SUSCEPTIBILITY CRITERIA FOR VOCAL FATIGUE

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MAY 1995

CERTIFICATE

This is to certify that the dissertation entitled "SUSCEPTIBILITY CRITERIA FOR VOCAL FATIGUE" is the bonafide work in partial fulfilment for the final year M.Sc (Speech and Hearing) of the student with Register No. M 9318.

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This to certify that the dissertation entitled "SUSCEPTIBILITY CRITERIA FOR VOCAL FATIGUE" has been prepared under my supervision and guidance.

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DECLARATION

This dissertation is the result of my own study undertaken under the guidance of Dr.N.P.Nataraja, Prof and Head, Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any university for any other Diploma or Degree.

Mysore Reg no. M9318,

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CONTENTS

LIST OF TABLES

LIST OF GRAPHS

INTRODUCTION

Voice is the primary instrument through which most of the people project their personalities and influence compatriots. Voice production involves a complex and precise control by the central nervous system of a sense of events in the peripheral phonatory organs.

There is an ever increasing segment of the population which is dependent on vocal endurance and quality for their livelihoods. They are referred to as professional voice users and comprise of actors, singers, teachers, etc. It is generally observed that most professional voice users neither have awareness of anatomy and physiology of the vocal mechanism nor do they understand vocal hygiene.

Teachers, singers, actors, and other persons who use their voice vocationally often involve in vocal overuse or abuse. They are the high risk groups to develop voice problems i.e., vocational dysphonia (Sapir.S, Attias.J,& Shahar, A.), strenuous vocal activity can lead to mucosal tensions, vocal fatigue, sore throat, dryness, sensation of burning, hoarseness, aphonia, pitch breaks, throat clearing etc.The vocal symptoms mainly seen in professional voice users is vocal fatigue (sataloff 1984).

In our educational set ups the teachers are often the victims of abuse because of their vocally taxing job. They may have to use their voices for long hours, and speak loudly and continuously to overcome poor acoustic conditions. The vocal pathology along with the high level of anxiety associated with it would have potential impact on the person's reputation, ability to make a living. They do affect the physical and psychological health (Cooper 1973, Reich 1986). Abnormal voice in teachers is correlated with negative judgement of personality by children (Blood, Hyman and Mahan 1979).

Since voice plays a major role in speech and hence communication, it needs to be constantly monitored and in the event of abnormal functioning of voice, an immediate assessment should be undertaken which would lead to the diagnosis which not only identifies the voice disorders but also acts as a indicator for the treatment and management to be followed.

There are various means of analyzing voice developed by different workers like acoustic analysis, Psychoacoustic evaluation etc. Hirano(1981) states that Acoustic analysis may be one of the most attractive method of assessing the phonatory function or laryngeal pathology because it is non invasive and provides objective and quantitative data. Presently computer based techniques are being used to extract different parameters of voice to aid in diagnosis of different vocal pathologies.

It has been found that the concept of vocal fatigue and its acoustics correlates is poorly understood due to the limited research . The present study was designed to find the susceptibility criteria for vocal fatigue so that it would be possible for speech clinicians to advice the susceptible clients to take appropriate measures.

NEED FOR THE PRESENT STUDY

1. To understand vocal fatigue in terms of acoustic correlates using multi-dimensional voice analysis.

2. To develop susceptibility criteria for vocal fatigue.

3. To study vocal fatigue in school teachers who constitute the high risk group with reference to voice problems.

In the present study multi-dimensional analysis on voice using MDVP software was done to study vocal fatigue in five normals (4 males, 1 female). 29 acoustic parameters were extracted using vowels /a/,/i/ and /u/ , 3 trials each. There were three set of phonations i.e., prefatigue phonation (PI), phonation after 1/2 hour of reading (P2) and phonation after 1 hour of reading (P3).

A questionnaire was used to collect history of voice problems due to teaching activity in 55 teachers in Mysore city. 10 subjects were selected based on questionnaire responses and categorized into 2 groups. These subjects had to undergo similar task as the normals (group I). The phonations within each group and across groups were compared.

HYPOTHESIS

I a) There is no significant difference between pre-fatigue phonation (PI) , Phonation after 1/2 hour reading (P2) and phonation after 1 hour of reading (P3) in terms of different parameters in normal males and females (groupl)

b) There is no significant difference between prefatigue phonation (PI) and phonation after 1/2 hour of reading (P2) in terms of different parameters in normal males and females.

c) There is no significant difference between prefatigue phonation (PI) and phonation after 1 hour of reading (P3) in terms of different parameters in normal males and females.

d) There is no significant difference between phonation after 1/2 hour of reading (P2). and Phonation after 1 hour of reading (P3).

IIa) There is no significant difference between prefatigue phonation (p1), phonation after 1/2 hour reading (p2) and phonation after 1 hour of reading (p3) in terms of different parameters in male and female teachers with (0-3) current symptoms.

b) There is no significant difference between prefatigue phonation (p1) and phonation after 1/2 hour reading (p2) in terms of different parameters in male and female teachers with (0-3) current symptoms.

c) There is no significant difference between prefatigue phonation (p1) and phonation after 1 hour of reading (p3) in terms of different parameters in male and female teachers with (0-3) current symptoms. .

d) There is no significant difference between phonation after 1/2 hour reading (p2) and phonation after 1 hour of reading (p3) in terms of different parameters in male and female teachers with (0-3) current symptoms.

III a) There is no significant difference between prefatigue phonation (pi), phonation after 1/2 hour reading (p2) and phonation after 1 hour of reading (p3) in terms of different parameters in male and female teachers with (4-8) current symptoms.

b) There is no significant difference between prefatigue phonation (p1) and phonation after 1/2 hour reading (p2) in terms of different parameters in male and female teachers with (4-8) current symptoms.

c) There is no significant difference between prefatigue phonation (p1) and phonation after 1 hour of reading (p3) in terms of different parameters in male and female teachers with (4-8) current symptoms.

d) There is no significant difference between phonation after 1/2 hour reading (p2) and phonation after 1 hour of reading (p3) in terms of different parameters in male and female teachers with (4-8) current symptoms.

IV a) There is no significant difference across normals (group I), group II teachers (0-3 current symptoms) and group III teachers (4-8 current symptoms) in terms of means across the three phonations.

IV b) There is no significant difference across normals (group I), group II teachers (0-3 current symptoms) and group III teachers (4-8 current symptoms) in terms of number of parameters affected across the three phonations.

LIMITATIONS

1. The number of subjects were restricted to five normals and ten teachers.
2. The males and females were not equal in each group.
3. Vocal fatigue was simulated in laboratory conditions.

RECOMMENDATIONS

1. The same study can be carried out in field situation, that is, the voices of teachers before and after the classes can be recorded and analysed for vocal fatigue.

2. Repeated measurements/recordings of the same subject across days would yield better information about vocal fatigue.

3. Vocal fatigue can be studied with a large sample of subjects and with increasing fatiguing durations of 1/2, 1, l1/2hour.

4. Vocal fatigue phenomenon can be studied with sex as a variable.

REVIEW OF LITERATURE

There is nothing more elemental in all existence than communication. In humans we see its ultimate expression in the marvelous vehicle of language (Van Riper & Emerick 1990). The ability of the human beings to use their vocal apparatus with other organs to express their feelings, to describe an event and to establish communication is unique to them. It took millions of years for human beings to develop this faculty. The onset of the human era is recognized to have started with the acquisition of the ability to comnunicate using the vocal apparatus for social interaction. No normal person has failed to develop this faculty and no other species is know to have developed this ability.

Speech is the audible manifestation of language. It is the tool of thought and primary means of communication of human beings. Speech is a complex motor act brought about by sophisticated and fine movements of the components of the vocal tract and their complex interaction with one another. The speech results due to the fine organization, coordination and modulation between the respiratory, phonatory, and articulatory and resonatory systems.

Voice is the vehicle of the speech. It is the musical sound produced by the vibration of the vocal cords in the larynx by air from the lungs. "Voice plays the musical accompaniment to speech rendering it tuneful, pleasing, audible, and coherent being essential to efficient communication by the spoken word" (Green 1964).

Voice is more than a means of communication of verbal messages clearly. Voice constitutes the matrix of verbal communication infusing all parameters of human speech and the unique self one presents to the world. Voice has both linguistic and nonlinguistic functions in any language.

Voicing has been found to be a major 'distinctive' feature in almost all languages. Voicing (presence of voice) provides more phonemes and makes the language broader. When this function is 'absent' or used 'abnormally' it would lead to a speech disorder.

