SPECTROGRAPHIC ANALYSIS OF "HOARSENESS"

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**A Dissertation Submitted in Part Fulfilment
for the Degree of Master of Science
(Speech and Hearing)
University of Mysore
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TO MY PARENTS

CERTIFICATE

This is to certify that the dissertation "Spectrographic analysis of 'hoarseness'" is the bona fide work in part fulfilment for the Degree of M.Sc, (Speech and Hearing), carrying 100 marks, of the student with Register No. 15

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This is to certify that this dissertation has been prepared under my supervision and guidance.

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GUIDE

18/5/87

DECLARATION

This dissertation is the result of my own study undertaken under the guidance of Mr. N.P. Nataraja, Lecturer in Speech Pathology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other diploma or degree.

Reg. No. 15

Mysore

Dated: May, 1981

aithal, Mr. H.S. Gopal, Mr. R.S. Shukla, Miss Hemalatha, Miss Fulguni Pathak, Miss Kamini R, Miss Indira N, and Mr. Ravishankar K.C., for enabling this study success.

I express my thanks to Mr. Sanjeeva Murthy for typing the manuscript.

Finally, I thank all my subjects and friends who have extended a helping hand in all phases of my dissertation work.

CONTENTS

CHAPTER I

INTRODUCTION

"The less a science has advanced, the more its terminology tends to rest upon the uncritical assumption of mutual understanding"

W. Quine, "Truth Convention"
Philosophical essays for
A.N. Whitehead
(Longmans, Green), 1936.

This statement is applicable to the field of voice and its disorders.

There are several definitions of voice, some definitions of voice restricting the term upto generation of sound at the level of larynx, while others include the influence of vocal tract on the generated laryngeal tone and other broader definition describe the aspects of generation, resonance, articulation and prosody.

Voice has been defined as "the laryngeal modulation of the pulmonary air stream, which is then further modified by the configuration of the vocal tract" (Michel and

Wendahl, 1971, p. 466).

The characteristics of pitch, loudness and quality which make the meaning clear, arouse the proper emotional response or ensue a pleasant tonal effect upon the hearer."

Berry and Eisenson (1967) suggest two definitions of voice quality.

i) the psychoacoustic definition "the hearer's impression of the complex sound wave, its hormonic and in-hormonic partials and the relative intensity, number and duration of these components. Such impression he judges in terms of pleasantness and unpleasantness".

ii) the physiologists definition: "quality depends upon:

a) the power and control of respiration,

b) the size, elasticity, length and surface condition of vocal folds,

c) the size, shape, tension, flexibility of resonator-articulator mechanism, density and surface conditions of the walls of the resonators.

To define a problem voice the five characteristics of a normal voice can be listed as negative characteristics.

1. Disturbed voice quality caused by laryngeal dysfunction and characterized by hoarseness, harshness or breathiness.

2. Hypernasality and hyponasality caused by improper balance of oral and nasal resonance.

3. A voice too soft to be heard easily or so loud it is unpleasant.

4. A modal frequency level too high or too low for age, size and sex.

5. Inappropriate inflections of pitch and loudness. (Peterson, 1946)

There is no satisfactory definition for the term hoarseness. In this regard, Van Riper (1968) states that it would be possible to demonstrate hoarseness rather than defining it. Acoustically, the hoarseness has been said to be a combination of breathy and harsh voice. It is apparent that hoarseness is a complex concept and probably not fully accountable as related to any one perceptual dimension.

Need for the study

Considerable emphasis has been placed on this symptom and several approaches including acoustic, cinematographic, aerodynamic and electrophysiologic have been utilized to explore the mechanism and pathologic physiology of hoarse voice production. However, the evaluation of hoarseness, the estimation of degree and the quality of hoarseness, has been made chiefly on the basis of the clinician's subjective perception. This practice has led to the creation of confusing terms to describe similar changes of vocal quality. Little is known about acoustical properties of variations of pathologic voices and related dysfunctions of the larynx. Thus it is necessary to study the acoustic parameters of hoarseness.

Hence, here is an attempt to reduce the confusion involved in the term "hoarseness" by seeking quantitative measurement of hoarseness of voice.

Statement of problem

The problem was to study the factors contributing to the perception of degree of hoarseness of voice.

Hypotheses

1. There is no difference in the degree of perception of hoarseness of different vowels.

Sub-hypothesis: (i) there is no difference in the degree of perceived hoarseness between vowel /a/ and vowel /e/;

(ii) there is no difference in the degree of perceived hoarseness between vowel /a/ and vowel /i/;

(iii) there is no difference in the degree of perceived hoarseness between vowel /a/ and vowel /u/;

(iv) there is no difference in the degree of perceived hoarseness between vowel /e/ and vowel /i/;

(v) there is no difference in the degree of perceived hoarseness between vowel /e/ and vowel /u/;

(vi) there is no difference in the means of ratings of vowel /e/ and vowel /u/.

2. There is no difference in the spectrographs of of different degree of hoarseness.

3. There is no difference in fundamental frequency variation with varying degrees of hoarseness.

Methods and Results

To test the hypotheses, 17 hoarse voice subjects and 9 normal voice subjects were considered for this study. All the subjects were asked to phonate /a/, /e/, /i/ and /u/ vowels. The voice samples were recorded. They were analyzed subjectively and spectrographically, and findings have been discussed.

Limitations of the study

1. Only seventeen subjects with hoarse voice could be included for the study.

2. Different types of vocal pathologies could not be included for the study.

3. Other parameters like optimum frequency and amplitude variation in hoarse voice could not be studied.

Implication of the study

This study provides information regarding acoustic characteristics of different degree of perceived hoarseness.

Description of the term 'Hoarseness'

Hoarseness is a symptom of laryngeal pathology. Normal phonation requires complete approximation, adequate tension and regular vibrations. If any of these requisites are disturbed for any reason, resultant condition could be hoarseness.

CHAPTER II

REVIEW OF LITERATURE

"The loss of larynx in humans produce an obliteration of speech function that is unique. . . . ." The absence of a phonating mechanism makes production of vocal tones for speech impossible (Van Riper & Irwin, 1958, p. 172).

The one faculty which sets man apart from all other living organisms which makes him unique is, his ability to communicate, using his vocal tones for social interaction.

Voice conveys information regarding the sex and the age of the speaker, it indicates the emotional state of the speaker. Voice is also important in conveying meaning as in tonal languages.

Michel and Wendahl (1971), discussing the definitions of voice, state that:

"the random house dictionary lists 25 primary and secondary definitions of voice, the first of which is the sound or sounds uttered through the mouth of human beings in speaking, shouting, singing, etc.... If we accept the scientific definitions to be less variable and more precise than the 'lay' definitions, we will be disappointed".

Fant (1960) defines voice by using the formula P=ST, in which the speech sound P, is the product of the source S, and the transfer function of the vocal tract, T.

"When discussing the production of speech,it should be noted that the source S, of the formula, P=s.T., is an acoustic disturbance, superimposed upon the flow of respiratory air and is caused by a quasiperiodic modulation of the air flow due to the opening and closing movement of the vocal folds." (Fant 1960).

Michael and Wendahl (1971) define voice as "the laryngeal modulation of pulmonary air stream, which is then modified by the configuration of the vocal tract."

The production of voice depends on the coordination of essentially three factors:

1. Pulmonary air pressure, supplied by the respiratory system.

2. Laryngeal vibration, i.e., phonation, a function of the vocal cords.

3. Transfer function of the vocal tract, i.e., resonance.

This definition is made use of in this study.

Sound is the alternate compression and rarification of air molecules. Subglottic air, trapped in the trachea by the closed vocal cords, is compressed by the accessory muscles of respiration. As the pressure beneath the glottis increases, the vocal cords are separated, allowing the escape of the compressed air. When Subglottic pressure falls, the vocal cords can not be held open. They move back passively by their intrinsic tension. The subglottic pressure can then build to produce another wave of compressed air. The result is a train of compressions and rarifications and the result is sound.

The role of larynx as central voice organ has upto now been widely used. Galen (130 A.D.) thought the trachea to be the central organ acting as a flute. Dodart (1700) showed that vowel originates from larynx. Ferre

(1741) proved sound was directly produced by the vibration of vocal cords. Helmholtz (1875) showed that the puffs of air escaping through the glottis are the primary source of sound.

"The mechanism of human larynx, often regarded as sphincteric, more nearly represents graduated folding or plication. Taking the end of normal expiration as the reference condition, folding decreases with inspiration and increases successively with reserve expiration, phonation, efforts closure and swallow closure' (Fink, 1971).

"When vibrating, the vocal folds provide a wide spectrum of quasiperiodic modulations of the air stream, accounting for various tonal qualities, reflecting the different ways the vibrator behaves". (Brackett, 1971).

The basic conditions necessary for the production of good voice are:

1. Speech organs which are normal, both in terms of anatomy and physiology, to the subject's age, sex and physique;

2. Normal emotional or physical conditions of the subject;

3. Appropriate habits of voice production and proper use of voice.

In total, the production of a good voice depends on the synchrony or co-ordination between respiration, phonation and resonance.

The mechanism of the voice production is not completely understood. There are mainly two schools of thought.

i) Myoelastic theory of phonation or Aerodynamic theory. According to this theory:

"When the vocal cords are closed, the subglottic air compressed to such an extent that its mounting pressure explodes the glottal closure. At this moment the condensation of air is propagated through the oral cavity into the surrounding air. Following this explosive reduction of air pressure, the vocal cords are driven back into the closed position through the elasticity of their contracted musculature. Subglottic pressure increases again and the process is repeated." (Luschsinger, R and Arnold G.E., 1965, p. 25-26).

ii) Neurochronaxic theory of phonation:

"Husson (1950) proposed that the vocal cord vibration is an active neuromuscular process. He believes that the periodic opening of the vocal cords is controlled by action potentials of equal frequency, which are supposed to be conducted to the fibers of vocalis muscle through the recurrent laryngeal nerve. The return motion of closure would then occur through the elasticity of the vocal muscle. In this neuromuscular process the subglottic air pressure functions merely to increase the opening amplitude" (Luchsinger, R and Arnold, G.E., 1965, p. 26-27).

The neurochronaxic theory, advanced by Husson (1950), postulates that each new vibratory cycle is initiated by a nerve impulse transmitted from the brain to the recurrent branch of the vagus nerve. The frequency of vocal fold vibration is dependent upon the rate of impulses delivered to the laryngeal muscles. Investigators are still working on mechanism of production of voice to support their theories. However, according to Fant (1960), the mechanical, myoelastic theory of voice production is commonly accepted. Based on Myoelastic theory, he considers the following factors as responsible for determining the frequency of vibration of the vocal cords.

1. Control of the laryngeal musculature affecting the tension and mass distribution of the cords. Increased tension and smaller effective mass increases fundamental frequency.

