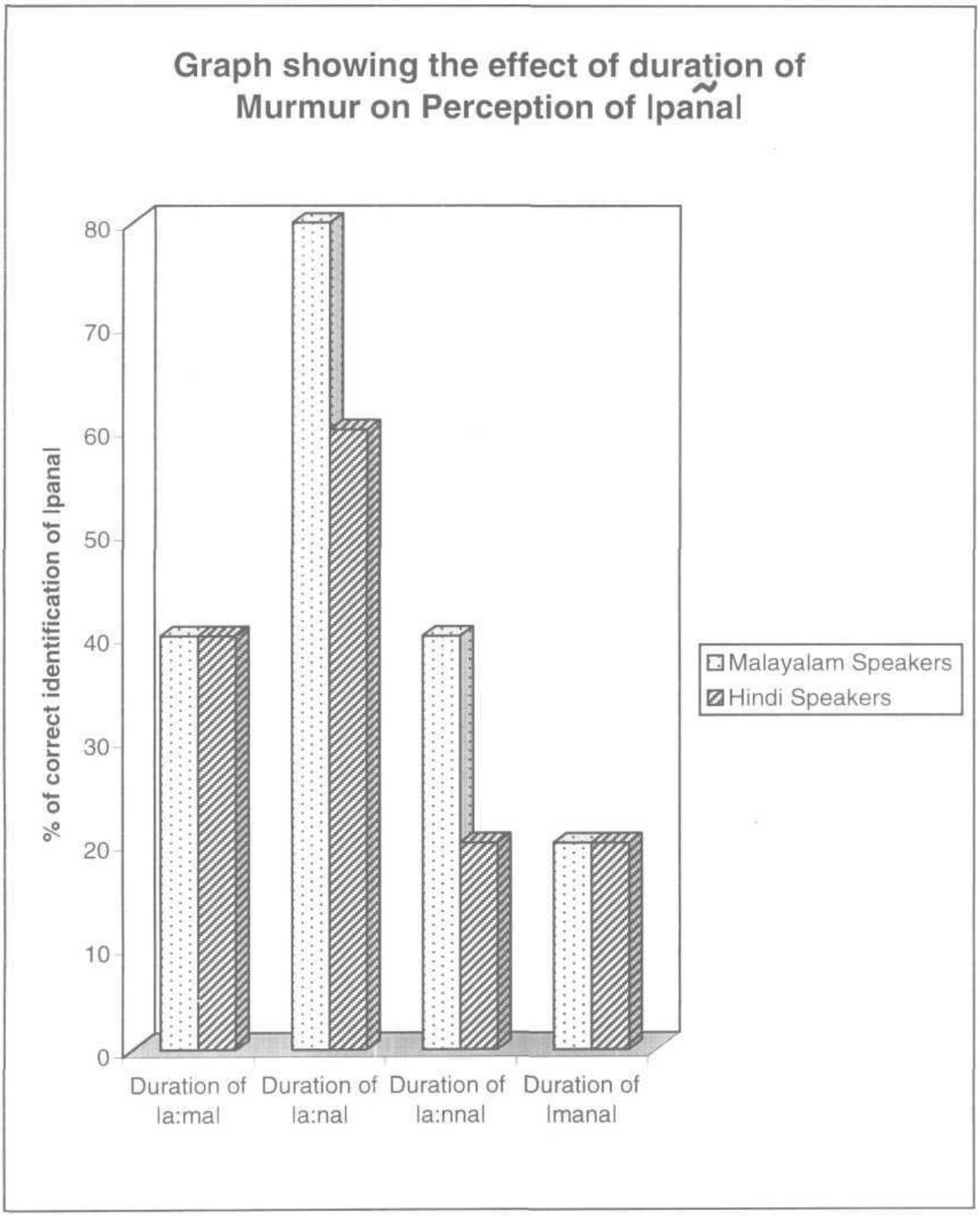
The graph 19 shows the effect of duration of murmur on the perception of /a:ṇṇa/.

In case of the word /maɲa/ similar results as in /a:ṇṇa/ and /a:ṇa/ was observed. Except with duration of /paña/, the perception of /maɲa/. This results shows that abnormal increase in duration decreases the intelligibility. Repp (1986) reports similar findings.

The graph 20 shows the effect of duration of murmur on the perception of /maɲa/.