At the semantic level also voice plays an important role. The use of different pitches-high and low with the same string of phonemes would mean different things. Speech prosody - intonation, stress, rhythm of a language is a function of vocal pitch and loudness as well as phonetic duration.

Perkins(1971) has identified at least five nonlinguistic. functions of voice. Voice can reveal speaker identity i.e. voice can give information regarding sex, age, height and weight of the speaker. Lass, Brong, ciccolella, (1980) reported several studies which have shown that it was possible to identify the speaker's age, sex, race, Voice reflects the anatomical and physiological conditions of the respiratory, phonatory and resonatory system, deviations in which may lead to voice disorders.

Thus voice serves numerous and varied linguistic and nonlinguistic functions. As it plays a major role in speech and hence communication, it becomes vital to monitor it constantly and undergo immediate assessment in the event of abnormal functioning of voice.

The term voice has been defined differently by different people. Some definitions of voice restrict the term to the generation of sound at the level of larynx, while others include the influence of the vocal tract upon the generated tone, and still others broaden the definition by including aspects of speech like articulation and prosody.

Fant (1960) defined voice using the formula, P=sxt where 'P' the speech sound is product of the source 'S' and the transfer function of the vocal tract 'T'. Michael and Wendhal (1971) defined voice as the laryngeal modulation of the pulmonary airstream which is then further modified by the configuration of the vocal tract.

Green (1980) states that voice is the result of breath under pressure from lungs causing the approximated vocal cords to perform the rythmic excursion of separation and closure.

socio economic status, racial features, height and weight based on voice.

Several investigators contend that voice reflects the personality of an individual. (Starkweather 1961, Markel, Meisels and Hanck 1964). Fairbanks (1942, 1966) and Huttar (1967) have concluded from their study that voice reflects the emotional status of an individual.

Voice has also been considered to be reflecting the physiological state of an individual. For eg:- a very weak voice may indicate that the individual may not be keeping good health or a denasal voice may indicate that the speaker has common cold.

Infant cry research has yielded valuable data for the early identification of the neurological and other conditions in new born babies (Indira 1982).

Speaker identification by voice would be of immense value in computer technology (development of machines that will respond to spoken commands), Forensic medicine (identification of the speaker by his voice and lie detection) and in defence (availability of classified information).

The quality and efficiency to use the voice optimally may be of utmost importance for certain professionals like T.V/radio announcers, actors, singers and teachers.

A study of various definitions available, indicates that the pulmonary air stream (acting as power supply), the participation of vocal cords (vibration), and the vocal tract transfer function (resonator or modulator), are common among them. Therefore any definition of voice must include these three aspects. Hence for the present purpose the definition given by Micheal and Wendhal (1971) will be used.

Though there are varied definitions of voice it is a difficult task to define normal voice.

Johnson (1956) provides only general standards for normal voice. They are :-

a) Quality must be pleasant. This criterion implies the presence of certain musical quality and the absence of noise or atonality.

b) Pitch level must be adequate. It must be appropriate to the age and sex of the speaker.

c) Loudness must be appropriate. The voice must not be so weak that it cannot be heard under ordinary speaking conditions nor should it be so loud that it calls undesirable attention to itself.

d) Flexibility must be adequate. Flexibility refers to variation in pitch and loudness that aid in the expression of emphasis, meaning indicating the feelings of the individual.

Wilson (1962) is of the opinion that good voice should have the following characteristics.

a) Pleasing voice quality.

b) Proper balance of oral and nasal resonance.

c) Appropriate loudness.

d) A model frequency level suitable for his age and sex.

e) An appropriate voice reflections involving pitch and loudness.

An attempt has been made by Nataraja and Jayaram (1975) to review the definitions of normal voice critically. They conclude that each of the available definitions of voice have used subjective terms, which are neither defined nor measurable. They have suggested a possibility of defining good voice operationally - "The good voice is one which has optimum frequency as its fundamental (habitual) frequency".

Voice production involves a complex and precise control by the central nervous system of a series of events in the peripheral phonatory organs. The crucial event essential for voice production is vibration of the vocal folds. It changes DC air stream to AC air stream converting aerodynamic energy into acoustical energy.

Two broad categories of theories have dominated in dealing with voice production. They are -

Myoelastic Aerodynamic theory (Muller 1843) - Holds that phonation is the result of the balancing of forces of air pressure against the tension, elasticity and mass of the vocal folds. Displaced by the air pressure the vocal folds return to a resting state due to combination of factors, the chief ones being the drop of air pressure at the glottis following the valvular opening and the vocal fold mass and elasticity the function of the vocal fold themselves is in large part passive. As in respiration, the final movements of the vocal folds are not under specific concious control.

Neurochronaxic theory (Husson 1950) holds that vocal fold vibration is an active process. Motor impulses are said to be emitted from cortical centers to the muscles of the folds via the recurrent laryngeal nerves under the regulation of- a "cochlear-recurrential reflex ! vocal fold stimulation of this kind assumes that the recurrent nerve is capable of transmitting high frequency stimuli i.e. of the order of 1,000 impulses per second.

It has been established that coordination between the three systems, the respiratory, the phonatory and the resonatory, are essential for the production of voice. Variations in the conditions of these three systems would be reflected in voice produced.

Professional voice users constitute an ever increasing segment of the population and their need for expert care has inspired new interest in understanding the functions and dysfunctions of the human voice. "Professional voice users are those individuals who are directly dependant on vocal communication for their livelihood." (stemple 1991).

Professional voice users include not only singers and actors but also politicians, educators, telephone receptionists and others. The use of speech for singing, public speaking, theatrical performance etc can be considered as supranormal use of speech.

Kaufman and Isaacson (1991) suggested a "vocal usage" classification system. It comprised of four levels.

LEVEL I is the elite vocal performer i.e. professional singers and actors for whom even slight vocal difficulty may cause serious consequences.

LEVEL II is the professional voice user, for whom even modern vocal difficulty would prevent adequate job performance i.e. clergy, public speakers, lecturers, telephone operators etc.

LEVEL III is the nonvocal professionals. This level is comprised of doctors, lawyers, business persons, sales persons and others who could not perform their work properly if suffering with severe dysphonia. Mild or moderate dysphonia may be inconvenient but would not preclude adequate job performance.

LEVEL IV is the nonvocal professional. This includes factory workers, labourers and clerks who would not be prevented from doing their work if experiencing vocal disability.

Professional voice users neither have awareness of anatomy and physiology of the vocal mechanism nor do they understand the consequence of poor vocal hygiene. Cheer leaders, teachers, Rock singers, actors and other persons who use their voice vocationally often involve in vocal overuse or abuse. They form the high risk group to develop voice problems (Sapir 1991 a).

Voice disorders in professional voice users : causes & symptoms.

In general a voice disorder exists when quality pitch and loudness or flexibility differs from the voices of others of similar age, sex and cultural group.

Aronson (1980) has classified voice disorders as organic and psychogenic or functional type. According to him a voice disorder is organic if it is caused by structural (anatomic) or physiologic disease, either a disease of the larynx itself or remote systemic illnesses which impairs laryngeal structure or function. Psychogenic voice disorders include disorders of quality, pitch, loudness and flexibility caused by psychoneurosis, personality disorders or faulty habits of voice usage.

Sataloff (1991) considers causes of voice disorders in professional voice users as follows:-

1) Misuse and abuse:- Poor singing/speaking techniques, singing out of range, chronic coughing / throat clearing, smoking, poor hydration, overuse of the voice.

2) chronic medical problems:- Esophageal reflux, allergies, sinusitis, upper respiratory tract infection, poor diet, fatigue, illicit drug use. :

3) Environmental factors:- Performing in smoky, dry environment, exhaustive schedules, poor acoustics, loud music.

4) Emotional factors:- stage fright, anxiety, depression, performance stress.

Cooper (1973) has reported a predominance of voice disorders in certain occupations such as teachers, singers, lawyers and theologians. Negative symptoms were mainly due to the misuse of voice.

Vocal misuse and abuse were the predominant causative factors for voice problems in vocations involving high demands on vocal mechanism (Sapir 1992). Cooper (1973) has defined vocal misuse as the use of incorrect pitch, tone focus, quality, volume breath support and rate either discretely or in combinations.

Vocal abuse means the mistreatment of the vocal folds as well as the laryngeal and pharyngeal musculature by shouting, screaming or talking in competition with noise, in talking above under, around or through noise.