2. Decreased subglottal pressure.

3. Increased degree of supraglottal construction as in voiced consonants reduces the pressure drop across the glottis, thus reducing the alternating positive and negative pressures and fundamental frequency decreases.

4. A shift of the tongue articulation towards a high front position results in an increase in fundamental frequency due to increased vocal cord tension.

The three attributes of voice are: (i) Pitch, (ii) Loudness and (iii) Quality.

Pitch is the psychological correlate of frequency. Mel (for melody) is the scale used to quantify pitch. A sound whose frequency is 1000 Hz with an intensity of 40 dB has a pitch of 1000 mels.

Judson and Weaver (1965) say that relationship between frequency and pitch is logarithmic.

The frequency of vibration of any vibrator is determined mainly by mass, length and tension of the vibrator.

Wood presents this relationship on

$$F = \sqrt{\frac{1}{2L}}\sqrt{\frac{KT}{M}}$$

where, F = Frequency

L = Length of the vibrator

T = Tension of the vibrator

M = Mass of the vibrator, and

K = a constant.

However, this formula, though applicable precisely in case of musical instruments, does not satisfactorily explain all vocal cord conditions.

Loudness is the psychological correlate of intensity. It describes the degree of strength of sensation which one receives by way of one's hearing mechanism.

In a complex sound, the loudness will depend upon its frequency components or its spectrum.

The loudness of a sound depends upon its duration within certain ranges (Bekesy, 1933, Lifshitz, 1936).

Variation in loudness results from:

i) the force of subglottic breath,
ii) the elasticity of vocal cords, and
iii) the resonance effect of the vocal tract.

Quality is the psychological correlate of resonance and timber patterns (Murphy, 1964).

Berry and Eisenson (1967) suggest two definitions of voice quality:

i) the psycho acoustic definition "the hearer's impression of the complex sound wave, its hormonic and inhormonic partials and the relative intensity, number and duration of these components. Such impression he judges in terms of pleasantness and unpleasantness."

ii) the physiologists definition: "quality depends upon:

a) the power and control of respiration

b) the size, elasticity, length and surface condition of vocal folds

c) the size, shape, tension and flexibility of the resonator-articulator mechanism, and

d) the rigidity, density and surface conditions of the walls of the resonators.

Fant (1960) states that "the term voice will be adopted here with reference both to a source category and feature of the speech wave." Thus it seems that the term voice can be used to refer to source characteristics (S) in one case and to a combination of source (S) and tract characteristics (T) in another case.

While commanalities exist among definitions and each has merit, there seems to be no precise definition of voice.

Beck and Schneider (1926) demonstrated that any part of the larynx might be sight of congenital or acquired malformation. Vocal disturbances are particularly to be expected when the vocal cords are affected. Any irregularity in length, breadth,thickness, specific weight, muscular development, vertical position, insertion, motility and contractivity in short, any asymmetry in physical properties of the vocal cords affects the acoustical qualities of the voice. Other regions may also disturb the voice or add pathological noises to expiration.

Williams and Stevens (1972) stated that anger, fear and sorrow situations tended to produce characteristic differences in contour of fundamental frequency, average speech spectrum, temporal characteristics, precision of articulation and waveform regularities of successive glottal pulses. Attributes for a given emotional situation were not always consistent from one speaker to another.

West, Ansberry, Carr (1957), Van Riper and Irwin (1958), and Anderson (1961) write that, in general, nodules are caused by too high a pitch, among other factors. Van Riper and Irwin (1958) and Wilson (1966) recommended lowering the pitch, usually in cases of vocal nodules. Fisher and Logemann (1970) concur with Luchsinger and Arnold's (1965) observation that many patients with nodules use an unnaturally low speaking pitch. They also note that many patients with nodules had histories suggesting that prior to dysphonia they habitually used an unnaturally low speaking pitch, which might have contributed to the development of lesion. Peacher (1966) emphasizes that most people with dysphonia need to raise their pitch from two to five notes, contradicting the popular belief that a good speaking voice is always low-pitched.

Languaite and waldrop (1964) write that "there is a general agreement in the literature that vocal nodules are produced by using a pitch that is too high and contact ulcers are presumed to be caused by the use of too low a pitch. Other types of laryngeal pathologies, such as polyps, polypoid degeneration and chronic laryngitis although not associated especially with the use of wrong pitch, are thought to be primarily the result of vocal abuse.

The words like "mettalic, hoarse, harsh, husky, pectoral, raspy" etc., were used when they related not to what was actually occuring in the vocal mechanism, but rather to the auditory impression of the listner.

Brodnitz (1966) wrote that "much of the terminology conventionally employed . . . . is based on incorrect conceptions of vocal function . . . .".

Various disorders of larynx interfering with the approximation, tension and vibration of the vocal cords may lead to hoarseness. More common local causes like viral and bacterial infections, benign tumors like papillomas and recurrent laryngeal nerve paralysis. Less common pathologies like cricoarytenoid joint fixation, scarring of vocal cords and false cord phonation and squamous carcinoma of larynx.

Many authors have discussed hoarseness as a major deviant quality found in patients with voice disorders. (Van Riper and irwin 1958; More, 1971). More (1971) notes that a growth on the vocal folds lowers the pitch and affects the quality of voice.

Systemic diseases also have been implicated in the causation of hoarseness. Among them mentioned tuber-culous laryngitis, rheumatoid cricoarytenoiditis, sarcoidosis, syphilis, leprosy, histoplasmosis, myedema and amyloidosis.

Okada (1964) observed hoarseness in a case having Gouty Tophus in vocal cords. Hoarseness general term used by clinician and laymen to describe a variety of perceived voice abnormalities. These abnormalities may range from psychologically based problems to disease based problems.

Van Riper and Irwin (1978) describe hoarseness in terms of breathiness and harshness. Thurman (1952) noted confusion between hoarseness and breathiness in labeling voice samples. Shipp and Huttington (1957) found significant correlations between hoarseness and breathiness judgement for patients with acute laryngitis, but reported inverse relationship between hoarse and harsh judgement in their speaker.

Diagnostic evaluation of patients with voice disorders have always required a multidimensional approach including medical examination of voice generating systems, a psychological evaluation, an appraisal of patient's social conditions and relations, and auditory judgement of vocal sound. Although last procedure always has been considered to be very important, phoniatrists have learned not to rely too heavily on auditory impressions in making diagnosis.

There is no satisfactory definition for the term hoarseness. Hoarseness has been described in terms of physiology involved at the level of larynx. It is said that hoarseness refer to combinations of harmonic and inhormonic composites of sound resulting from the way the laryngeal valve with its vibrating structures behavior. Seth and Guthrie (1935) state that the hoarseness is tonal quality produced when the vocal folds vibrate in an aperiodic, irregular or hapazard manner.

Acoustically, the hoarse voice may be said to be a combination of breathy and harsh voice quality disorders.

while reports in the literature continue to refer various dysphonias with interchangeable and at times contradictory perceptual terminology. Attempts have been made to reduce this confusion by seeking quantitative measurement of dysphonia to accompany qualitative judgement.

It is apparent that hoarseness is a complex concept and probably not fully accountable on any one perceptual dimension. That is, a voice is hoarse evokes differing perceptual constructs from the listners. Those may be psychological (strain-stangled voice), acoustic (shrill voice), anatomic (massive vocal folds), or physiologic (incomplete cord closure). It is possible that listeners are responding upon the type and severity of voice disorders.

Acoustic analysis of hoarseness especially breathy voice reveals a high frequency component which is supposed to originate at the glottis when the glottis is not completely closed, air flow through the glottal chink becomes turbulent when the speed of the air flow exceeds a certain value. The relation between the intensity of noise and the air flow also depends on the shape of structure where the noise is produced. (Isshiki, 1978).

Permanent objective evaluation of vocal changes associated with or without laryngeal pathologies is a goal which has been difficult for laryngologist and speech pathologist to attain. Most attempts at achieving objective records are focused on direct visual examination of the larynx, using techniques such as high speed photography, X-ray studies, etc.

Clinical modifications in voice spectrographic analysis have allowed adequate visualization of these components. Once these patterns are formalized, they can be applied to a variety of clinical situations.

Description of voice spectrography:

The voice spectrograph is not a new method of voice analysis. Potter et al first developed this technique at Bell Telephone Laboratories in 1940's. Spectrography has been a useful tool in voice research since its first development. It differs from visible speech translator in that an actual graphic analysis of speech pattern rather than a display in a cathode ray tube is produced. The graphic display is known as a spectrogram.

Sound spectrography, through a series of filters, present a picture of intensity, frequency and duration characteristics of the voice. These characteristics are translated into an electrical impulse represented by an electrical stylus which prints out the pattern on a rotating paper graph. Either steady state vowels such as /a/ or /i/ or spoken words and sentences can be evaluated by this technique. Depending on the information desired, a number of different patterns can be elucidated. A trained individual may then "read" the spectrograms produced and view the phonatory, articulatory and resonance qualities of the human voice.

Periodicity of vocal cord movement is a measure of regularity of the opening and closing of the vocal cords. It is translated on spectrogram as vertical straiations.

The synchronous, periodic opening and closing of the vocal cords in a normal voice will produce a corresponding regularity in the vertical straiations seen. While periodicity is measured by the pattern of individual vertical striations, certain pitch characteristics of the voice can be observed in the closeness of the vertical straiations on the spectrogram.

The spectrogram also measures the formant of the normal voice. These formants are the horizontal bars represented as the darker bands on the spectrogram. These bars or formants relate to the size and shape of resonating cavities of the vocal tract. Formants will shift the position during connected speech and with each sound being produced. On spectrogram clear/and adequate formant structure is dependent upon a good resonating system and a lack of breathyness, as well as normal periodicity of vocal cord movement.

Sound spectrograph best analyzes steady state vowels for the purpose of evaluation of phonatory characteristics.

Iwata & Von Leden (1970) have discussed the use of spectrograms in the study of laryngeal disease. They suggested that different laryngeal diseases might yield different spectrographic characteristics.

Ishiki (1978) et al have presented a classification system for hoarseness using spectrograms.

Rontol et al (1975) pointed out the usefulness of spectrographic analysis as a clinical tool in evaluation of the voice following paste injection of paralyzed vocal cords. Inspite of these contributions, few laryngologists or speech pathologists are utilizing this important, objective method of voice analysis.

Acoustic analysis and synthesis by sound spectrography suggests that acoustic properties of hoarseness are mainly determined by the interactions of the following three factors: 1) noise components in the main formant of each vowel, 2) high frequency noise components above 3000 Hz and 3) the loss of high frequency hormonic components. These three findings are more pronounced in the vowels /a/, / e / and /i/ than /u/ and / e / . with the progression of severity of hoarseness, these three abnormal patterns become more prominent and exaggerated. On the basis of these findings, a classification of four types of hoarseness was presented by Yanagihara (1967), using sonogram tracings.