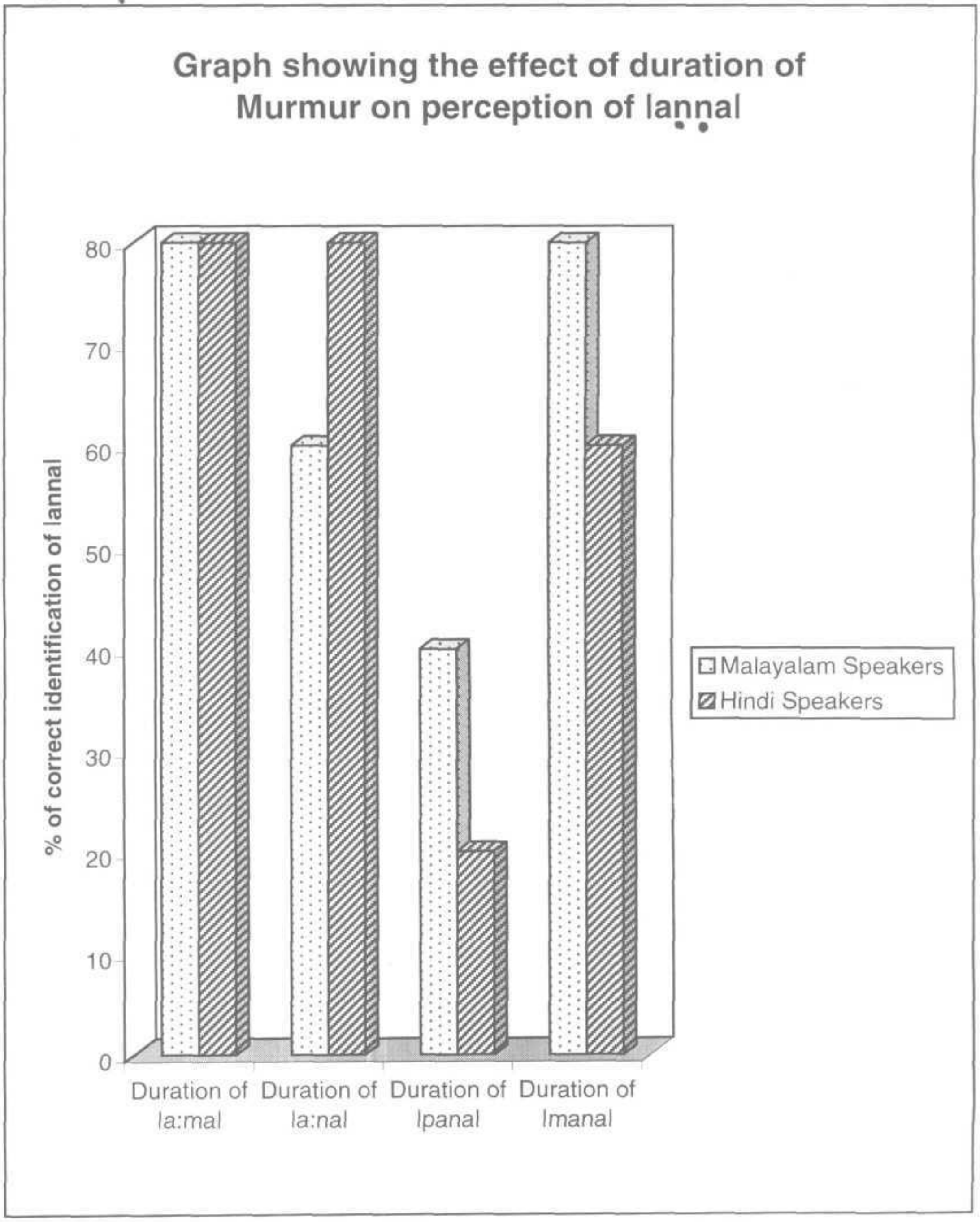
To conclude, temporal cues effects the intelligibility *of* the nasal consonants. But this rejects the hypothesis that the temporal cues aids in place perception of nasal consonants. There was no difference seen in the perception of Hindi speakers and Malayalam speakers. This rejects the hypothesis that there is a difference in the perception of Hindi speakers and Malayalam speakers.