Sapir (1992) is of the opinion that excessive use, misuse or abuse of the vocal mechanism alone or in combination with biologic and psychosomatic factors may result in chronic or acute symptoms of vocal attrition (overall reduction in vocal capabilities, wear and tear of the vocal mechanism), such as vocal fatigue, hoarseness, throat discomfort or pain and benign mucosal lesions.

Another problem that is noticed among professional voice user is vocal attrition. It refers to laryngeal tissue pathology, muscle fatigue and voice disorders secondary to acute or chronic abuse or misuse of the vocal mechanism.

Strenuous vocal activity may lead to mucosal lesions, vocal fatigue, sore throat, dryness, sensation of burning, hoarseness, aphonia, pitch breaks, limited phonatory range, low pitch, frequent coughing, throat clearing etc.

It has been reported that the vocal symptom mainly seen in professional voice users as vocal fatigue. It is usually described as a negative sensory vocal symptom that corresponds to a change in vocal quality or a change in vocal response, contrary to an intended and usually quality or response (Sataloff 1984).

Symptoms of vocal fatigue include vocal quality changes (hoarseness, huskiness, register breaks), vocal limitations (loss of range, need to use greater effort, lack of vocal carrying power), deterioration of vocal control (inability to use or maintain intended pitch, unsteadiness of voice, pitch breaks), discomfort (throat and neck pain, pain on swallowing, throat clearing and discomfort in the chest, ear and back of neck) and laryngeal tissue change (inflammation, swelling, bowing) - (Boon 1980, Sataloff 1984). Brodnitz (1954) reported that the common voice problems of the actors and singers were acute laryngitis, polyps, vocal nodules, contact ulcers which were attributed to vocal abuse.

Raphael and Scherer (1986) found that 36 professional actors associated the following symptoms with vocal fatigue - general physical fatigue, throat fatigue, throat tightness or constriction, strained or tense throat, greater awareness of the voice and its mechanism, more difficulty in producing and sustaining the voice, reduction in pitch range and more difficulty in producing higher pitches.

"Singers who are properly trained and who use the techniques of good voice production do not damage the vocal fold" (Greene 1980).

Bunch (1982) opines that an excellent singer may have some vocal strain following lengthy rehearsals or a demanding performance. A tiny vocal fold hemorrhage can occur but will gradually disappear when the exertion is over. However if the voice is poorly produced or excessive effort is being used the longterm result will be damage to laryngeal mucosa and eventually vocal nodules.

"As a group school teachers are considered at risk for vocal attrition and they constitute a significant proportion of patients seeking medical and phoniatric help for voice problems" (Stemple 1991).

Cooper (1973) found a high prevalence of single and multiple symptoms of vocal attrition in classroom teachers.

Bistrizki and Frank (1981) in their study of Israeli female elementary school teachers, compared 37 teachers who had received instructions in vocal hygiene prior to becoming teachers with 40 teachers who had not received such training. The two groups carefully matched, were studied 2-4 years after they had begun teaching of the teachers without vocal training 85% reported vocal fatigue, 80% hoarseness, 70% sore throat and 42% aphonia. The prevalence of these and other symptoms was significantly lower (P<0.0l) in the vocally trained group.

Sapir et al. (1990) are of the opinion that vocal attrition may have a deleterious effect on performance, work efficiency, physical and psychological health.

Sapir (1993) used a survey questionnaire to assess the prevalence and impact of vocal attrition among school teachers. Over half of the teachers reported multiple symptoms of vocal attrition. Over one third of them reported that their voice problems interfered with their ability to teach effectively, nearly one third indicated that they had to miss work because of voice problems, one fifth reported that they sought medical intervention and nearly another one fifth indicated that their voice had ben a source of chronic stress or frustration. There was a high correlation between the number of current symptoms and number of carrier linked symptoms and neither current symptoms nor career linked symptoms correlated with years of teaching, hours of teaching or age.

Heidel et. al (1993) administered a questionnaire to determine the characteristics of vocal problems in 75 female aerobic instructors and 75 aerobic participants (20-40 years of age).Results indicated aerobic instructors generally experienced more hoarseness and episodes of voicelessness during and after instructing and a significantly higher prevalence of nodules than their counterparts in the study.

Sapir (1993) considers that factors such as idiosyncratic dysphonia (life long vocally abusive speech habits associated with one's personality), psychogenic or psychosomatic dysphonia (voice disturbances . induced by stress, anxiety etc) and biogenic dysphonia (voice disturbances associated with mucosal irritation or changes due to chalk dust, dehydration, mensuration, allergies, acid reflux etc.) are likely to contribute to vocal pathology in teachers.

H'etn, Trunchon-Gagon & Bilodean (1990) states that the teachers complained of vocal fatigue as not only they use their voice for may hours, but in many schools they have to raise and strain their voice constantly to overcome poor acoustic conditions such as classroom noise and room reverberation.

There have been some studies stating that there are wide individual differences in symptom change over a period of a prolonged phonatory task thought to induce vocal fatigue. Sherman and Jensen (1962) reported increased vocal strain in their subjects over the half hour of oral reading but adapted so well following that period and felt they could continue reading indefinitely.

Stone and Sharf (1973) found that the prolonged reading at different pitches and intensities, maximum voice quality change occurred in the first 5-10 minutes of phonation, after the subject apparently adapted to the vocal task. The above studies suggest that an initial warmup or vocal adaptation/adjustment period takes place during prolonged phonatory task. The recovery of voice during a rest period after prolonged phonation may be experienced differently by different subjects.

There have been few quantitative studies in vocal fatigue to chart directly or indirectly physiological changes due to phonation overlong periods of time.

Breiss (1960) concluded that 15 seconds of noise exposure at levels between 70 and 100 db were sufficient to induce voice fatigue symptoms. Recovery time varied from 10 seconds for normal subjects to one hour for subjects with histories of voice problems.

Sherman and Jensen (1962) have reported that perceptual study suggested normal readers tended to decrease vocal harshness rating at the end of 1% hours, with a subsequent increase in the harshness rating at the end of a % hour vocal rest period.

Brodnitz (1971) has used LTAS in evaluating voice fatigue. There were changes in spectral tilt. Vocal fatigue is expressed by a greater skewness of the straight line of formant region in men.

Sander and Ripich (1981) has reported that a 10 minutes speaking task at 96 and 102 dB did not produce vocal fatigue for majority of their normal subjects.

Zagoruiko and Tambovstev (1982) found that after 4 hours of reading aloud (with short breaks, no longer than 10 minutes) reading syllable rates for male and female readers decreased by 22-73 percent. Neils and Yairi (1987) confirmed vocal fold inflammation within 15 minutes of reading in a stimulated harsh voice by a photographic technique.

Reimers, Neils and Yairi (1987) have studied the vocal production of normal females reading for 45 minutes under three conditions of noise heard through earphones. Voice quality did not significantly change overtime according to a panel of listeners. A significant finding was that peak airflow values increased between the inhibition and end of the 45 minutes reading period.

Titze et.al (1986) has used vocal perturbation measures in an attempt to obtain physiological interpretation of vocal fatigue. A vocally trained subject and a vocally untrained subject read a text at high loudness level at a pitch one octave above their lowest pitches. Acoustic measures and the subjects responses to questions about sensory and psychological reactions were obtained. The untrained subject produced vocal fatigue symptoms but no significant changes in the acoustic measures over 1% hours. The vocally trained subject reported vocal fatigue symptoms, in addition went through a vocal warming up resulting in adaption to the task as well as significant changes in acoustic measures over 1% hours. The change in shimmer was correlated significantly with the subjects self evaluation of the relative condition of their voice. The jitter measure remained high during the rest period, whereas the shimmer values recovered to prefatigue levels.

Overall the limited speech research has yielded some contradictory findings leaving the concepts of vocal fatigue and vocal rest still poorly understood. The review suggests that there has been not enough work in the area of vocal fatigue to chart directly or indirectly physiological changes due to phonation over long periods of time.

Diagnostic procedures for voice disorder comprises of tests that elicit information regarding the actual process of voice production and the nature of sound generated. The purpose of the diagnostic procedures are

a) To determine the cause of a voice disorder.
b) To determine the degree and extent of the causative disorder.
c) To evaluate the degree of disturbance in phonatory function.
d) To determine the prognosis of the voice disorder as well as that of the cause of the disorder.
e) To establish a therapeutic program.