Yanagihara (1967 a, 1967 b) conducted the spectrographic analysis of hoarseness and categorized four degrees of hoarseness ranging from slight hoarseness (Type I) to severe hoarseness (Type IV). He has observed the major acoustic factors relating to hoarseness as noise components in the main formant regions of vowels and loss of hormonic components.

Classification of hoarseness suggested by Yanagihara (1967) is as follows:

Type I: The regular hormonic components are mixed with noise component chiefly in the formant region, of vowels.

Type II: The noise components in the second formants of /e / and / i / predominate over the hormonic components and slight additional noise components appear in the high frequency region above 3000 Hz in the vowels / e / & / i /.

Type III: The second formants of / e / and / i / are totally replaced by noise components and additional noise components above 3000 Hz further intensity their energy and expand their range.

Type IV: The second formants of /a/, /e/ and /i/ are replaced by noise components and even the first formants of all vowels often lose their periodic components which are supplemented by noise components. In addition, more intensified high frequency additional noise components are seen.

Liberman (1963) has observed pitch perturbations i.e., the small measurable deviations in successive pitch period and suggested these irregularities might be useful in the detection of laryngeal disease. He also noted that speakers with pathologic larynges had larger pitch perturbations than normals.

Moore (1962, 1968), Moore and Thomson (1965) have filmed the vocal cord vibrations of normal and hoarse individuals. In normals the vibratory pattern is characterized by three phases: (1) opening, (2) closing of the vocal cords and (3) closed during which the air flow is interrupted and subglottal pressure increases. He has discussed that in abnormal cases the vocal cord movement vary at least in five ways.

Iwata and Vonleden (1970) have analyzed the hoarse and normal voice taking contour spectrograms and have recommended spectrographic analysis as an objective measure for the acoustic quality as well as degree of hoarseness.

Cooper (1974) has analyzed spectrographically the vowels /a/, /i/ and /u/ and has observed that in dysphonic patients before therapy, higher pitch is accompanied by less hoarseness and low pitch by more hoarseness.

Vaidyanathan, R. and Oza R.K. (1976) have observed change in hormonic structure and replacement of hormonic structure by noise component in the main formant region are the acoustic characteristic of hoarseness. The presence of noise component was more predominant in low vowel /a/ than in other vowels.

Attempts have been made to note the difference, the mean amplitude difference between consecutive periods, between pathological and normal voices.

Nataraja (1981): Spectrograph of hoarseness and normal indicate that the presence of a periodic vibration of vocal cord, presence of noise components, variation in frequency and amplitude as contributing to the hoarseness of voice.

Thus the review of literature indicates that a periodic vibration of vocal cords leading to presence of noise in higher frequency range and loss of harmonics, rapid change in frequency (Jitter) and amplitude (Shimmer) as related to hoarseness of voice.

However, it is not passible to find a way of defining the perceived abnormalities of quality of voice. The present study is an attempt at correlating the subjective judgement of 'Hoarseness of Voice' and the spectrographic findings, and if possible, to relate the spectrographic findings with pathologies/vocal cord behaviours.

CHAPTER III

METHODOLOGY

This study was conducted in speech lab of the All India Institute of Speech and Hearing.

The study involved 6 parts:

1. Selection of subjects
2. Noise level measurement in test room
3. Recording of voice samples
4. Subjective analysis
5. Validity and reliability checks
6. Spectrographic analysis

Part 1: Selection of subjects

Two groups of subjects were selected for the study.

Group A: This group consisted of cases who were diagnosed as having voice problem particularly exhibiting hoarseness of voice by a speech pathologist.

Thirteen males and four females were present in this group. Male subjects ranged from 20 to 70 years. Four females subjects ranged from 12 to 60 years.

The subjects were from:

1. All India Institute of Speech and Hearing, Mysore
2. P.K. Sanatorium, Mysore
3. K.R. Hospital, Mysore

Brief history of subjects regarding age, sex, onset of problem and diagnosis made by a speech pathologist and otolaryngologist are given in Appendix I.

Group B: This group consisted of five males and four females, who were considered to be normal in terms of voice by the same speech pathologist, who selected the subjects of group A. This group was selected as a representative of normal male subjects ranged from 22 to 30 years, Female subjects ranged from 20 to 22 years.

All the subjects of both group A and group B were examined by otolaryngologist and condition of larynx was specified.

		Group A	Group B
Age range	Male	20-70 years	22-30 years
	Female	12-60 years	20-22 years
Mean Age	Male	44.47 years	24.60 years
	Female	37.33 years	21.00 years
Sex	Male	13	5
	Female	4	4
Total subjects		17	9

Table shows age range, mean age, sex distribution and total subjects of group A and group B.

Part 2: Noise level measurement in the test room

One of the rooms of speech lab was used as test room. The noise level in the room was measured by using a Sound Pressure Level Meter on different days before conducting the experiment. The noise analysis data was as follows:

Filter net work of SPL meter	Readings in dB		
	1	2	3
A	31	27	28
B	34	28	30
C	33	34	29

Instrumentation

Following instruments were used for the experiment:

1. National Panasonic Tape Recorder (Model No. RQ 2157)

2. UHER - SG 631 Logic Tape Recorder

3. The Voice Identification Series - 700 Sound Spectrograph.

Part 3: **Recording of voice samples**

Voice samples were recorded on National Panasonic Tape Recorder (Model No. RQ 2157).

Subjects were seated on a chair and instructed to phonate four vowels /a/, /e/, /i/ and /u/ individually for a period of atleast 5 seconds, approximately, at their comfortable level with no restriction imposed on pitch and loudness. A demonstration was also given. Lip to microphone distance was twelve inches.

Photograph of spectrograph VII - 700 Series

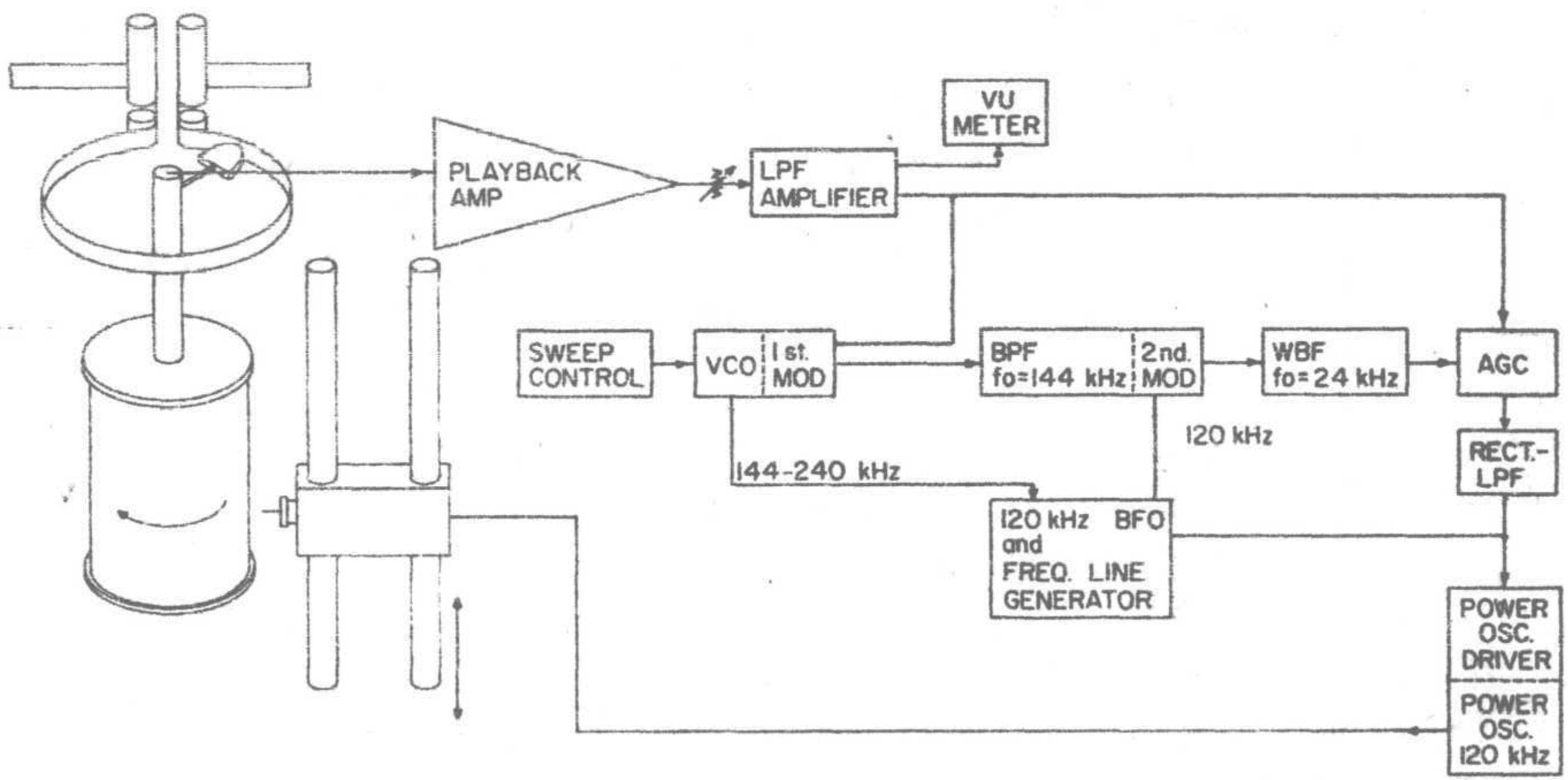
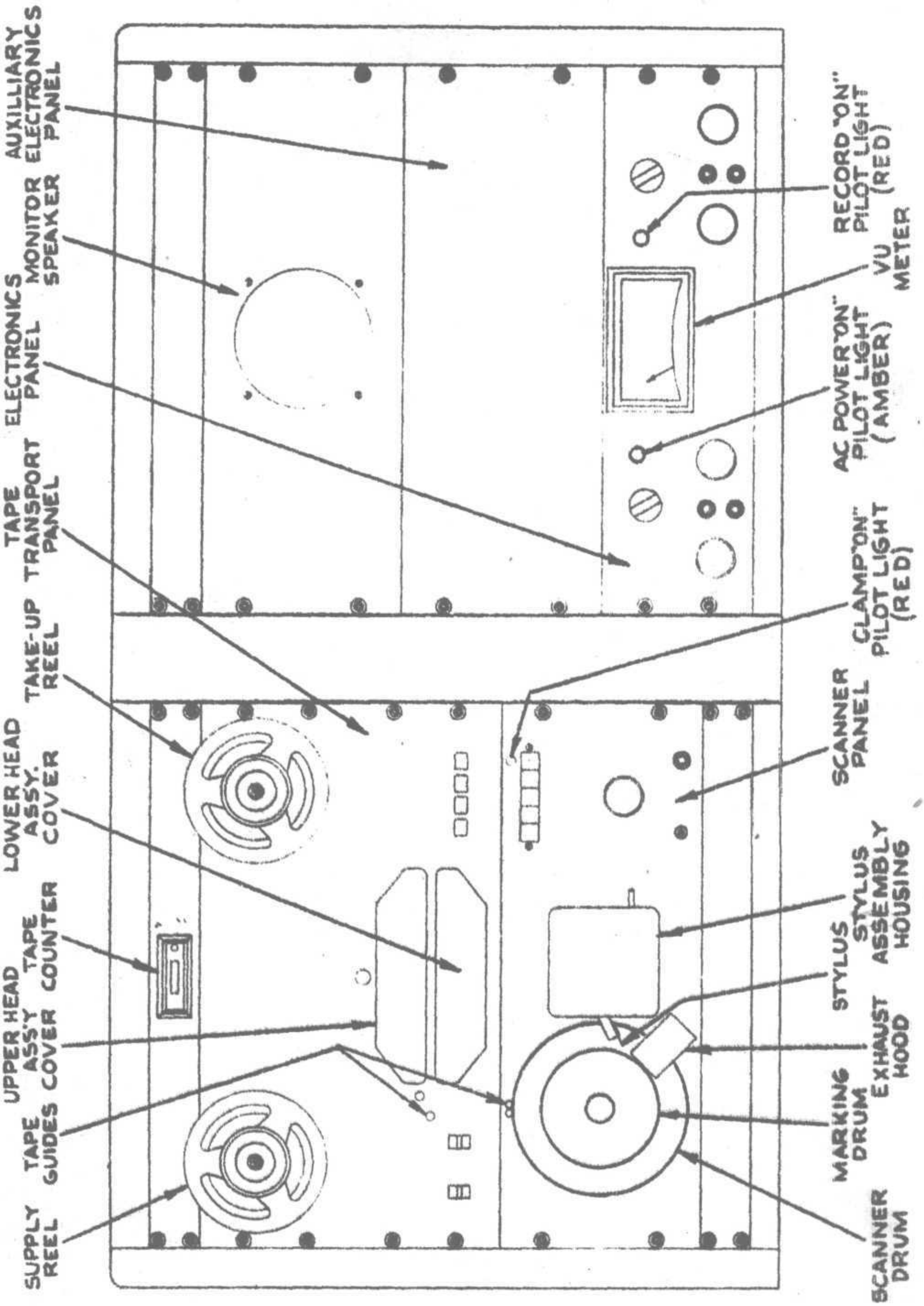