GRAPH NO: 18

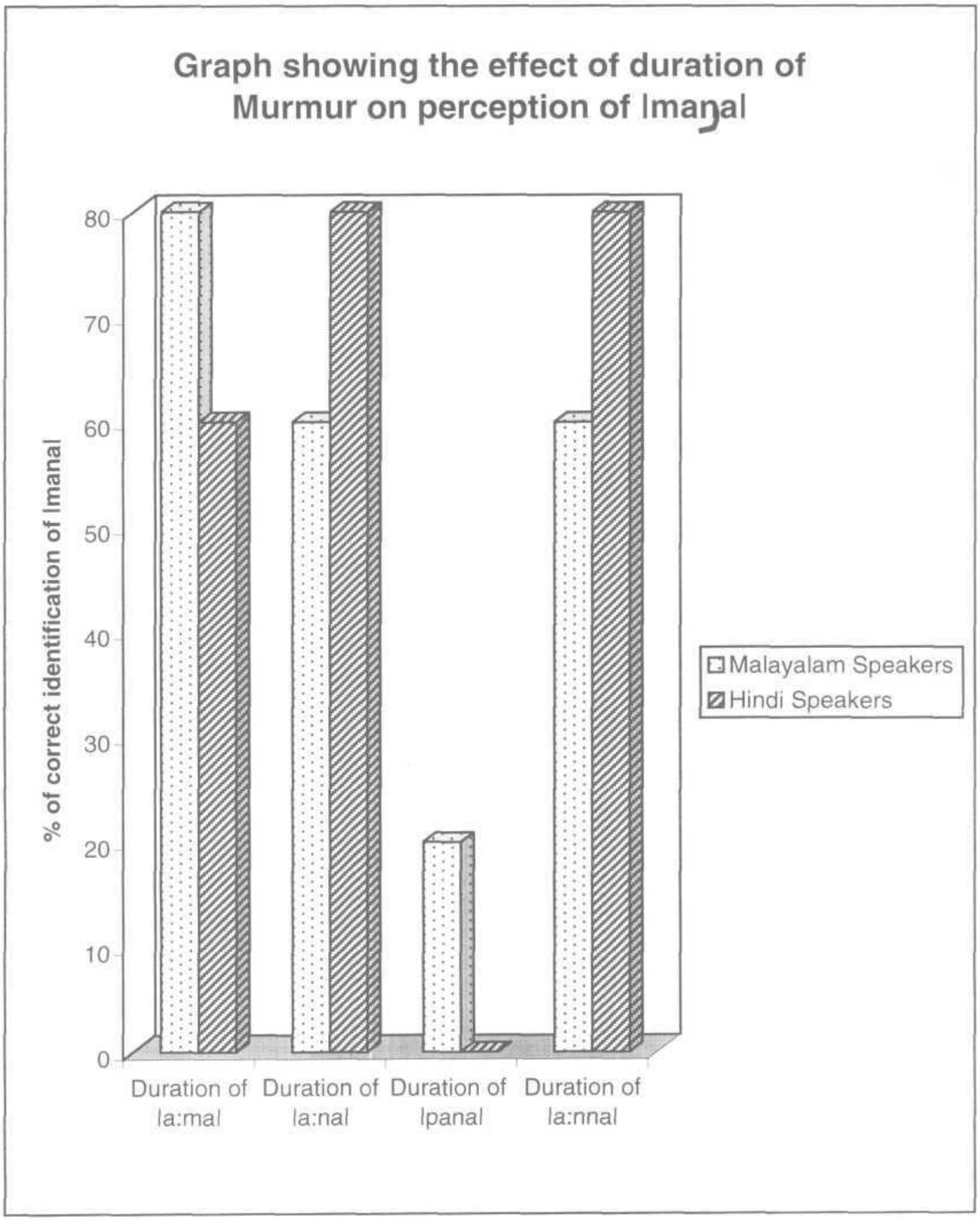


Graph showing the effect of duration of Murmur on Perception of /panal/
% of correct identification of /panal/
80
70
60
50
40
30
20
10
0
Duration of /a:ma/
Duration of /a:na/
Duration of /a:nna/
Duration of /mana/
Malayalam Speakers
Hindi Speakers

No:19


Graph showing the effect of duration of
Murmur on perception of lannal
% of correct identification of lannal
80
70
60
50
40
30
20
10
0
Duration of la:mal
Duration of la:nal
Duration of lpanal
Duration of lmanal
Malayalam Speakers
Hindi Speakers

No: 20



Graph showing the effect of duration of Murmur on perception of /maɲal/
% of correct identification of /manal/
80
70
60
50
40
30
20
10
0
Duration of /a:mal/
Duration of /a:nal/
Duration of /panal/
Duration of /a:nnal/
Malayalam Speakers
Hindi Speakers

Summary and Conclusion

To understand the speech sounds of a language, it is necessary to learn about the articulatory and acoustic nature of the speech sounds. The speech sounds are perceived by the human being as an acoustic event. These acoustic events are the consequence of articulartory 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 (Pickett 1980). Acoustic analysis and perception studies serve many purposes

1) They would furnish information about the cues that could be used with speech and language handicapped.
2) The information obtained from this could be used in automatic speech recognition and in constructing synthesizers for speech handicapped.
3) It can be used in text to speech conversion.
4) It will help in mapping of the speech processor in cochlear implant.

The present study was aimed at determining the acoustic characteristics of nasals in Malayalam, and also to find the major cues in the perception of nasals in Malayalam.