Michael and Wendahl (1971) consider voice as a multidimensional series of measurable events, implying that a single phonation can be assessed in different ways. They present a tentative list of twelve parameters of voice, "most of which can be measured and correlated with specific perceptions, while others are more elusive and difficult to talk about in more than ordinal terms." The twelve parameters listed by them are

1) Vital capacity
2) Maximum duration of controlled sustained blowing
3) Model frequency range.

4) Maximum frequency range.
5) Maximum duration of sustained phonation.
6) Volume/Velocity airflow during phonation.
7) Glottal wave form
8) Sound pressure level
9) Jitter of the vocal signal.
10) Shimmer of the vocal signal
11) Effort level (vocal).
12) Transfer function of the vocal tract.

Hirano (1989) did an international survey and has recommended the following measures for clinical voice evaluation.

1. Air flow
   Phonation quotient (PQ)
   Vocal velocity index (VVl)
   Maximum phonation time.
2. Fo range
   SPL range
   Habitual FO
   Habitual SPL
3. Electroglottography.
4. Tape recording.
   Pitch perturbation
   amplitude perturbation
   S/N ratio
   LTAS

Inverse filter acoustic

VOT

perceptual evaluation.

5. Laryngeal mirror

Fibroscopy of larynx

Microscopy of larynx.

6. Xray laryngography

7. Vital capacity

Ribcage and abdominal movements

8. Audiometry.

There are various objective methods to evaluate these parameters. Stroboscopic procedure, high speed cinematography, electrogrottography, ultrasonic recordings and high resolution signal analyzer can be used.

Electromyography is a test which evaluated some of the parameters which regulate the vibratory pattern of the vocal folds at physiological level.

Aerodynamic measurements deals with the aerodynamic factors. Respiratory volumes, control of expiration and temporal aspects are the essential feature of assessment. Spirometry, pneumatochograph, pneumography can be used for air flow measurement.

Psycho acoustic evaluation of voice is based on the fact that the human ear has a surprising capacity to identify the speakers simply by listening to the voice. Well trained voice clinicians are frequently able to determine the causative pathologies on the basis of the psychoacoustic impression of abnormal voice (Takahashi 1974, Takahashi et al 1974, Hirano 1975).

To study the vibratory pattern of the vocal folds the methods recommended are stroboscopy, ultra high speed photography, glottography and acoustic analysis.

The acoustic analysis of the voice quantifies the parameters which determine the acoustic characteristics of the sound generated. It has been considered vital in the diagnosis and management of patients with voice disorders.

Hirano (1981) has pointed out that the acoustic analysis of the voice signal may be one of the most attractive methods for assessing phonatory function or laryngeal pathology because it is noninavasive and provides objective and quantitative data.

Since any single acoustic parameter is not sufficient to demonstrate the entire spectrum of vocal function or of laryngeal pathology, multi dimensional analysis using multiple acoustic parameters was attempted by Davis (1976). He used parameters such as pitch perturbation quotient, amplitude perturbation quotient, pitch amplitude, coefficient of excess, spectral flatness of the inverse filter spectrum and spectral flatness of the residue signal spectrum to differentiate pathological voices from normal voices.

At present various computer based methods are being evolved to extract different parameters of voices. These methods are being used mostly in clinical and research work because they are time saving and they don't need interpretation on the part of experimenter since the parameters are automatically analyzed and given. Multidimensional voice program model 4305 is one such program and is being used in the present study on vocal fatigue.

Hirano (1981) has pointed out that it is necessary to use as many parameters of voice as possible in assessing voice and its disorders. Before using the acoustic parameters for the study on vocal fatigue it is essential to review the usefulness and effectiveness of these- parameters in the assessment, diagnosis and treatment of voice and its disorders.

Fundamental Frequency:

Fundamental frequency is the lowest frequency that occurs in the spectrum of a complex tone. In voice also, the fundamental frequency is considered the lowest frequency in the voice spectrum. This keeps varying depending upon several factors.

"---____________both quality and loudness of voice are mainly dependent upon the frequency of vibration. Hence it seems apparent that frequency is an important parameter in voice" (Anderson 1961). There are various objective methods to measure the fundamental frequency of the vocal cords like stroboscopic procedure, high speed cinematography, electrography, high resolution signal analyser frequency meter, visipitch, vocal II, etc.,

The study of fundamental frequency has important clinical implications. Cooper (1974) has used spectrographic analysis, as a clinical tool to describe and compare the F0 and hoarseness in dysphonic patients before and after vocal rehabilitation. Jayaram (1975) found a significant differences in habitual frequency measures between normal's and dysphonics.

A study was conducted by Asthana (1977) to find the effect of frequency and intensity variation on the degree of nasality in cleft palate speakers. The results of the study showed that the cleft palate speakers have significantly less nasality at higher pitch levels than the habitual pitch. But the degree of perceived nasality did not change significantly when habitual pitch was lowered.

Most of the therapies of voice disorders are based on the assumption that each individual has an optimum pitch at which the voice will be of a good quality and will have maximum intensity with least expense of energy (Nataraja and Jayaram 1982). Most of the therapies aim to alter the habitual pitch level of the patients or make the patient to use his optimum pitch (Anderson 1961, Van Riper and Irwin, 1966).

Thus it is apparent that the measurement of the fundamental frequency is important in the diagnosis ar.d treatment of voice disorders.

Frequency range in Phonation:

Variations in fundamental frequency and the extent of range used relate to the intent of the speaker (Fairbanks and Pronovast 1939).

As far as variability of fundamental frequency is concerned the most extensive study is that of Eguchi and Hirsh (1969), who collected data for 84 subjects representing adulthood and the age levels of 3-13 years, at one year intervals, for the vowels /a/, /i/ and /u/ as produced in the sentence contexts. The variability of fundamental frequency progressively decreased with age until a maximum was reached at about 10-12 years. This is taken as an index of the accuracy of the laryngeal adjustments during vowel production, then the accuracy of control improves continuously over a period of atleast 7-9 years.

Shipp and Huntington (1965) indicates that laryngitic voices had significantly smaller ranges than did post-laryngitic voices.

Sheela (1974) has found that the pitch range was significantly greater in trained singers than in untrained singers.

Jayaram (1975) reported that in normal males the frequency range ranged from 90Hz to 510Hz in dysphonic males. The females of the normal and dysphonic groups presented 140 Hz to 710 Hz and 60Hz to 400 Hz as their range of frequency range respectively. He also reported that as a group, dysphonics, both males and females presented a restricted frequency range as compared to normals. Thus, the measure of frequency range gains importance in differential diagnosis of dysphonics.

Nataraja (1986) found that the frequency range did not change much with age i.e, in the age range 16-45 years. He also found that females showed a greater frequency range than males in phonation.

Nataraja and Savithri (1990) in a study on frequency range of phonation in normals and dysphonics reported 1 - 29 in normals and 117-470 in dysphonics.

Perturbation measures

Thus review indicates frequency range is an important parameter and extensive data on pitch variations is needed before it can be applied to clinical population.

"The cycle to cycle variation is fundamental frequency is called pitch perturbation or jitter. Presence of small amount of perturbation in normal voice has been known (Moore, von leden 1958). A periodic laryngeal vibratory pattern have been related to the abnormal voice. (Browler 1964, Carhart

1983), Wyke (1969), sorenson, Horii and Leonard (1980) have reported the possible role of laryngeal mucosal reflex mechanism in Fo perturbation. This view of possible role of laryngeal mucosal reflex findings get support from the studies where deprivation or reduction of afferent information from the larynx occurred by anesthetizing the laryngeal muscles. This might have reduced the laryngeal mucosal reflex (Wyke '67, '69) and inturn increase the Jitter size in sustained phonation (Sorenson et al. 1970).

Baer (1980) explains vocal Jitter as inherent to the method of muscle excitation based on the neuromuscular model of the fundamental frequency and muscle physiology. He has tested the model using EMG from Crico-thyroid muscle and voice signals, and claims neuromuscular activities as the major contributor for the occurrence of perturbation.

A number of high speed laryngoscopic motion pictures reveal that the laryngeal structures (the vocal folds) were not totally symmetric. Different amounts of mucous accumulates on the surface of the vocal folds during vibration. In addition turbulent air flow at the glottis also causes some perturbations. Limitation of laryngeal servomechanism through the articular myotitic mucosal reflex system (Gould and Okamura 1974; Wyke 1967) may also introduce small perturbations in laryngeal muscle tone. Even without consideration of reflex mechanism, the laryngeal muscle tone have inherent perturbation due to the time staggered activities, which exists in any voluntary muscle contractions.