Figure 3. Simplified block diagram of Series 760.

LOCATION OF MAJOR COMPONENTS (FRONT)



LOCATION OF MAJOR COMPONENTS AND PILOT LIGHTS

Line recording technique was used to transfer the voice samples from tape recorder (National Panasonic) to the internal tape recorder of sound spectrograph. Only middle portion of voice sample were taped for the spectrographic analysis. This was done assuming that mid portion would have more stability and consistency in phonation. Duration of each voice sample was approximately of 2.5 seconds.

Part 4: Subjective Analysis

The voice recordings of the subjects of both group A and group B were subjected to perceptual evaluation of degree of hoarseness by five first year M.Sc, students of Speech and Hearing. Instructions to the judges were as follows:

"Now I am going to play voice samples of 26 subjects. Each subject has phonated following vowels: /a/, /e/, /i/ and /u/. You are going to rate the degree ofhoarseness on four point scale, 0 being no hoarseness or normal, 1 being mild hoarseness, 2 being moderate hoarseness and 3 being severe hoarseness.

When atleast three judges among five agreed upon a particular rating then it was considered as rating of that particular voice sample.

Part 5: Validity and reliability checks

In order to assess whether changes occur in perceptual evaluation of degree of hoarseness by the judges, correlation was calculated for each vowel.

After 3 days the sample were presented to three of the five judges without informing that the same sample is being played and they were asked to rate the voice samples.

Again the same sample were presented to the five judges to rate the degree of hoarseness. This time judges were informed regarding age, onset of problem and otolaryngologist diagnosis. This was done to see that whether the judgement varies with and without description of the case.

Part 6: Spectroqraphic Analysis

Stage 1: Middle portion of each voice sample having a duration of approximately 2.5 seconds segment of magnetic tape was positioned on scanning drum. Spectrograph was set to obtain wideband linear bar spectrograms. Spectrograph scanning range was from 50 Hz to 8 KHz. Thus 104 spectrographs were obtained for each vowel of all the subjects of group A and group B.

Stage 2: Using pitch analyzer, an optional part of spectrograph, changes in frequency over time and average fundamental frequency in each voice sample was noted by feeding the taped voice samples of all the subjects by playing the tape at slow scan. Table showing frequency variation is given in Appendix III.

CHAPTER IV

RESULTS AND DISCUSSION

Subjective analysis

In this experiment five judges (First year Master Degree students in Speech and Hearing) judged the 104 samples of 26 subjects of group A and group B, consisting of dysphonics and normals using a four point scale. The score given by at least three judges for a particular voice sample was considered to be rating of that particular voice sample.

Table I shows the 1st, 2nd and 3rd sets of ratings of voice samples as given by judges.

The inspection of Table I indicates that the judges were able to distinguish between dysphonic and normal voice samples. However, voice samples of a normal subject have been rated as '1' being mild hoarseness. Similarly dysphonic voice samples have been rated as 'O', being no hoarseness. Thus it is possible that some times a mild hoarseness (as judged by the Speech Pathologists and the

Table I showing 3 sets of ratings of voice samples of both the group A and group B

Subjects	vowels											
	1st set				2nd set				3rd set			
	a	e	i	u	a	e	i	u	a	e	i	u
1	1	1	1	2	1	1	1	2	1	1	1	1
2	2	2	1	1	2	2	2	2	2	2	2	2
3	1	1	1	1	1	1	1	1	1	1	1	1
4	2	2	2	2	2	2	2	2	2	1	1	2
5	3	2	2	1	2	1	1	0	2	1	1	0
6	3	3	3	3	3	3	3	3	3	3	3	3
7	1	1	1	1	1	1	1	1	1	1	1	1
8	2	2	1	1	2	2	2	1	2	2	1	0
9	3	3	3	3	3	3	3	3	3	3	3	3
10	2	2	2	2	3	3	2	2	3	3	3	2
11	2	2	2	2	2	2	2	2	2	2	2	2
12	1	1	1	1	1	1	1	1	1	1	1	1
13	3	3	3	3	3	3	3	3	3	3	3	3
14	2	2	2	2	1	2	1	2	2	2	2	2
15	2	2	2	2	2	2	2	2	2	2	2	2
16	2	2	1	1	2	2	2	1	2	2	1	1
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	1	1	1	1	0	1	1	1
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	1	0	0	0	1	1	0	0
21	1	1	0	0	1	1	1	1	1	1	0	0
22	0	0	0	O	0	0	0	O	0	O	0	0
23	0	0	0	0	0	0	0	0	0	1	1	0
24	1	1	1	1	1	1	1	1	1	1	1	1
25	0	O	0	0	0	0	0	0	0	0	C	0
26	0	0	0	0	0	0	0	0	0	0	0	0

	a	e	i	u	a	e	i	u	a	e	i	u
1	3	3	2	3	2	3	2	2	3	3	2	3
2	1	1	1	1	2	3	2	3	2	2	1	2
3	2	1	1	2	2	2	2	2	2	2	2	2
4	3	3	2	3	2	3	2	2	2	3	2	3
5	1	i	2	1	C	1	1	1	0	1	1	0
6	3	3	3	3	3	3	3	3	3	3	3	3
7	1	1	1	1	1	1	1	1	1	1	1	1
8	O	0	C	1	1	1	0	1	2	1	1	1
9	3	3	3	3	3	3	3	3	3	3	3	3
10	2	3	2	3	3	3	2	3	3	3	3	3
11	2	2	2	2	3	2	3	3	3	3	2	2
12	1	1	1	1	1	1	1	1	1	2	2	1
13	2	3	3	3	3	3	3	2	3	2	2	3
14	1	1	0	1	1	2	1	2	2	3	2	3
15	2	2	2	3	2	1	2	1	2	2	2	2
16	2	2	1	2	1	2	1	1	2	2	2	2
17	0	C	0	0	0	1	1	1	0	1	1	1
18	0	0	0	0	0	0	O	0	0	0	0	0
19	0	1	0	1	0	0	0	0	0	1	0	0
20	0	0	0	0	1	0	0	0	1	1	0	0
21	0	0	0	0	1	0	0	1	0	1	0	0
22	0	0	0	0	0	C	0	0	0	0	0	O
23	0	1	1	0	0	0	0	0	1	0	0	0
24	0	0	0	1	0	0	0	0	0	0	0	0
25	0	0	0	O	0	0	O	0	0	0	0	0
26	0	0	1	1	0	0	0	0	1	0	0	0

	a	e	i	u	a	e	i	u	a	e	i	u
1	2	2	1	2	1	1	1	1	2	2	2	2
2	3	3	2	2	0	1	0	1	2	2	1	1
3	0	0	0	0	1	2	2	2	1	1	1	1
4	1	1	1	1	1	2	2	2	1	2	1	2
5	0	0	0	0	0	0	0	0	0	0	0	1
6	3	3	3	3	3	3	3	3	3	3	3	3
7	1	1	1	0	1	2	2	1	1	1	2	1
8	0	0	0	0	1	1	0	1	1	0	0	1
9	3	3	3	3	3	3	3	3	3	3	3	3
10	3	3	3	3	3	3	2	2	3	3	3	3
11	1	1	2	2	2	2	2	1	2	2	2	2
12	0	0	1	1	0	1	1	2	1	1	2	2
13	2	3	2	2	3	3	3	3	3	3	3	2
14	0	0	0	0	0	1	1	1	0	0	1	0
15	0	0	0	0	0	0	1	1	1	1	1	1
16	2	2	1	1	0	1	0	1	2	2	1	2
17	0	0	0	0	0	0	0	0	0	0	1	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	1
20	1	0	0	0	1	0	0	0	1	1	0	0
21	1	1	0	0	1	1	0	0	0	1	0	0
22	0	0	0	0	0	1	1	1	0	0	0	0
23	1	0	0	1	0	1	1	0	0	0	0	1
24	1	1	1	0	0	0	0	0	1	1	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	1	2	0	0	1	1	0	0	0	0