Acoustic analysis of nasal consonants in the intervocalic position vowel being /a/ was carried out using a wide band spectrogram (300 Hz filter) display. Five meaningful Malayalam words were taken. They were /a:ma/. / a:n̠a/. /a:ṇṇa/, /pan̆a/ and maɲa. All these five words were frequently used in the language. The parameters analyzed were : spectral parameters

1) Murmur frequency (N_1, N_2, N_3),
2) Frequency of the preceding vowel steady state,
3) Frequency of the following vowel steady state,
4) Frequency of the preceding transition end point,
5) Frequency of the transition beginning of the following vowel.

Temporal parameters analysed were :

1) Duration of the murmur,

2) duration of the preceding transition,

3) duration of the following transition.

The perceptual study was done under five conditions

1. Interchanging the murmur with different words.
2. Interchanging the preceding vowel steady state and transition with different words.
3. Interchanging the following vowel steady state and transition with different words.
4. Interchanging both the preceding and following vowel steady state and transition with different words.
5. Interchanging the duration of murmur.

Five native female Malayalam speakers and five native female Hindi speakers served as the listners. They were made to judge whether the synthesized stimulus was similar to the correct one or some what similar to the correct one (intermediate) or completely different from the correct signal.

Following conclusions were drawn from the study

1) Nasal consonants are characterized by poles and zero's.

The poles are the regions of maximum energy and zero's are the regions of minimum energy.

A summary of the frequency values obtained through the acoustic analysis given in the table.1.

To summarize the findings of perception study.

1) It is still inconclusive whether transition or murmur, or transition and murmur together gives a place cue for the perception of bilabial nasal consonant (/m/).
2) For alveolar nasal consonant and palatal nasal consonant all the experiments shows that transition is a major cue in place perception.
3) For retroflex and velar nasal consonants through all the experiments it was shown that transition and murmur play a equal role in place perception.

Implication

1) To enhance the knowledge about spectral characteristics of nasals.
2) To enhance the knowledge about process of speech perception.
3) To furnish information about the uses that could be used with speech and language handicapped.
4) This information can be used in automatic speech recognition and in construction of synthesizers for speech handicapped.
5) It could be used in text to speech conversion systems.
6) It will also be helpful in mapping the speech processor in cochlear implant.

Recommendations

1) The effect of transition and murmur on nasal perception can be studied separately to get a thorough information about the place cue provided by them.
2) The perceptual relevance of the timing relationship between nasal closure and transition onset can give a better understanding about the effect of duration on place perception.
3) The perceptual change in different vowel context can be studied.
4) The same study can be carried out in a larger sample of population.

APPENDIX

RESPONE SHEET

		Similar	Somewhat similar	Different
1)	/a:ma/	+	-	-
2)	/a:n̠a/	-	+	-
3)	/paña/	+	-	-
4)	/a:ṇṇa/	-	-	+
5)	/maɲa/	-	+	-
6)	/a:n̠a/	+	-	-
7)	/paña/	-	-	+
8)	/a:ṇṇa/	-	+	-
9)	/maɲa/	-	-	+
10)	/a:ma/	+	-	-
11)	/a:ṇṇa/	-	+	-
12)	/a:ma/	+	-	-
13)	/a:n̠a/	-	+	-
14)	/paña/	-	-	+
15)	/a:ṇṇa/	-	+	-
16)	/maɲa/	+	-	-
17)	/a:n̠a/	-	-	+
18)	/paña/	-	+	-
19)	/a:ṇṇa/	+	-	-
20)	/maɲa/	-	+	-
21)	/a:ma/	-	-	+
22)	/a:ṇṇa/	+	-	-
23)	/a:ma/	-	+	-
24)	/a:ṇa/	+	-	-
25)	/paña/	-	-	+

26)	/a:ṇṇa/	-	-	+
27)	/maɲa/	+	-	-
28)	/a:ṉa/	-	+	-
29)	/paña/	+	-	-
30)	/a:ṇṇa/	-	-	+
31)	/maɲa/	-	+	-
32)	/a:ma/	+	-	-
33)	/maɲa/	-	+	-
34)	/a:ma/	+	-	-
35)	/a:ṉa/	-	+	-
36)	/paña/	-	-	+
37)	/a:ṇṇa/	-	+	-
38)	/maɲa/	+	-	-
39)	/a:ṉa/	-	-	+
40)	/paña/	+	-	-
41)	/a:ṇṇa/	-	-	+
42)	/maɲa/	+	-	-
43)	/a:ma/	-	-	+
44)	/paña/	-	+	-
45)	/a:ma/	-	-	+
46)	/a:ṉa/	+	-	-
47)	/paña/	-	-	+
48)	/a:ṇṇa/	-	+	-
49)	/maɲa/	+	-	-
50)	/a:ṉa/	-	-	+
51)	/paña/	+	-	-
52)	/a:ṇṇa/	-	+	-