Von Leden et al (1960), reported that the most frequent observation in the pathological conditions is that there is a strong tendency for frequent and rapid changes in the regularity of vibratory pattern. The variations in the vibratory pattern are accompanied by transient pressure changes across the glottis which are reflected acoustically in disturbance of the fundamental frequency and amplitude patterns. Hence, pitch perturbation and amplitude perturbation values are greater in pathological conditions.

Liberman (1963) found that pitch perturbations in normal voice never exceeded 5msecs in the steady state portion of sustained vowels. Similar variations in fundamental periodicity of the acoustic wave form have been measured by Fairbanks (1940).

Wilcox (1978), Wilcox and Horii (1980) reported that a greater magnitude of Jitter occurs in the advancing age which they attributed to the reduced sensory contribution from laryngeal mechanoreceptors. However, these changes in voice with age may also be due to physical changes associated with respiratory and articulatory mechanism. These perturbations are related parameters in pitch and amplitude and can be measured. There are different algorithms for the measurement of pitch perturbations. Some of them are : Absolute Jitter, Jita percent, pitch period perturbation quotient, smooth pitch period perturbation quotient, co-efficient of Fo variation, relative average perturbation. The definition method of computation and description is given in the appendix I.

Several factors have been found to effect the values of Jitter such as age, sex, vowel produced, frequency and intensities.

Higgins and Saxman (1989) reported higher values of frequency perturbation in males then females. Gender difference may exist not only in magnitude, but also in the variability of frequency perturbation.

Zemlin (1962) has found greater Jitter values for /a/, than /i/ and /U/ showed lowest value.

Sorenson and Horii (1984) studied the vocal Jitter during sustained phonation of /a/, /i/ and /u/ vowels. The result showed that Jitter values were low for /a/ with 0.17% high for /i/ with 0.96% and intermediate for /u/ with 0.86%.

Ramig (1980) postulated that Jitter values should increase when subjects are asked to phonate at a specific intensity and/or as long as possible.

Cycle to cycle variation of amplitude is called intensity perturbation or shimmer. These perturbations in amplitude can be measured using several parameters. There are different algorithm for measurement of amplitude perturbations. Some of them are shimmer in dB, shimmer % amplitude perturbation quotient, smoothed amplitude perturbation quotient, coefficient of amplitude variation. The definition, method of computation and description is given in the appendix I.

Shimmer in any given voice is dependent atleast upon the model frequency level, the total frequency range and the SPL relative to each individual voice, Michael and Wendahl (1971) and Ramig (1980) postulated that shimmer values should increase when subjects are asked to phonate at a specific intensity and/or as long as possible.

Kitajima and Gould (1976) have found that vocal shimmer is a useful parameter for the differentiation of normals and vocal cord polyp groups. They found the value of vocal shimmer ranging from 0.04 dB to 0.21dB in normals and from 0.08dB to 3.23 dB in the case of vocal polyps.

Sorensen and Horii (1983) studied the vocal shimmer during sustained phonation of /a/, /i/ and /u/ vowels. The results showed that shimmer values was lowest for /u/ with 0.19 dB, highest for /a/, with 0.33 dB and intermediate for /i/ with 0.23 dB.

Nataraja (1986) has found that speed of fluctuation in fundamental frequency and extent of fluctuation in intensity parameters were sufficient to differentiate the dysphonics from the normals.

Higgins and Saxman (1989) investigated within subject variations of 3 vocal frequency perturbation indices over multiple sessions for 15 female and 5 male young adults (pitch perturbation quotient and directional perturbation factor). Co-efficient of variation for pitch perturbation quotient and directional perturbation factor was considered indicative of temporal stability of these measures. Jitter factor and pitch perturbation quotient provided redundant information about laryngeal behaviour. Also jitter factor and pitch perturbation quotient varied considerably within the individual across sessions, while directional perturbation quotient varied considerably within the individual across sessions which directional perturbation factor was a more temporarily stable measure.

Venktesh et al, (1992) reported Jitter Ratio (JR), Relative Average perturbation, 3 point(RAP3), deviation from linear Trend (DLT), shimmer in dB (SHIM) and amplitude perturbation Quotient (APQ) to be most effective parameters in differentiating between normal males, normal females and dysphonic groups. They added that in the clinical application, shimmer in dB is most effective and can act like a quick screening device and in pitch perturbation measures like Jitter ratio (JR), relative average perturbation (3 point) and DLT are most useful in differentiating laryngeal disorders.

Measurement of Noise:-

Yanagihara (1967) states that in cases with a slight degree of perceived hoarseness the noise component appears in the formant region and in severe hoarseness additional noise over 3KHz can be noticed.

On sound spectrographic analysis Yanagihora (1967) has found that the sustained vowels perceived as hoarse has the following characteristics:

1. Noise components in the main formants of various vowels.
2. High frequency noise component.
3. Loss of high frequency harmonic component.

As the degree of judged hoarseness increases more noise appears and replaces the harmonic structure. He also developed a technique for visually evaluating hoarseness based on the spectrogram.

Kitajima (1981) did a study in which he obtained a quantitative magnitude of the noise in the sustained vowel /ah/ when uttered by speakers with pathologic voice. The findings indicated that the noise ratio obtained could be used as one of the reliable acoustic parameters of the hoarse voice.

Yumoto (1982) and Yumoto et.al (1983) determined H/N ratio directly from the voice signals. They reported significant agreement between the H/N ratio and objective spectrographic evaluation, thereby concluding that the H/N ratio would be useful in the assessment of clinical treatment for hoarseness.

Kasuya, Ogawa, Mashima and Ebihara (1986) devised as adaptive comb filtering method operating in the frequency domain to estimate noise components from a frequency drain to estimate noise component from sustained vowel phonation and proposed n acoustic measure of the amount of noise in the pathologic voice signal for the purpose of applying it in the screening of laryngeal diseases by voice.

Experiments with voice samples shows that the normalized noise energy is especially effective for detecting glottic cancer, recurrent nerve paralysis and vocal nodules. But 22.6% of patients with glottic - Tl cancer are incorrectly classified as normal. However, normalised noise energy has been shown effective in discriminating glottic T2-T4 cancer. The detectability of other laryngeal disease can be improved by incorporating other measures such as filter and shimmer (Kasuya et al., 1984).

Thus the review of Literature regarding different acoustic parameters show that these have been found to be useful to study to the normal and abnormal functioning of voice. However there are very few studies reporting the use of acoustic parameters in exploring the area of vocal fatigue. To add, the studies have been carried out on normal speakers and thus very little is known about vocal fatigue in the high risk groups i.e professional voice users.

The present study was designed with the aim to

* Study vocal fatigue in teachers and investigate the acoustic correlates of vocal fatigue in them.

* To develop susesptibility criteria for vocal fatigue among teachers.

* To highlight the sensitive parameters in MDVP for the measurement of vocal fatigue.

METHODOLOGY

Experiment - 1

The purpose of the study was to develop a susceptibility criteria for vocal fatigue by multidimensional analysis of voice. The following twenty nine acoustic parameters of multidimensional analysis of voice program developed and marketed by Kay Elemetrics Inc. were used.

1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (TO)
3. Highest Fundamental frequency (Fhi)
4. Lowest fundamental frequency (Flo)
5. Standard Deviation of Fo (STD)
6. Fo-tremor frequency (Fftr)
7. Amplitude Tremor frequency (Fatr)
8. Absolute Jitter (Jita)
9. Jitter percent (Jitt)
10. Relative average perturbation (RAP)
11. Pitch perturbation quotient (PPQ)
12. Smoothed pitch perturbation quotient (sPPQ)
13. Fundamental frequency variation (vFo)
14. Shimmer in dB (ShdB)
15. Shimmer percent (Shim)
16. Amplitude perturbation quotient (APQ)
17. Smoothed amplitude perturbation quotient (sAPQ)
18. Peak-amplitude variation (vAM)
19. Noise to harmonic Ratio (NHR)

20. Voice Turbulence Index (VTI)
21. Soft phonation Index (SPI)
22. Fo Tremor intensity Index (FTRI)
23. Amplitude tremor Index (ATRI)
24. Degree of voice breaks (DVB)
25. Degree of sub-Harmonics (DSH)
26. Degree of voiceless (DUV)
27. Number of voice breaks (NVB)
28. Number of sub-Harmonic segments (NSH)
29. Number of unvoiced segments (NUV)

Definition of all the parameters are given in appendix I.