	a	e	i	u	a	e	i	u	a	e	i	u
1	2	2	1	1					2	2	2	1
2	3	3	2	2					3	2	2	2
3	0	O	0	0					1	1	1	1
4	2	2	2	2					2	2	2	1
5	2	2	1	1					3	2	1	1
6	3	3	3	3					3	3	3	3
7	1	1	1	1					1	1	1	1
8	1	1	1	1					2	2	2	1
9	3	3	3	3					3	3	3	3
10	1	1	0	2					2	2	1	1
11	2	2	2	2					2	2	2	1
12	1	1	0	0					1	1	2	1
13	2	3	2	2					2	3	3	3
14	1	2	2	2					1	2	2	2
15	2	2	2	2					2	3	3	3
16	2	2	1	1					2	2	2	1
17	0	0	0	0					0	1	0	0
18	1	0	0	0					1	0	1	0
19	C	0	O	0					0	0	0	0
20	0	0	C	0					1	0	0	0
21	1	1	1	0					0	0	0	0
22	0	0	0	0					1	1	0	0
23	1	1	1	1					1	1	0	0
24	2	0	2	0					1	1	1	0
25	0	0	0	0					0	0	0	0
26	0	0	0	0					1	0	0	0

	a	e	i	u	a	e	i	u	a	e	i	u
1	2	2	1	1					2	2	2	2
2	3	3	2	2					2	2	2	1
3	1	1	1	2					1	1	1	1
4	2	2	1	1					2	2	1	1
5	1	1	1	0					1	1	1	0
6	3	3	3	3					3	3	3	3
7	2	2	1	1					2	2	2	1
8	0	1	0	0					1	1	0	0
9	3	3	3	3					3	3	3	3
10	3	3	2	2					2	2	2	1
11	3	2	2	2					2	2	1	2
12	2	1	2	2					1	2	1	1
13	3	3	2	3					3	3	3	3
14	2	2	1	2					1	2	2	1
15	2	2	2	2					1	2	2	2
16	3	3	1	1					2	2	1	1
17	0	1	0	0					1	0	0	0
18	0	0	0	0					0	0	0	0
19	1	0	0	0					1	0	0	0
20	0	0	0	0					0	1	0	0
21	0	0	0	0					0	0	0	0
22	0	0	0	0					1	1	0	0
23	0	1	0	0					0	0	1	0
24	0	1	1	1					1	1	0	0
25	0	0	0	0					0	0	0	0
26	0	0	0	0					0	0	0	0

experimenter) may be considered as no hoarseness and no hoarseness may be considered as mild hoarseness.

This variation in the judgement may be due to definitions that are being used by the judges and the experimenter. This is further confirmed when the data is obtained by not giving brief history of subjects and by giving history of subjects. That is the judges have rated voice samples of one dysphonic (Subject 17 of group A) as no hoarseness even though they had been given brief history of this case. This case had acute laryngitis. Similarly they had judged a subject's (Group B) voice samples as mild hoarseness even though they were told that subject had no vocal pathology nor abnormal voice as judged by the experimenter. Thus the perception of voice quality varies with the definition used by the listner which in turn depends upon his background, experience and many other factors (Van Riper and Irwin, 1978). However, it can be stated that the judges were able to distinguish between the hoarseness and no hoarseness conditions. Thus the judgement made by these judges can be considered as valid. Further inter-judge reliability of ratings made by the judges were determined.

The ratings of hoarseness of all the voice samples were taken three times with an interval of three days between 1st and 2nd set of ratings and of 24 hours between 2nd and 3rd set of ratings. The first two ratings were done without providing brief history and diagnosis of each subject. Before 3rd rating session, the judges were given brief history and diagnosis of each subject. This was done to find out reliability and also to observe the effect of knowledge of history on ratings of hoarseness.

The Table II shows the percentage of agreement between first two sets of ratings (without providing brief history and the diagnosis of each subject). Inspection of this table reveals that the judgements were highly reliable, except for one judge who has shown a reliability below 50% of the times. However, further comparison of judgements set 1 and set 3 which is shown in table III indicates that all the judges had made reliable judgement. That is the judges had assigned the same number as in the 1st session for more than 50% of the samples in the 3rd session also. Thus it can be considered that the judgements made were reliable, even after providing interval between the judgement sessions.

Table II shows the percentage of agreement between first two sets of ratings (without providing brief history and the diagnosis of each subject

Vowels	1	2	3
a	84	56	76
e	92	72	48
i	76	76	52
u	88	52	44

Table III showing the percentage of agreement between the 1st and 3rd set of ratings (In first set of rating brief history regarding the subjects was not given to the judges. In 3rd set of ratings judges were provided with brief history of each subjects)

	Judges				
Vowels	1	2	3	4	5
a	92	72	60	60	64
e	80	68	64	72	76
i	80	52	60	80	60
u	84	72	68	76	64

It is stated in the literature that very rarely one can find the judges who can reliably assign the same ratings in terms of quality to the same voice samples at different times. However, in this study, the judges have been found to be reliable. This may be because of their training.

Further analysis was done to find out the relationship between the vowel type and perceived degree of hoarseness. That is to test the hypothesis 1 that there is no difference in the perception of degree of hoarseness in different vowels.

The Table IV indicates the ratings of the judges for different voice samples of subjects of group A.

On comparison of means of ratings of different vowels, it can be said that the hoarseness in vowel /e/ has been rated as severe than in vowel /a/. Thus the sub-hypothesis (i) that there is no difference in the degree of perceived hoarseness between vowel /a/ and /e/ is rejected.

Hoarseness in vowel /i/ has been found to be less severe when compared to vowel /a/. Thus sub-hypothesis (ii)

Table IV showing the ratings of judges for different voice samples of subjects of group A

Subjects	Vowels			
	a	e	i	u
1	2	2	1	2
2	3	3	2	2
3	1	1	1	2
4	2	2	2	2
5	2	2	1	2
6	3	3	3	3
7	1	1	1	1
8	0	1	0	1
9	3	3	3	3
10	3	3	2	2
11	2	2	2	2
12	1	1	1	1
13	2	3	2	3
14	1	2	1	2
15	2	2	2	2
16	2	2	1	1
17	0	0	0	O
Total ratings	30	33	25	31

that there is no difference in the degree of perceived hoarseness between vowel /a/ and vowel /i/ has been rejected.

Vowel /u/ has been rated as having greater hoarseness than vowel /a/. Thus sub-hypothesis (iii), that there is no difference in the degree of perceived hoarseness between vowel /a/ and vowel /u/ has been rejected.

To test sub-hypothesis (iv) that there is no difference in the degree of perceived hoarseness between vowel /e/ and vowel /i/, the means of the ratings of these two vowels were compared. Vowel /e/ has been rated higher than the vowel /i/. Thus sub-hypothesis (iv) is rejected.

Sub-hypothesis (v) that there is no difference in degree of perceived hoarseness between vowel /e/ and vowel /u/ is rejected as there is no difference in the ratings of vowel /e/ and vowel /u/. That is, vowel /u/ has been rated as having less hoarseness when compared to vowel /e/.

The comparison of ratings of vowel /i/ and vowel /u/ reveals that vowel /u/ has been rated as higher than vowel

/i/, indicating that vowel /u/ was perceived as more hoarse than vowel /i/, thus hypothesis (vi) is rejected.

Thus, the main hypothesis that there is no difference in the perception of degree of hoarseness of different vowels, has been rejected. Thus the degree of perceived hoarseness seems to vary with the vowel /e/, being perceived as having greater hoarseness than vowel /u/, vowel /u/ was perceived greater hoarseness than vowel /a/, vowel /a/ was perceived more hoarseness than vowel /i/. However, Vaidyanathan, R. and Oza, R.K. (1976) have observed presence of noise component was more predominant in low vowel /a/ than in other vowels, which differs from the findings of the present study.

Analysis of spectrographs

Group 'B'

The spectrographic analysis of this group revealed the regular vertical striations which represent regular normal glottal cycle in all the vowels. It also reveals the hormonic components with concentration of energy at or around 1 KHz indicating the occurance of vocal tract transfer function.

Group 'A'

Spectrographs of all the subjects of this group were categorized into four groups, such as, severe hoarseness, moderate hoarseness, mild hoarseness and no hoarseness, depending on the ratings given by the judges. Later, each category of spectrographs were inspected for the corresponding changes in the spectrograph.

Judges rated the subjects of 2, 6, 9, 10 and 13 of this group as '3' indicating severe degree of hoarseness.

On inspection of these subjects, spectrographs showed following findings.

Majority of the spectrographs of these five subjects showed the following findings:

1. Total irregularity in vertical striations;

2. random markings of vertical striations, i.e., intermittent vocal cord vibration is indicated;

3. absence of hormonic components;

4. presence of noise components by irregular patches

of marking at higher frequencies. It is observed upto 3 KHz.

The following subjects 1, 4, 5, 11, 14, 15 and 16 were rated as '2' representing moderate hoarseness by the judges.

When the spectrographs of voice samples of these were examined, most of them were revealed following factors:

1. Slight irregular striations;

2. additional noise components in the fundamental frequency region;

3. absence of higher hormonics, i.e., above 3 KHz.

Subjects 3, 7, 8 and 12 of group A were rated as '1' being mild hoarseness. Findings of spectrograph of voice samples of the above subjects showed:

1. No irregular vertical striations;

2. presence of noise component represented by patches around 2 KHz.

Subject 17 was rated as '0' being no hoarseness by judges. The spectrograph of voice samples of this subject on inspection, revealed:

1. Regular vertical striations;

2. presence of hormonics; and

3. in vowel /e/, slight noise component was present in the hormonics.