53)	/maɲa/	-	+	-
54)	/a:ma/	+	-	-
55)	/a:ma/	-	-	+
56)	/a:ma/	-	+	-
57)	/a:ṇa/	+	-	-
58)	/paña/	-	-	+
59)	/a:ṇṇa/	-	+	-
60)	/maɲa/	+	-	-
61)	/a:n̲a/	-	-	+
62)	/paña/	+	-	-
63)	/a:ṇṇa/	-	+	-
64)	/maɲa/	-	-	+
65)	/a:ma/	+	-	-
66)	/a:ṇṇa/	+	-	-
67)	/a:ma/	-	+	-
68)	/a:n̲a/	-	-	+
69)	/paña/	+	-	-
70)	/a:ṇṇa/	+	-	-
71)	/maɲa/	-	+	-
72)	/a:n̲a/	-	-	+
73)	/paña/	-	+	-
74)	/a:ṇṇa/	+	-	-
75)	/maɲa/	+	-	-
76)	/a:ma/	+	-	-
77)	/a:ṇṇa/	-	-	+
78)	/a:ma/	-	+	-
79)	/a:n̲a/	-	+	-

80)	/paña/	+	-	-
81)	/a:ṇṇa/	+	-	-
82)	/maɲa/	-	-	+
83)	/a:ṉa/	-	+	-
84)	/paña/	+	-	-
85)	/a:ṇṇa/	-	+	-
86)	/maɲa/	-	-	+
87)	/a:ma/	+	-	-
88)	/a:ṇṇa/	-	-	+
89)	/a:ma/	-	+	-
90)	/a:ṉa/	-	-	+
91)	/paña/	+	-	-
92)	/a:ṇṇa/	-	-	+
93)	/maɲa/	+	-	-
94)	/a:ṉa/	-	+	-
95)	/paña/	-	+	-
96)	/a:ṇṇa/	-	-	+
97)	/maɲa/	+	-	-
98)	/a:ma/	-	-	+
99)	/a:ṇṇa/	-	+	-
100)	/a:ma/	-	-	+
101)	/a:ṉa/	-	+	-
102)	/paña/	-	-	+
103)	/a:ṇṇa/	-	+	-
104)	/maɲa/	+	-	-
105)	/a:ṉa/	-	-	+
106)	/paña/	+	-	-

107) /a:ṇṇa/	-	+	-
108) /maɲa/	+	-	-
109) /a:ma/	+	-	-
110) /maɲa/	-	+	-
111) /a:ma/	-	-	+
112) /a:ṉa/	-	+	-
113) /paña/	+	-	-
114) /a:ṇṇa/	-	-	+
115) /maɲa/	-	-	+
116) /a:ṉa/	+	-	-
117) /paña/	+	-	-
118) /a:ṇṇa/	-	-	+
119) /maɲa/	-	+	-
120) /a:ma/	+	-	-
121) /a:ɲɲa/	-	-	+
122) /a:ma/	+	-	-
123) /a:ṉa/	-	-	+
124) /paña/	+	-	-
125) /a:ṇṇa/	-	-	+
126) /maɲa/	+	-	-
127) /a:ṉa/	-	-	+
128) /paña/	-	-	+
129) /a:ṇṇa/	-	+	-
130) /maɲa/	-	-	+
131) /a:ma/	+	-	-
132) /a:ṇṇa/	-	-	+
133) /a:ma/	-	-	+

TABLE - 1

	Murmur Frequecy (In Hz)	Duration of the murmur	Frequency of the preceding vocalic steady state	Frequency of the preceding vocalic transition end point	Duration of the preceding vocalic transtion	Frequency range of preceding vocalic transition	Direction of the preceding vocalic transition	Frequency of following transition begining	Frequency of following steady state	Duration of following vowel transition	Frequency range of following vowel transition	Direction of the following vowel transition
/m/	250 1110 1420	120	850 1328 2737	796 1248 2692	20	54 80 45	- - -	632 1181 2518	707 1281 2568	30	75 700 50	+ + +
/n̲/	310 1130 2230	122	796 1341 2537	746 1571 2567	60	50 230 30	- + +	712 1725 2623	787 1475 2548	75	75 250 75	+ - -
/ñ/	350 1120 2280	130	814 1360 2355	694 1785 2475	70	120 425 120	- + +	696 1866 2628	796 1416 2553	90	100 450 75	+ - -
/ṇ/	370 1260 2496	144	856 1380 2785	781 1625 2535	80	75 245 250	- + -	776 1754 2481	851 1479 2706	110	75 275 225	+ - +
/ŋ/	390 1400 2650	150	802 1349 2377	782 1449 2283	45	20 100 94	- + -	769 1420 2598	793 1295 2798	40	24 125 125	+ - +