SUBJECTS (Group I)

Five normal subjects (4 males, 1 female) in the age range of 20-45 years were considered for the study. They had no apparent speech, hearing or E.N.T problems. Their profession did not involve excessive use, misuse or abuse of the vocal mechanism.

INSTRUMENTATION

The following instruments were used in the present study.

1. Dynamic microphone (carodid, spny F - 760)
2. Pre amplifier
3. C.S.L speech interface unit (model 4300 B)
4. 486 sx with C.S.L 50 hardware card.
5. MDVP software.

All the measurements were carried out in a sound treated room of the phoniatrics laboratory of the Department of speech sciences. A.I.I.S.H, Mysore-6.

BLOCK DIAGRAM

```
     +-------------+  +-----------------+    +-----------+
O--  |Pre amplifier+--+ Speech interface+---+ PC 486 SX |
Mic  +-------------+  |      unit       |    +----+------+
                      +-----------------+         |
                                               +--+--+
                                               | MDVP|
                                               +-----+
```

PROCEDURE

For the purpose of automatic extraction of the acoustic parameters using MDVP software it was decided to use the phonation i.e of vowels /a/, /i/ and /u/. Three trials of phonation were recorded for each vowel.

The subjects were instructed to take a deep breath and say /a/ and the microphone was placed 4-6 inches from the month of the subject. They had to maintain a constant intensity and pitch at comfortable level. Similar recordings for vowels /i/ and /u/ were carried out. The first set of phonation (p1) were recorded before the subject underwent fatiguing task i.e reading. After recording the I set of phonation subjects were involved in a fatiguing task. They were asked to read a non emotional story for a duration of 1/2 hour without interruption maintaining an average intensity of 65dB ($\pm$5dB). The LED of the speech interface unit was used to monitor the intensity. Subjects were told to lower the intensity when the red light flickered and raise the intensity when the green lights were not on.

The II set of phonation (p_2) were recorded after the subject completed 1/2 hour of reading using the same procedure. Similarly there was another fatiguing task and the subjects had to continue reading for another 1/2 hour following which the III set of phonations (p_3) were recorded.

The voice samples were analysed using multidimensional analysis of voice program. After the analysis the results were obtained for each trial of each vowel for all the subjects. Further data was subjected to statistical analysis using the NCSS software to obtain descriptive as well as inferential statistical information.

Experiment - 2

A survey of questionnaire consisting of three parts(25 questions) was designed for teachers with an aim to obtain information about vocal fatigue and to identify teachers suffering from vocal fatigue

PART-A(l-ll) was designed to obtain Biographical information and details of work (teaching)

PART-B(12-22) addressed variety of symptoms typically associated with vocal attrition in order to determine which of these symptoms were frequently and currently experienced by the respondents during or after teaching. The symptoms were labelled under current symptoms. The items in this part involved a YES/NO forced choice response type.

PART-C(23-25) addressed questions on the impact of voice problem on teaching and general health. They had to compare the voice quality before and since they began teaching. The teachers also had to describe if they had to take any precautionary measures or medical treatment for voice problems. The questionnaire is given in appendix-11.

DATA COLLECTION.

The questionnaire was administered to primary and secondary school teachers in Mysore city. Four schools namely, Demonstration Multipurpose school, VijayaVittala Vidhyashala, Kukkarahalli Higher primary school and Manasa gangotri school were considered for the survey. The teachers were informed about the purpose of the study in advance through staff meeting. The subjects participation in the survey was on a voluntary and anonymous basis.

The data was collected from 55 teachers through direct interviews. Table 1. shows school, Age and sex wise distribution of teachers.

School	Age Range	Males	Female
Demonstration multipurpose school	24 - 57	4	14
Vijayavittala Vidhya Shala	22 - 39	2	8
Kukkarahali Higher primary school	33 - 56	4	9
Manasagangotri School	24 - 54	3	11

ANALYSIS OF THE RESPONSES

The number of current symptoms(PART-B) were totalled for each teacher. Two groups were made depending on the number of symptoms i.e groupII (0-3 symptoms) and groupIII (4-8 symptoms) as the current symptoms in teachers ranged from (0-8).

Experiment - 3

The study of vocal fatigue were extended to teachers selected from the Questionnaire.Ten teachers subjects were divided into two groups (group-II and group-III) based on the number of current symptoms experienced. Group II comprised of five teachers (3 males, 2 females) with current symptoms ranging from 0- 3. GroupIII consisted of five teachers (1 male, 4 females) with current symptoms ranging from 4-8.

The instrumentation, procedures for recording and analysis of voice samples in GroupII and Group III were similar to groupl i.e using the same experimental setup and procedure as in experiment I. Phonations of /a/, /i/ and /u/ three trials each under prefatigue condition, after 1/2 hr of reading and lhr of reading were recorded.

RESULTS AND DISCUSSIONS

The purpose of the study was to develop susceptibility criteria for vocal fatigue. There were three experiments involved in the study.

1. Determining the duration after which the vocal fatigue may be observed in terms of parameters measured through MDVP and to identify the parameters which can be used to find out the vocal fatigue.

2. Administration of questionnaire to identify the subjects who were suffering from vocal fatigue because of their teaching activities.

3. Assessment of vocal fatigue in two different groups of subjects (groupII,III) who had history of vocal fatigue.

EXPERIMENT - 1

NORMAL-SUBJECTS(GroupI)

Three sets of phonation tasks (pl,P2,P3) were measured. PI was recorded before the reading task. P2 and P3 were recorded after reading for 1/2 hour and 1 hour respectively. This group consisted of four males and one female. The parameters were subjected to statistical analysis. The mean, SD are given in Table 2 and graphs la and lb for males and females respectively.

Parameter		Subject	P1	P2	P3
Fo(Hz)	M	Mean	114.64	118.02	117.29
		S.D.	13.41	13.22	12.37
	F	Mean	207.63	229.103	227.05
		S.D	16.41	24.12	18.43
TO(mS)	M	Mean	8.84	8.57	8.60
		S.D.	1.07	0.98	0.94
	F	Mean	4.84	4.42	4.51
		S.D	0.38	0.50	0.28
Fhi(Hz)	M	Mean	120.65	123.99	153.15
		S.D.	14.72	14.96	0.86
	F	Mean	217.04	236.29	233.27
		S.D	27.72	26.08	14.78
Flo(Hz)	M	Mean	108.07	110.76	110.62
		S.D.	13.31	11.46	10.69
	F	Mean	193.14	218.63	204.62
		S.D	18.30	21.82	15.81
STD(Hz)	M	Mean	1.404	1.56	1.49
		S.D.	0.64	0.511	0.56
	F	Mean	2.035	2.31	2.24
		S.D	0.41	0.94	0.51
Fftr(Hz)	M	Mean	4.73	6.46	6.79
		S.D.	5.55	6.60	6.90
	F	Mean	1.34	1.26	2.304
		S.D	0.52	0.104	1.16

Fatr(Hz;)	M	Mean	2.79	2.28	2.17
		S.D.	1.82	1.17	1.39
	F	Mean	2.36	1.46	1.72
		S.D	1.34	0.24	1.22
Jita(usec)	M	Mean	71.70	78.72	76.02
		S.D.	43.98	40.45	49.93
	F	Mean	23.09	30.84	15.49
		S.D	7.40	17.24	00.00
Jitt(X)	M	Mean	0.82	0.93	0.89
		S.D.	0.51	0.55	0.57
	F	Mean	0.47	0.71	0.34
		S.D	0.13	0.43	4.39
RAP(%)	M	Mean	0.47	0.55	0.51
		S.D.	0.31	0.34	0.34
	F	Mean	0.27	0.42	0.09
		S.D	5.07	0.23	7.32
PPO(X)	M	Mean	0.42	0.52	0.52
		S.D.	0.24	0.30	0.33
	F	.Mean	0.27	0.40	0.19
		S.D	7.80	0.23	5.52
sPPO(X)	M	Mean	0.702	0.88	0.72
		S.D.	0.27	0.84	0.30
	F	Mean	0.393	0.48	0.35
		S.D	8.27	0.22	0.05
vFo(%)	M	Mean	1.23	1.32	1.26
		S.D.	0.54	0.38	0.41
	F	Mean	0.97	0.99	1.004 .
		S.D	0.26	0.32	8.17
ShdB(%)	M	Mean	7.43	7.60	7.26
		S.D.	8.34	8.72	8.27
	F	Mean	0.17	0.15	0.13
		S.D	5.47	6.45	0.19
Shim(%)	M	Mean	3.04	2.83	3.02 .
		S.D.	0.84	0.80	0.97
	F	Mean	1.93	1.76	1.55
		S.D	0.61	0.74	0.03
APO(%)	M	Mean	2.43	2.17	2.31
		S.D.	0.79	0.71	0.89
	F	Mean	1.30	1.21	1.04
		S.D	0.44	0.51	0.43