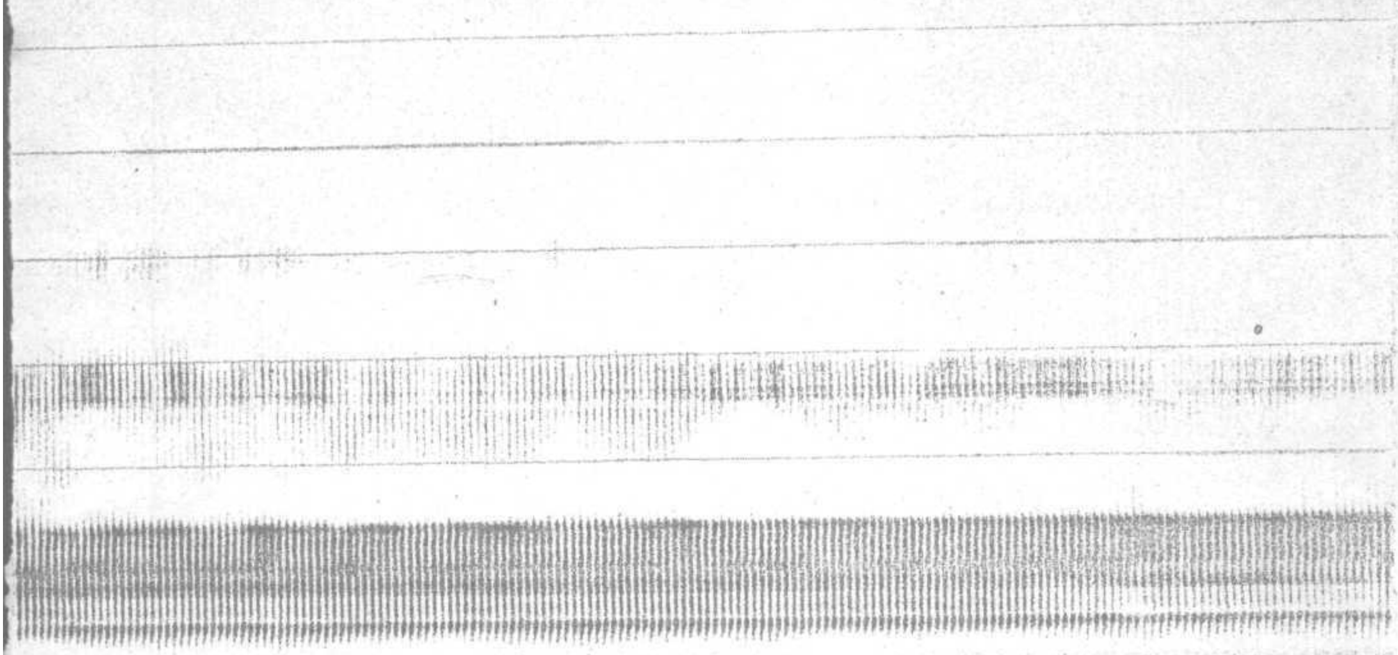
As stated earlier while discussing the spectrographic analysis of normal voice samples (group B) the vertical striations presence of hormonics indicate the presence of normal glottal cycle or normal vocal cord vibrations.

The irregular vertical striations, indicate the aperiodic vibrations of vocal cords. The absence of hormonics and additional noise components in different frequency regions are indicative of incomplete closure of the glottis and thus the escape of air through the glottis. The intensity of noise components vary with the sub-glottal air pressure and the air flow rate and the glottal area.

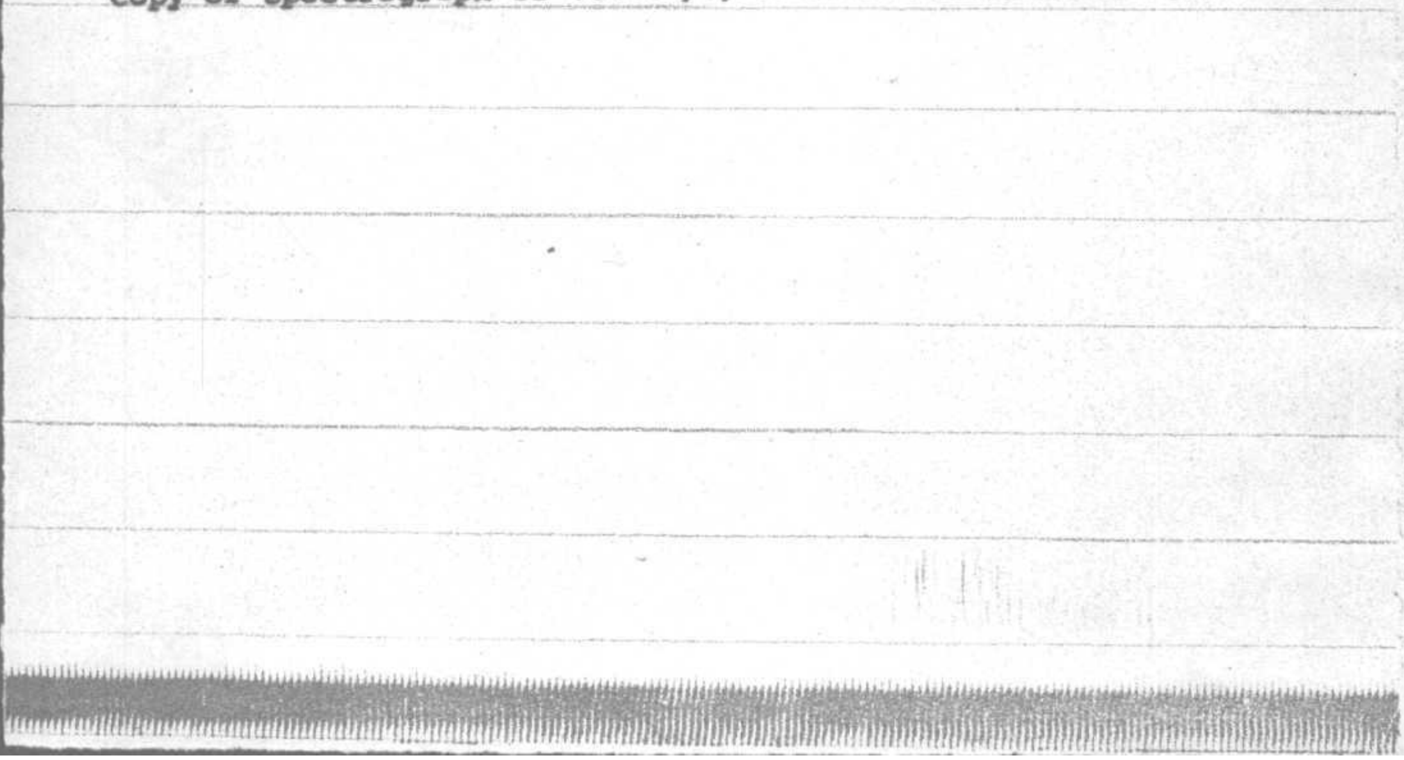
Thus it is possible to categorise the spectrographs

Copy of spectrograph of vowel /a/ - (no hoarseness)

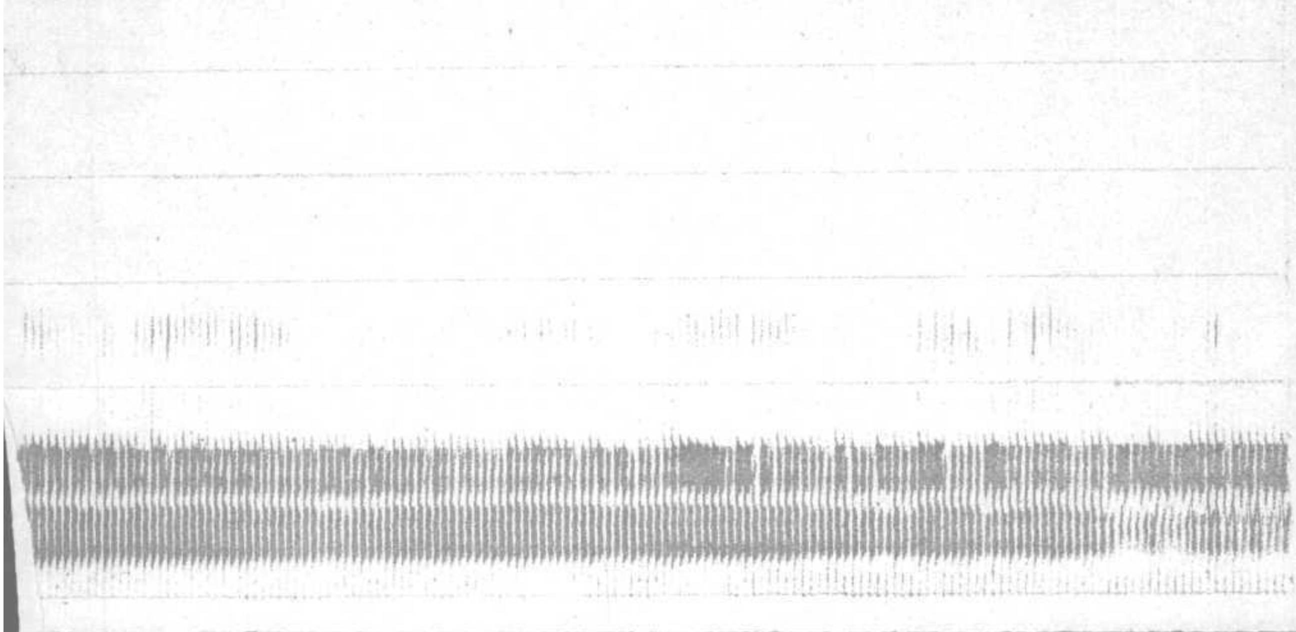
Copy of spectrograph of vowel /a/ - (no hearseness)



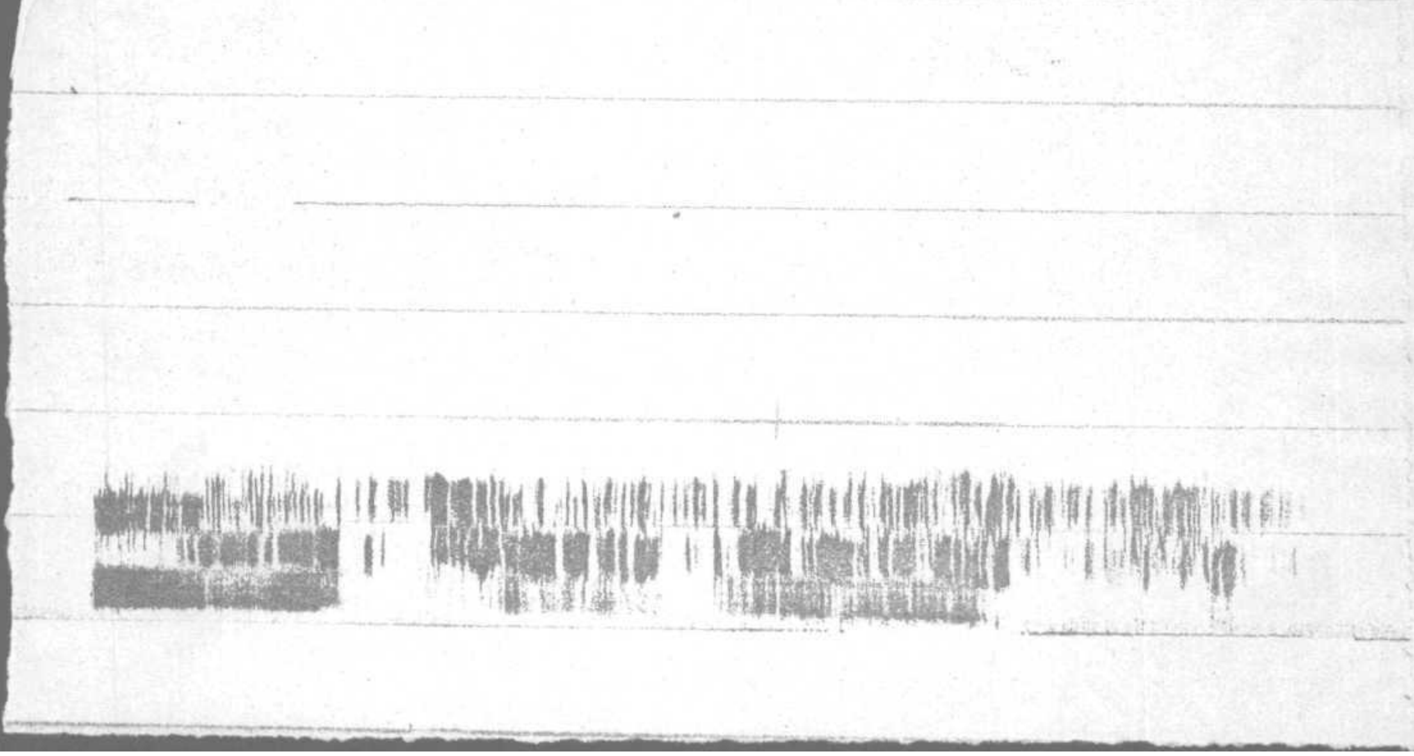
Copy of spectrograph of vowel /u/ - (mild hoarseness)