134) /paña/	-	+	-
135) /maŋa/	+	-	-
136) /a:ma/	-	-	+
137) /paña/	-	+	-
138) /maŋa/	+	-	-
139) /a:ṉa/	-	-	+
140) /a:ṇṇa/	-	+	-

Experiment No. 1

Correct Stimulus	Synthesized StimulusA.
1. /a:ma/	/a:ma/ with the murmur of /a:ṉa/
2. /a:ma/	/a:ma/ with the murmur of /paña/
3. /a:ma/	/a:ma/ with the murmur of /a:ṇṇa/
4. /a:ma/	/a:ma/ with the murmur of /maɲa/
B.	
5. /a:ṉa/	/a:ṉa/ with the murmur of /a:ma/
6. /a:ṉa/	/a:ṉa/ with the murmur of /paña/
7. /a:ṉa/	/a:ṉa/ with the murmur of /a:ṇṇa/
8. /a:ṉa/	/a:ṉa/ with the murmur of /maɲa/
C.	
9. /paña/	/paṇa/ with the murmur of /a:ma/
10. /paña/	/paña/ with the murmur of /a:ṉa/
11. /paña/	/paña/ with the murmur of /a:ṇṇa/
12. /paña/	/paña/ with the murmur of /maɲa/
E.	
13. /a:ṇṇa/	/a:ṇṇa/ with the murmur of /a:ma/
14. /a:ṇṇa/	/a:ṇṇa/ with the murmur of /a:ṉa/
15. /a:ṇṇa/	/a:ṇṇa/ with the murmur of /paña/
16. /a:ṇṇa/	/a:ṇṇa/ with the murmur of /maɲa/
F.	
17. /maɲa/	/maɲa/ with the murmur of /a:ma/
18. /maɲa/	/maɲa/ with the murmur of /a:ṉa/
19. /maɲa/	/maɲa/ with the murmur of /paña/
20. /maɲa/	/maɲa/ with the murmur of /a:ṇṇa/

Experiment No. 2

G.	
21. /a:ma/	/a:ma/ with the preceding vowel steady state and transition of /a:ṉa/
22. /a:ma/	/a:ma/ with the preceding vowel steady state and transition of /paña/
23. /a:ma/	/a:ma/ with the preceding vowel steady state and transition of /a:ṇṇa/

24. /a:ma/	/a:ma/ with the preceding vowel steady state and transition of /maɲa/
H.	
25. /a:n̪a/	/a:n̪a/ with the preceding vowel steady state and transition of /a:ma/
26. /a:n̪a/	/a:n̪a/ with the preceding vowel steady state and transition of /paña/
27. /a:n̪a/	/a:n̪a/ with the preceding vowel steady state and transition of /a:ṇṇa/
28. /a:n̪a/	/a:n̪a/ with the preceding vowel steady state and transition of /maɲa/
I.	
29. /paña/	/paña/ with the preceding vowel steady state and transition of /a:ma/
30. /paña/	/paña/ with the preceding vowel steady state and transition of /a:n̪a/
31. /paña/	/paña/ with the preceding vowel steady state and transition of /a:ṇṇa/
32. /paña/	/paña/ with the preceding vowel steady state and transition of /maɲa/
J.	
33. /a:ṇṇa/	/a:ṇṇa/ with the preceding vowel steady state and transition of /a:ma/
34. /a:ṇṇa/	/a:ṇṇa/ with the preceding vowel steady state and transition of /a:n̪a/
35. /a:ṇṇa/	/a:ṇṇa/ with the preceding vowel steady state and transition of /paña/
36. /a:ṇṇa/	/a:ṇṇa/ with the preceding vowel steady state and transition of /maɲa/
K.	
37. /maɲa/	/maɲa/ with the preceding vowel steady state and transition of /a:ma/
38. /maɲa/	/maɲa/ with the preceding vowel steady state and transition of /a:n̪a/

39. /maɲa/ — /maɲa/ with the preceding vowel steady state and transition of /paña/

40. /maɲa/ — /maɲa/ with the preceding vowel steady state and transition of /a:ṇṇa/

Experiment No. 3

L.

41. /a:ma/ — /a:ma/ with the following vowel steady state and transition of /a:ṉa/

42. /a:ma/ — /a:ma/ with the following vowel steady state and transition of /paña/

43. /a:ma/ — /a:ma/ with the following vowel steady state and transition of /a:ṇṇa/

44. /a:ma/ — /a:ma/ with the following vowel steady state and transition of /maɲa/

M.