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sAPQ(%)	M	Mean	4.01	4.36	3.S7
		S.D.	1.80	3.58	1.97
	F	Mean	2.07	1.805	1.57
		S.D	0.60	0.64	0.31
VAM (%)	M	Mean	9.43	10.13	9.58
		S.D.	3.27	3.86	3.64
	F	Mean	8.29	7.104	12.64
		S.D	2.32	2.81	0.605
NHR(%)	M	Mean	0.13	0.12	0.14
		S.D.	0.03	3.03	0.11
	F	Mean	0.107	0.108	9.54
		S.D	2.23	1.45	15.84
VTI(%)	M	Mean	5.30	4.92	5.23
		S.D.	2.77	2.87	2.76
	F	Mean	3.74	3.42	3.79
		S.D	2.23	1.91	1.48
SPI (%)	M	Mean	16.17	16.81	16.78
		S.D.	19.08	19.03	17.35
	F	Mean	41.37	28.504	26.54
		S.D	1.08	3.05	1.06
FTRI(%)	M	Mean	0.41	0.42	0.36
		S.D.	0.16	0.14	0.15
	F	Mean	0.44	0.32	0.29
		S.D	46.05	7.56	31.63
ATRI(%)	M	Mean	3.77	3.09	3.56
		S.D.	2.07	1.81	1.57
	F	Mean	1.59	1.33	2.46
		S.D	0.11	0.82	0.14
DVB (%)	M	Mean	0.00	0.00	0.00
		S.D.	0.00	0.00	O.JO
	F	Mean	0.00	0.00	0.00
		S.D	1.30	0.00	0.00
DSH {%)	M	Mean	0.00	0.00	0.00
		S.D.	0.00	0.00	0.00
	F	Mean	0.00	0.00	0.00
		S.D	0.00	0.00	0.00
DUV (%)	M	Mean	0.00	0.26	0.12
		S.D.	0.00	0.19	0.76
	F	Mean	0.00	0.00	0.00
		S.D	0.00	0.00	0.00

NVB (%)	M	Mean	0.00	0.00	0.00
		S.D.	0.00	0.00	0.00
	F	Mean	0.00	0.00	0.00
		S.D	0.00	0.00	0.00
NSH (%)	M	Mean	5.03	5.52	5.55
		S.D.	0.00	0.33	0.00
	F	Mean	0.00	0.00	0.00
		S.D	0.00	0.00	0.00
NUV (%)	M	Mean	0.00	2.77	0.11
		S.D.	0.00	0.16	0.66
	F	Mean	0.00	0.00	0.00
		S.D	0.00	0.00	0.00

The inspection of Table 2 and graphs la and lb showed that there was a means of the following parameters across phonations.

Pre fatigue phonation (PI), phonation after 1/2 hour of reading (P2), phonation after 1 hour of reading(p3).

No parameter showed difference (in means) across three phonations in both male and female subjects. The female subject showed difference in means of Fo(207.63- 229.10 Hz) between PI and P2 and (207.63-227.05Hz) between PI and P3. In addition there was difference in Fhi(217.04-236.29Hz) between p1 and p2, (217.04-233.27Hz) between p1 and p3. Jita differed between pi, p2(23.09-30.84 msec.) and pi p3 Jita (23.09-15.49 msec).

INDEX FOR GRAPHS

1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (TO)
3. Highest Fundamental frequency (Fhi)
4. Lowest fundamental frequency (Flo)
5. Standard Deviation of Fo (STD)
6. Fo-tremor frequency (Fftr)
7. Amplitude Tremor frequency (Fatr)
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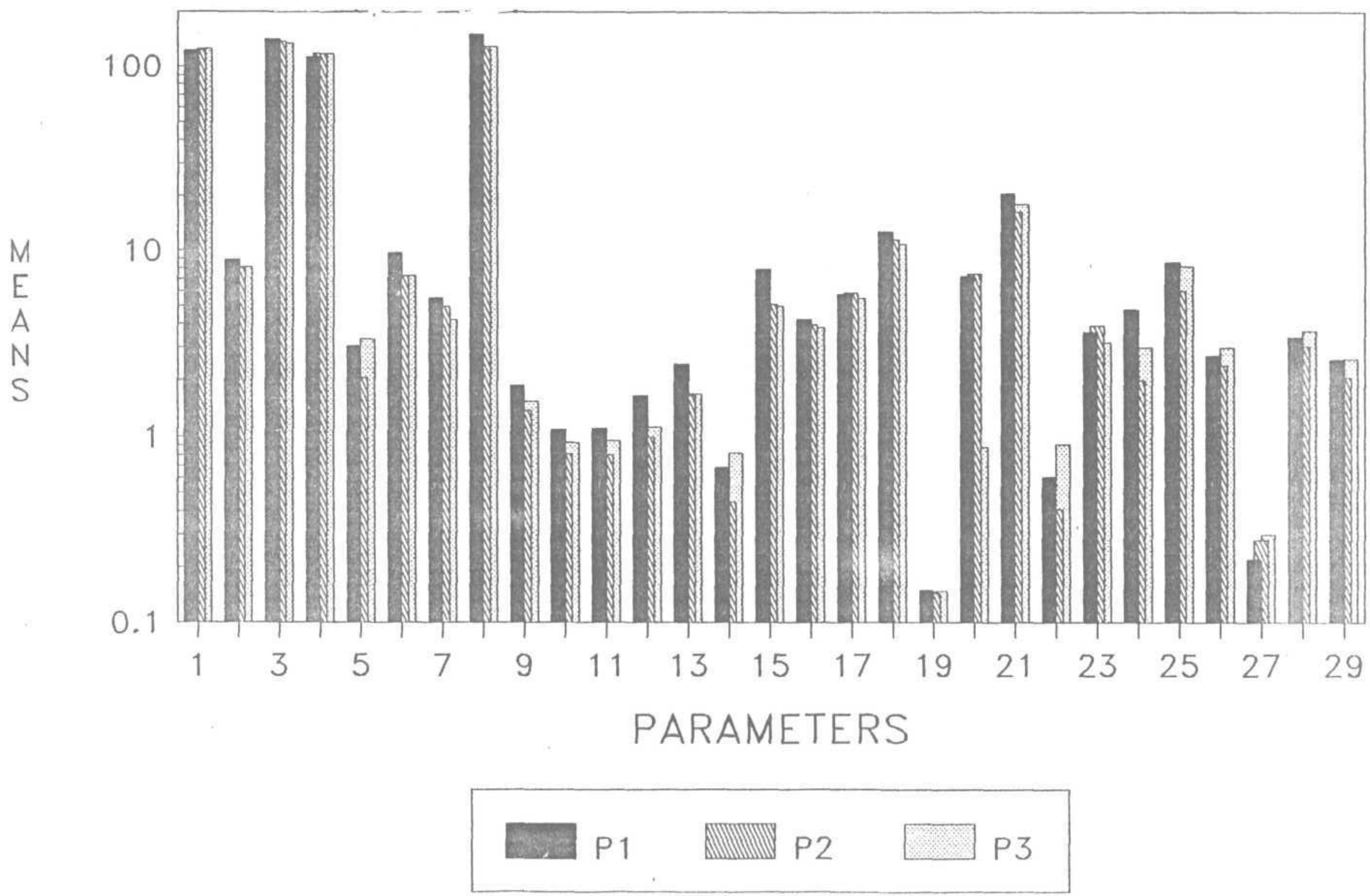
19. Noise to harmonic Ratio (NHR)
20. Voice Turbulence Index (VTI)
21. Soft phonation Index (SPI)
22. Fo Tremor intensity Index (FTRI)
23. Amplitude tremor Index (ATRI)
24. Degree of voice breaks (DVB)
25. Degree of sub-Harmonics (DSH)
26. Degree of voiceless (DUV)
27. Number of voice breaks (NVB)
28. Number of sub-Harmonic segments (NSH)
29. Number of unvoiced segments (NUV)