Copy of spectrograph of vowel /a/ - (moderate hoarseness)



Copy of spectrograph of vowel /a/ - (severe hoarseness)



of varying degree of hoarseness in general. However it was not possible to draw a clear cut boundary between the different categories. It was difficult to categorize spectrograph as belonging to group 1 or group 2 or between group 2 and group 3.

Therefore, the hypothesis 2, that there is no difference in the spectrographs of different degree of hoarseness has been rejected. That is, the spectrographs of different degree of hoarseness do differ from each other and difference depends upon the degree of hoarseness. It was possible to find a common pattern among these spectrographs which were categorized based on subjective judgement. In spite of these common pattern it was difficult to categorize some of the spectrographs. Thus it may be appropriate to view the results of spectrographic analysis as a continuum representing varying degree of hoarseness ranging from no hoarseness to severe hoarseness in lieu of categorizing them as discrete groups like mild, moderate and severe hoarseness or Type I, Type II, Type III and Type IV as proposed by Yanagihara (1967).

The findings of present study are similar to the findings of Yanagihara (1967), who has given the classification of hoarseness, as follows:

Type I: The regular hormonic components are mixed with noise component chiefly in the formant region of vowels.

Type II: The noise components in the second formants of /e/ and /i/ predominate over the hormonic components and slight additional noise components appear in the high frequency region above 3000 Hz in the vowels /e/ and /i/.

Type III: The second formants of /e/ and /i/ vowels are totally replaced by noise components and additional noise components and additional noise components above 3000 Hz further intensify their energy and expand their range.

Type IV: The second formants of vowels /a/, /e/ and /i/ are replaced by noise components and even the first formants of all vowels often lose their periodic components which are supplimented by noise components. In addition, more intensified high frequency additional noise components are seen.

Further, Vaidyanathan, R and Oza R.K. (1976) have observed change in hormonic structure and replacement of hormonic structure by noise component in the main formant region are the acoustic characteristics of hoarseness. The presence of noise component was predominant in low vowel /a/ than in other vowels.

Thus it may be concluded that it would be possible to determine the degree of hoarseness based on 1) irregular vertical striations, 2) absence of hormonics and 3) presence of additional noise components in different frequency ranges. These factors may vary depending upon the vocal pathology, the vocal habits and the compensatory mechanism that have been used by an individual.

Hence it becomes necessary to examine each spectrographs based on all these factors, to determine the degree of hoarseness, instead of categorizing them into distinct groups.

In addition to spectrographic analysis frequency variation were noted using pitch analyzer, an optional part of the spectrograph instrument and it was compared.

Table V shows fundamental frequency variation observed in different vowels of different groups of subjects as rated by judges.

It reveals that frequency variation was 3 to 84 Hz in severe hoarseness group. In moderate hoarseness group, frequency variation was 1 to 17 Hz, where as in mild hoarseness group showed 3 to 12 Hz and no hoarseness group revealed 1 to 14 Hz frequency variation. Though much frequency variation was not observed in the groups of no hoarseness and mild hoarseness, the frequency variation was more in the group of severe hoarseness, and some variations were observed in moderate group. Thus, the hypothesis 3 is partly rejected and partly accepted. That is, no difference was observed between no hoarseness and mild hoarseness groups in terms of frequency variations. Where as in the groups of mod. hoarseness and severe hoarseness showed the difference, when compared with no hoarseness and mild hoarseness groups. So, frequency variation could be one of the contributing factors to the hoarseness of voice. The findings of this study are similar to the reports made by Yanagihara (1967 a, 1967 b), Liberman (1963), Iwata and Vonleden (1970) and Nataraja (1981). This variation indicates the inability of the individual to control the vocal

Table V showing fundamental frequency variations of different groups of hoarseness.

No hoarseness group

Subjects	Vowels			
	a	e	i	u
17	4	0	1	3
18	5	4	5	1
19	5	5	10	9
20	10	14	9	5
21	12	8	11	4
22	8	9	7	7
23	5	2	2	4
24	3	5	2	1
25	4	1	8	4
26	6	5	4	6

Mild hoarseness group

3	3	9	8	5
7	9	9	4	6
8	11	10	8	5
12	6	4	11	12

Moderate hoarseness group

Subjects	Vowels			
	a	e	i	u
1	5	5	3	7
4	10	5	5	6
5	10	7	3	1
11	5	6	17	7
14	7	5	2	9
15	6	5	10	7
16	12	11	11	10

Severe hoarseness group

2	3	9	8	5
6	35	30	17	84
9	21	13	17	24
10	6	7	4	17
13	10	10	7	18

Frequency in Hz.

cord vibration, because of changes in the larynx.

Thus, the results of the present study shows that the irregular vertical striations, absence of hormonics and presence of noise components in the higher frequency range, i.e., the spectrographs and the variation in fundamental frequency in a single phonation are indicators of hoarseness. Physiologically these are related to a periodic vibration of vocal cords, in complete glottal closure and irregular vibrations of vocal cords.

Hence, it would be possible to describe the qualities more objectively using spectrographic analysis. It is recommended that the spectrographic analysis is used to describe other kinds of quality deviation rather than describing them using subjective terms.

CHAPTER V

SUMMARY AND CONCLUSIONS

There is no satisfactory definition for the term hoarseness. Acoustically hoarseness has been said to be a combination of breathy and harsh voice. It is apparent that hoarseness is a complex concept and probably not fully accountable on any one perceptual dimension.

Hence this study was an attempt to reduce the confusion involved in the term "hoarseness" by seeking quantitative measurement of hoarseness of voice.

The following hypotheses were proposed:

1. There is no difference in the degree of perception of hoarseness of different vowels.

2. There is no difference in the spectrographs of different degree of hoarseness.

3. There is no difference in fundamental frequency variation with varying degrees of hoarseness.

To test the hypotheses, 17 hoarse voice subjects and 9 normals were selected and their voice samples consisted of four vowels such as /a/, /e/, /i/ and /u/. Voice samples were analyzed subjectively and spectrographically.

From the results of the present study, the following conclusions have been drawn:

1. The vowel /e/ being perceived as having greater hoarseness than vowel /u/, vowel /u/ was perceived greater/ hoarseness than vowel /a/ was perceived more hoarseness than vowel /i/.

2. The spectrographs of different degrees of hoarseness do differ from each other and difference depends upon the degree of hoarseness. It was possible to find a common pattern among these spectrographs which were categorized based upon subjective judgement. In spite of these common pattern, it was difficult to categorize some of the spectrographs. Thus it may be appropriate to view the results of spectrographic analysis as a continuum representing varying degree of hoarseness ranging from no hoarseness to severe hoarseness in lieu of categorizing them as discrete groups like mild, moderate and severe hoarseness.

3. No difference was observed between no hoarseness

group in terms of fundamental frequency variation. Where as in the groups of moderate hoarseness and severe hoarseness showed more fundamental frequency variations.

Further recommendations

1. To conduct the similar study on large population with varied pathological conditions of larynx.

2. The other parameters like optimum frequency, amplitude variation in hoarse voice subjects, may be studied,

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APPENDIX I

BRIEF HISTORY OF SUBJECTS

<u>Group 'A'</u>

Subject 1: Name: M.N. Age: 21 years

Sex: Male

Onset of problem: Since one month

Diagnosis:

a) Otolaryngologist : Hoarseness due to pulmonary tuberculosis and chronic laryngitis

b) Speech Pathologist: Hoarse voice.

Subject 2: Name: N Age: 45 years

Sex: Male

Onset of problem: Since 20 days

Diagnosis:

a) Otolaryngologist : Chronic laryngitis

b) Speech Pathologist: Hoarse voice

Subject 3: Name: C Age: 70 years

Sex: Male

Onset of problem: Since 15 days

Diagnosis:

a) Otolaryngologist : Chronic Laryngitis secondary to pulmonary tuberculosis

b) Speech Pathologist: Hoarse voice.