45. /a:ṉa/ — /a:ṉa/ with the following vowel steady state and transition of /a:ma/

46. /a:ṉa/ — /a:ṉa/ with the following vowel steady state and transition of /paña/

47. /a:ṉa/ — /a:ṉa/ with the following vowel steady state and transition of /a:ṇṇa/

48. /a:ṉa/ — /a:ṉa/ with the following vowel steady state and transition of /maɲa/

N.

49. /paña/ — /paña/ with the following vowel steady state and transition of /a:ma/

50. /paña/ — /paña/ with the following vowel steady state and transition of /a:ṉa/

51. /paña/ — /paña/ with the following vowel steady state and transition of /a:ṇṇa/

52. /paña/ — /paña/ with the following vowel steady state and transition of /maɲa/

O.

53. /a:ṇṇa/ — /a:ṇṇa/ with the following vowel steady state and transition of /a:ma/

54. /a:ṇṇa/ — /a:ṇṇa/ with the following vowel steady state and transition of /a:n̠a/

55. /a:ṇṇa/ — /a:ṇṇa/ with the following vowel steady state and transition of /pan̄a/

56. /a:ṇṇa/ — /a:ṇṇa/ with the following vowel steady state and transition of /maɲa/

P.

57. /maɲa/ — /maɲa/ with the following vowel steady state and transition of /a:ma/

58. /maɲa/ — /maɲa/ with the following vowel steady state and transition of /a:n̠a/

59. /maɲa/ — /maɲa/ with the following vowel steady state and transition of /pan̄a/

60. /maɲa/ — /maɲa/ with the following vowel steady state and transition of /a:ṇṇa/

Experiment No. 4

Q.

61. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /pan̄a/.
62. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /a:ṇṇa/.
63. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /maɲa/.
64. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /a:n̠a/.
65. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /a:ṇṇa/.
66. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /maɲa/.
67. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /a:n̠a/.

68. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /paña/.
69. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /maŋa/.
70. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /a:n̠a/.
71. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /paña/.
72. The murmur of /a:ma/ with preceding vowel of /a:n̠a/ and following vowel of /a:ṇṇa/.

S.

73. The murmur of /a:n̠a/ with preceding vowel of /a:ma/ and following vowel of /paña/.
74. The murmur of /a:n̠a/ with preceding vowel of /a:ma/ and following vowel of /a:ṇṇa/.
75. The murmur of /a:n̠a/ with preceding vowel of /a:ma/ and following vowel of /maŋa/.
76. The murmur of /a:n̠a/ with preceding vowel of /paña/ and following vowel of /a:ma/.
77. The murmur of /a:n̠a/ with preceding vowel of /paña/ and following vowel of /a:ṇṇa/.
78. The murmur of /a:n̠a/ with preceding vowel of /paña/ and following vowel of /maŋa/.
79. The murmur of /a:n̠a/ with preceding vowel of /a:ṇṇa/ and following vowel of /a:ma/.
80. The murmur of /a:n̠a/ with preceding vowel of /a:ṇṇa/ and following vowel of /paña/.
81. The murmur of /a:n̠a/ with preceding vowel of /a:ṇṇa/ and following vowel of /maŋa/.
82. The murmur of /a:n̠a/ with preceding vowel of /maŋa/ and following vowel of /a:ma/.
83. The murmur of /a:n̠a/ with preceding vowel of /maŋa/ and following vowel of /paña/.
84. The murmur of /a:n̠a/ with preceding vowel of /maŋa/ and following vowel of /a:nna/.

T.

85. The murmur of /paña/ with preceding vowel of /a:ṉa/ and following vowel of /a:ma/.
86. The murmur of /pana/ with preceding vowel of /a:ṉa/ and following vowel of /a:ṇṇa/.
87. The murmur of /pana/ with preceding vowel of /a:ṉa/ and following vowel of /maɲa/.
88. The murmur of /paña/ with preceding vowel of /a:ma/ and following vowel of /a:ṉa/.
89. The murmur of /paña/ with preceding vowel of /a:ma/ and following vowel of /a:ṇṇa/.
90. The murmur of /paña/ with preceding vowel of /a:ma/ and following vowel of /maɲa/.
91. The murmur of /pana/ with preceding vowel of /a:ṇṇa/ and following vowel of /a:ṉa/.
92. The murmur of /paña/ with preceding vowel of /a:ṇṇa/ and following vowel of /a:ma/.
93. The murmur of /paña/ with preceding vowel of /a:ṇṇa/ and following vowel of /maɲa/.
94. The murmur of /paña/ with preceding vowel of /maɲa/ and following vowel of /a:ṉa/.
95. The murmur of /paña/ with preceding vowel of /maɲa/ and following vowel of /a:ma/.
96. The murmur of /paña/ with preceding vowel of /maɲa/ and following vowel of /a:ṇṇa/.

U.

97. The murmur of /a:ṇṇa/ with preceding vowel of /a:ṉa/ and following vowel of /a:ma/.
98. The murmur of /a:ṇṇa/ with preceding vowel of /a:ṉa/ and following vowel of /paña/.
99. The murmur of /a:ṇṇa/ with preceding vowel of /a:ṉa/ and following vowel of /maɲa/.
100. The murmur of /a:ṇṇa/ with preceding vowel of /a:ma/ and following vowel of /a:na/.

101. The murmur of /a:ṇṇa/ with preceding vowel of /a:ma/ and following vowel of /paña/.
102. The murmur of /a:ṇṇa/ with preceding vowel of /a:ma/ and following vowel of /maŋa/.
103. The murmur of /a:ṇṇa/ with preceding vowel of /paña/ and following vowel of /a:n̲a/.
104. The murmur of /a:ṇṇa/ with preceding vowel of /paña/ and following vowel of /a:ma/.
105. The murmur of /a:ṇṇa/ with preceding vowel of /paña/ and following vowel of /maŋa/.
106. The murmur of /a:ṇṇa/ with preceding vowel of /maŋa/ and following vowel of /a:n̲a/.
107. The murmur of /a:nna/ with preceding vowel of /maŋa/ and following vowel of /a:ma/.
108. The murmur of /a:ṇṇa/ with preceding vowel of /maŋa/ and following vowel of /paña/.

V.

109. The murmur of /maŋa/ with preceding vowel of /a:n̲a/ and following vowel of /a:ma/.
110. The murmur of /maŋa/ with preceding vowel of /a:n̲a/ and following vowel of /paña/.
111. The murmur of /maŋa/ with preceding vowel of /a:n̲a/ and following vowel of /a:ṇṇa/.
112. The murmur of /maŋa/ with preceding vowel of /a:ma/ and following vowel of /a:n̲a/.
113. The murmur of /maŋa/ with preceding vowel of /a:ma/ and following vowel of /paña/.
114. The murmur of /maŋa/ with preceding vowel of /a:ma/ and following vowel of /a:ṇṇa/.
115. The murmur of /maŋa/ with preceding vowel of /paña/ and following vowel of /a:n̲a/.
116. The murmur of /maŋa/ with preceding vowel of /paña/ and following vowel of /a:ma/.
117. The murmur of /maŋa/ with preceding vowel of /paña/ and following vowel of /a:nna/.

118. The murmur of /maɲa/ with preceding vowel of /a:ṇṇa/ and following vowel of /a:n̠a/.

119. The murmur of /maɲa/ with preceding vowel of /a:ṇṇa/ and following vowel of /a:ma/.

120. The murmur of /maɲa/ with preceding vowel of /a:ṇṇa/ and following vowel of /paña/.

Experiment No. 5

Correct Stimulus	Synthesized StimulusA.
W	
121. /a:ma/	/a:ma/ with the duration of /a:n̠a/
122. /a:ma/	/a:ma/ with the duration of /paña/
123. /a:ma/	/a:ma/ with the duration of /a:ṇṇa/
124. /a:ma/	/a:ma/ with the duration of /maɲa/
X.	
125. /a:n̠a/	/a:n̠a/ with the duration of /a:ma/
126. /a:n̠a/	/a:n̠a/ with the duration of /paña/
127. /a:n̠a/	/a:n̠a/ with the duration of /a:ṇṇa/
128. /a:n̠a/	/a:n̠a/ with the duration of /maɲa/
Y.	
129. /paña/	/paña/ with the duration of /a:ma/
130. /paña/	/paña/ with the duration of /a:n̠a/
131. /paña/	/paña/ with the duration of /a:ṇṇa/
132. /paña/	/paña/ with the duration of /maɲa/
Z.	
133. /a:ṇṇa/	/a:ṇṇa/ with the duration of /a:ma/
134. /a:ṇṇa/	/a:ṇṇa/ with the duration of /a:n̠a/
135. /a:ṇṇa/	/a:ṇṇa/ with the duration of /paña/
136. /a:ṇṇa/	/a:ṇṇa/ with the duration of /maɲa/
Z1.	
137. /maɲa/	/maɲa/ with the duration of /a:ma/
138. /maɲa/	/maɲa/ with the duration of /a:n̠a/
139. /maɲa/	/maɲa/ with the duration of /paña/
140. /maɲa/	/maɲa/ with the duration of /a:ṇṇa/

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