Subject 4: Name: V Age: 45 years

Sex: Male

Onset of problem: Since 6 months

Diagnosis:

a) Otolaryngologist: Chronic laryngitis secondary to pulmonary tuberculosis

b) Speech Pathologist: Hoarse Voice

Subject 5: Name:G. Age: 32 years

Sex: Male

Onset of problem: Since 3 days

Diagnosis:

a) Otolaryngologist: Acute Laryngitis

b) Speech Pathologist: Hoarse Voice

Subject 6: Name: J. Age: 60 years

Sex: Male

Onset of problem: Since one year

Diagnosis:

a) Otolaryngologist: Non-specific Laryngitis

b) Speech Pathologist: Hoarse Voice

Subject 7: Name: K. Age: 45 years

Sex: Female

Onset of problem: Since 3 days

a) Otolaryngologist: Acute Pharyngolaryngitis

b) Speech Pathologist: Hoarse voice

Subject 8: Name: L. Age: 62 years

Sex: Male

Onset of problem: Since one year

Diagnosis:

a) Otolaryngologist: Chronic laryngitis secondary to pulmonary tuberculosis
b) Speech Pathologist: Hoarse Voice

Subject 9: Name: P. Age: 65 years

Sex: Male

Onset of problem: Since 6 months

Diagnosis:

a) Otolaryngologist: Right vocal cord polyp

b) Speech Pathologist: Hoarse Voice

Subject l0: Name: P.U. Age: 60 years

Sex: Female

Onset of problem: Since 4 months

Diagnosis:

a) Otolaryngologist: Chronic laryngitis secondary to pulmonary tuberculosis
b) Speech Pathologist: Hoarse Voice

Subject ll: Name: B. Age: 50 years

Sex: Male

Onset of problem: Since one week

Diagnosis:

a) Otolaryngologist: Chronic laryngitis
b) Speech Pathologist: Hoarse Voice

Subject 12: Name: K.B. Age: 30 years

Sex: Male

Onset of problem: Since 5 months

Diagnosis:

a) Otolaryngologist: Chronic laryngitis
b) Speech Pathologist: Hoarse Voice

Subject 13: Name:VK. Age: 23 years

Sex: Male

Onset of problem: Since childhood

Diagnosis:

a) Otolaryngologist: Right vocal cord Paralysis
b) Speech Pathologist: Hoarse Voice

Subject 14: Name: K.M. Age: 26 years

Sex: Male

Onset of problem: Since 6 months

Diagnosis:

a) Otolaryngologist: Fibroma of left vocal cord
b) Speech Pathologist: Hoarse Voice

Subject 15: Name: M Age: 53 years

Sex: Male

Onset of problem: Since 15 years

Diagnosis:

a) Otolaryngologist: Singer's nodule
b) Speech Pathologist: Hoarse Voice

Subject 3: Name: SNS Age: 21 years

Sex: Female

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject 4: Name: A.D. Age: 21 years

Sex: Female

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal voice

Subject 5: Name: A.V. Age: 20 years

Sex: Female

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject 6: Name: G.R. Age: 30 years

Sex: Male

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject 7: Name: S.H. Age: 25 years

Sex: Male

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject 16: Name: K Age: 32 years

Sex: Female

Onset of problem: Since a week

Diagnosis:

a) Otolaryngologist: Acute laryngitis
b) Speech Pathologist:Hoarse Voice

Subject 17: Name: V Age: 12 years

Sex: Female

Onset of problem: Since one month

Diagnosis:

a) Otolaryngologist: Acute laryngitis
b) Speech Pathologist: Hoarse Voice

Group 'B'

Subject 1: Name: V. Age: 24 years

Sex: Male

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject 2: Name: S. Age: 21 years

Sex: Female

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject 3: Name: SNS Age: 21 years

Sex: Female

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject 4: Name: A.D. Age: 21 years

Sex: Female

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject 5: Name: A.V. Age: 20 years

Sex: Female

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject 6: Name: G.R. Age: 30 years

Sex: Male

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject 7: Name: S.H. Age: 25 years

Sex: Male

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject: 8: Name: KCR Age: 22 years

Sex: Male

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

Subject 9: Name: P.J. Age: 22 years

Sex: Male

Diagnosis:

a) Otolaryngologist: NAD
b) Speech Pathologist: Normal Voice

APPENDIX II a

SPECIFICATIONS FOR SERIES 700 SOUND SPECTROGRAPH

SPECTROGRAM PAPER SIZE - 123/4" x 55/8". Display is 41/4" high

ANALYSIS SEGMENT - 2.5 seconds of sound signal is analyzed to 8,000 Hz in 80 seconds, directly from magnetic tape, with no intermediate recording necessary.

TIME AXIS - Horizontal axis represents 2.5 seconds at recording speed of 7.5 ips.

FREQUENCY AXIS - Vertical axis represents 25 to 8,000 Hz with logarithmic scale.

DYNAMIC RANGE - Better than 50 dB

CALIBRATION - internal crystal oscillator provides marks at each 1 KHz point up to 8,000 Hz.

EQUALIZATION - Flat response, optimized for speech. (12 dB/per octave boost between 300 end 3,000 Hz).

TAPE ADVANCE - Automatic. Normally set at 2 seconds for contiguous spectrograms.

DIMENSIONS - 23" high, 44" wide, 16" deep. The weight is approximately 140 lbs. and shipping weight approximately 250 lbs.

POWER SOURCE - 120 volts, 60 Hz A.C. power, 240 volts, 50 Hz on special order. 300 watts nominal input power.

APPENDIX II b

STANDARD FEATURES

1. Direct spectrographic analysis from standard 1/4" polyster recording tape.

2. Standard unit uses a wide band (300 Hz) filter which produces bar type spectrograms, using a logarithmic frequency scale.

3. Automatic clamping and tensioning of tape.

4. Automatic advance of tape segments.

5. Single switch start,plus automatic stop.

6. Crystal controlled frequency markings.

7. Automatic stylus engagement.

8. High fidelity, self-contained tape recorder.

9. All solid state electronics; modular construction.

10. Safety interlocks in all modes of operation (protects tape deck and scanner assembly in case improper mode switches are activated).

11. A VU meter for monitoring playback, marking and record levels.

12. Output jacks are provided for external connection to remote speaker, line output and headset.

13. The basic unit includes a four-digit tape counter,

APPENDIX II c

OPTIONAL FEATURES AVAILABLE

1. Narrow Band Filter (45 Hz; other band widths available)

2. a) Switchable frequency scales for LOG/LINEAR FIXED EXPAND

   b) same as a) but with continuously adjustable LINEAR EXPAND capability

3. Quantizer (for contour display)

4. Signal (Speech) Gate

5. Cross Section Amplitude Display (requires Signal Gate feature)

6. Average Amplitude vs. Time Display

7. Performance Calibrator (includes 100 msec timing markers and 500 HZ & 100 HZ frequency markers

8. Pitch Analyzer with Digital Display

9. Scope output display (for use with Variable Persistance type storage oscilloscopes only.

APPENDIX III

Table showing fundamental frequency variation for different vowels of the subjects of both the group A and group B

Group A

	Subject 1:	Subject 5:
a	115, 119, 120	125, 128, 135
e	109, 110, 114	145, 152
i	125, 128, 128	145, 146, 148
u	124, 127, 131, 128	149, 150
	Subject 2:	**Subject 6:**
a	104, 105, 107	125, 137, 138, 160
e	103, 109, 112	137, 147, 152, 167
i	108, 110, 118, 126	340, 348, 357
u	100, 102, 103, 105	200, 247, 281, 284
	Subject 3:	**Subject 7:**
a	187, 189, 192, 195	205, 207, 214
e	195, 199, 200	226, 228, 237
i	202, 204, 206, 210	228, 230, 232
u	190, 192, 195, 198	252, 256, 258
	Subject 4:	**Subject 8:**
a	130,134, 136, 140	144, 147, 155
e	130, 132,135	135, 139, 141, 145
i	135, 140, 140	140, 143, 148
u	131, 134, 137	130, 132, 135

Appendix III Contd.

Subject: 9

a 167, 168, 181, 188
e 267, 270, 278, 280
i 157, 160, 168, 174
u 164, 177, 180, 188

Subject: 10

a 155, 161, 161
e 180, 183, 184, 187
i 177, 178, 181
u 187, 190, 194

Subject 11:

a 135, 140
e 159, 160, 165
i 151, 152, 154, 156, 158
u 170, 175, 177

Subject 12:

a 175, 180, 181
e 177, 179, 180, 181
i 169, 177, 180
u 181, 183, 183

Subject 13:

a 230, 232, 240
e 225, 230, 235
i 244, 248, 251
u 230, 237, 239, 248

subject 14:

140, 146, 147
155, 156, 158, 160
147, 148, 149
160, 162, 168, 169

Subject 15:

98, 99, 102, 104
110, 111, 114, 115
99, 100, 109
140, 141, 145, 147

Subject 16:

180, 188, 191, 192
201, 202, 205, 212
205, 208, 212, 215, 216
210, 213, 215, 220

Subject 17:

240, 241, 244
248
248, 249
255, 257, 258

Appendix III contd

Group B

Subject 1

a	125, 128, 130
e	127, 130, 131
i	144, 147, 149
u	148, 149

Subject 2

a	245, 246, 250
e	264, 268, 269
i	254, 257, 264
u	281, 287, 290

Subject 3:

a	235, 238, 245
e	230, 238, 244
i	263, 269, 272
u	275, - 282

Subject 4:

a	242, 246, 259
e	248, 249, 256
i	252, 261, 263
u	262, 264, 266

Subject 5:

a	210, 215, 218
e	203, 212
i	211, 217, 218
u	217, 219, 224

Subject 6:

140, 141, 144, 145
144, 144, 146
150, 151, 152
152, 153, 156

Subject 7:

119, 118, 122
124, 125, 129
145, 145, 147

Subject 8:

130, 131, 134, 134
150, 150, 151
149, 152, 157
154, 155, 158

Subject 9:

128, 130, 131, 134
150, 151, 154, 155
160, 161, 164
159, 159, 165

APPENDIX III

Table showing fundamental frequency and frequency variation of different vowels of each subject of group A and group B

Group 'A'

Sub-ject		Fundamental frequency	Frequency variation	Sub-ject		Fundamental frequency	Frequency variation
1	a	118	5		a	129	10
	e	111	5		e	148	7
	i	127	3		i	146	3
	u	128	7		u	150	1
2	a	105	3		a	140	35
	e	108	9		e	151	30
	i	116	8		i	348	17
	u	103	5		u	253	84
3	a	191	8		a	209	9
	e	198	5		e	219	9
	i	206	8		i	230	4
	u	194	8		u	253	6
4	a	135	10	8	a	149	11
	e	132	5		e	140	10
	i	138	5		i	144	8
	u	134	6		u	132	5

Subject		Fundamental frequency	Frequency variation	Subject		Fundamental frequency	Frequency variation
9	a	176	21	13	a	234	10
	e	174	13		e	230	10
	i	165	17		i	248	7
	u	177	24		u	239	18
10	a	158	6	14	a	144	7
	e	184	7		e	152	5
	i	179	4		i	148	2
	u	190	17		u	165	9
11	a	138	5	15	a	101	6
	e	161	6		e	113	5
	i	154	17		i	103	10
	u	174	7		u	143	7
12	a	178	6	16	a	188	12
	e	179	4		e	205	11
	i	175	11		i	214	11
	u	182	2		u	215	10
				17	a	242	4
					e	248	0
					i	249	1
					u	257	3

Group 'B'

Sub-jects		Fundamental frequency	Frequency variation	Sub-jects		Fundamental frequency	Frequency variation
1	a	128	5	6	a	143	5
	e	129	4		e	147	2
	i	146	5		i	151	2
	u	149	1		u	154	4
2	a	247	5	7	a	120	3
	e	267	5		e	126	5
	i	258	10		i	146	2
	u	286	9		u	149	1
3	a	239	10	8	a	132	4
	e	237	14		e	150	1
	i	268	9		i	153	8
	u	279	5		u	157	4
4	a	247	12	9	a	131	6
	e	251	8		e	152	5
	i	259	11		i	162	4
	u	264	4		u	161	6
5	a	214	8				
	e	208	9				
	i	215	7				
	u	220	7				