Pl-PREFATIGUE PHONATION

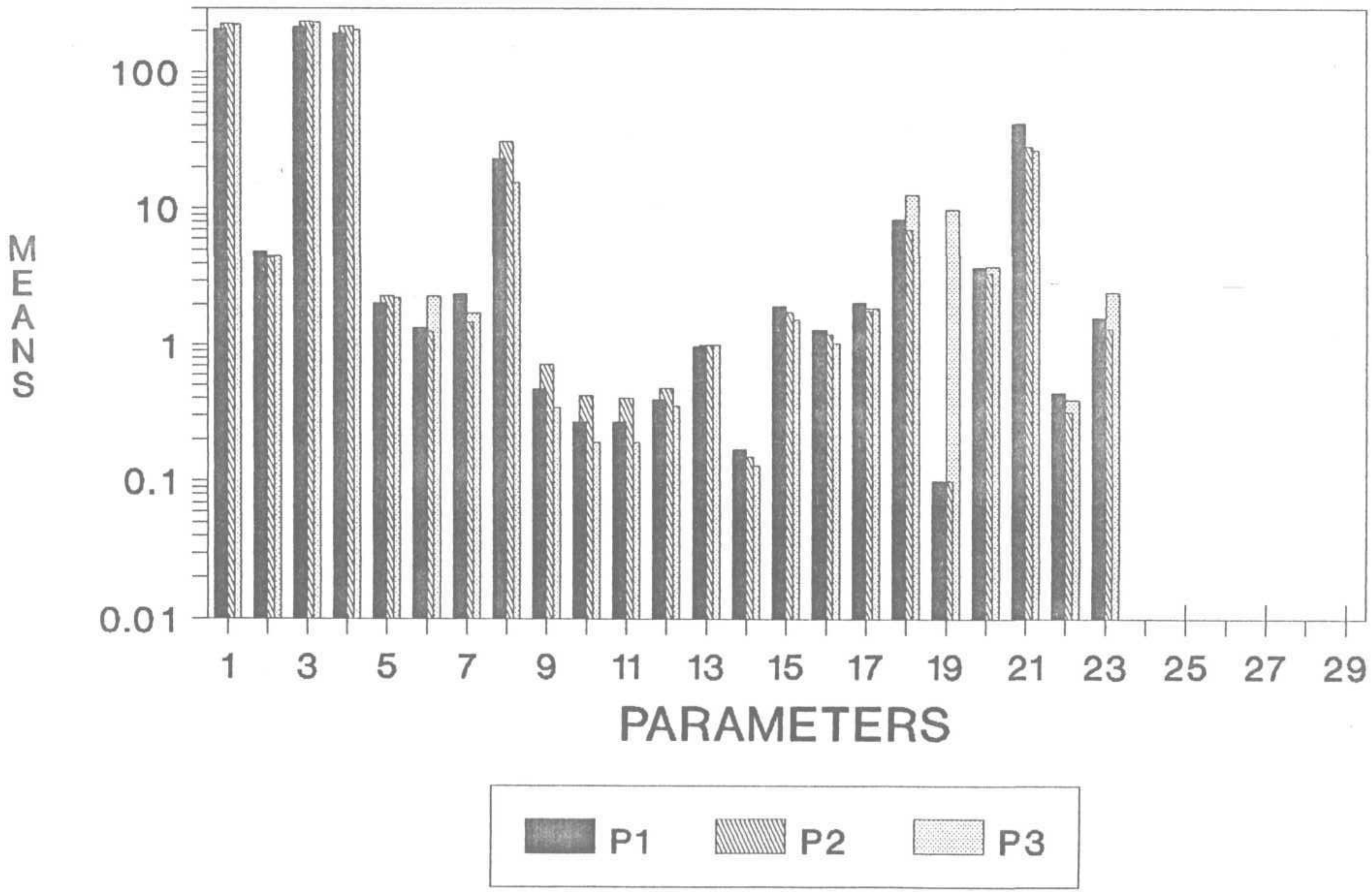
P2-PH0NATI0N AFTER %Hr OF READING

P3-PH0NATI0N AFTER lHr OF READING

GRAPH-1a: means of the acoustic paramaters in normal males across phonations.



GRAPH-1b: means of the acoustic paramaters in normal females across phonations. = (1 female)



Prefatigue phonation(pl) and phonation after 1/2 hour of reading(p2)

The parameters showing difference in means across p1i and p2 only were Jita (71.70-78.72usec.) in males. Flo(193.14-218.63Hz), sAPQ(2.07-1.805%) in female subject.

Prefatigue phonation (p1) and phonation after 1 hour of reading (p2).

In males fhi(120.65-153.15Hz) showed difference in means between p1 and p3.

Further the results were subjected to statistical analysis using paired T test. The following parameters showed statistically significant difference between the phonations at .05 level.

TABLE 2a : PARAMETERS SHOWING SIGNIFICANT DIFFERENCE AND CORRESPONDING T VALUES.

	PI vs P2	PI vs P3	P2 vs P3
Males	Fo(-6.16) T0(6.13) Fhi(-2.72) STD(-1.31)	Fo(-4.45) T0(4.61) Flo(-2.03)	
Females	Fo(-5.91) TO(6.63) Fhi(-3.32) Flo(-5.004) sAPQ(-1.38) Ftri(2.48)	Fo(-6.02) TO(5.71) STD(-2.37) Jita(3.28) Jitt(2.77) Rap(2.73) PPQ(2.72) ShdB(2.89) Shim(2.89) APQ(3.47)	Fftr(-2.59) Jita(2.74) Jitt(2.6) RAP(2.61) PPQ(2.63)

Prefatigue phonation(pl), phonation after 1 hour of reading (p2) and phonation after 1 hour of reading (p3).

From Table- 2a it is evident that there was no parameter showing significant difference both in males and females across all three phonations. In males Average fundamental frequency, Average pitch period and lowest fundamental frequency showed significant difference between p1 and p2, p1 and p3 only. For the female subject parameters showing similar results were Average fundamental frequency and Average pitch period. Absolute Jitter, Jitter percent, Relative Average perturbation, and pitch perturbation quotient showed significant difference across p2 and p3 and p1 and p3.

Hence hypothesis I a - stating there is no significant difference between prefatigue phonation (P1), phonation after 1/2 hour of reading (p2) and phonation after 1 hour of reading (p3) is rejected as none of the parameters showed significant difference across all the three phonations in both males and females. Also there was no linear pattern in the amount by which each parameter was affected with respect to fatiguing task.

Prefatigue phonation (p1) and phonation after 1/2 hour of reading(p2).

The parameters showing significant difference across PI and p2 only were - In males Highest fundamental frequency and standard deviation of Fo and . female subject showed significant difference on Highest fundamental frequency, Lowest fundamental frequency, smoothed amplitude, perturbation quotient, Fo tremor intensity index and pitch perturbation quotient.

The Hypothesis I b stating that there was no significant difference between prefatigue phonation (pl)and phonation after 1/2 hour of reading(p2) was partly accepted and partly rejected as some parameters showed significant difference across p1 and p2. Thus half an hour of reading was sufficient to bring changes in the acoustic parameters.

Prefatigue phonation (p1) and phonation after 1 hour of reading (p3).

Standard deviation of FO, shimmer in dB, shimmer percent and Amplitude perturbation quotient showed significant difference in female subject across p1 and p3 only.

Hypothesis I C stating that there was no significant difference between prefatigue phonation (p1) and phonation after 1 hour of reading (p3) is partly accepted and partly rejected as only some parameters showed significant difference across p1 and p3.

Phonation after 1/2 hour of reading (p2) and phonation after 1 hour of reading(p3).

In female subject parameters showing significant difference across p2 and p3 only were Fo-tremor frequency and pitch perturbation quotient.

Hence the hypothesis stating that there was no significant difference between phonation after 1/2 hour of reading (p2) and phonation after 1 hour of reading (p3) was partly accepted and rejected as some parameters showed significant difference across p2 and p3.

In case of female subject more number of parameters were affected to 16 as compared to males i.e, 5 across phonation task. In both males and females subjects the following parameters showed significant difference across phonation- Average fundamental frequency (Fo) Average pitch period (To), Highest fundamental (Fhi), Lowest fundamental frequency (Flo), Absolute Jitter (jita), Jitter percent(%), Relative Average perturbation (RAP) & pitch perturbation quotient (PPQ). It can be concluded that fundamental frequency related measurements (Fo,To,Fhi,Flo) and short and long term frequency perturbation measurements (Jita, Jitt, RAP, PPQ) were the most sensitive parameters in MOVP accounting to measurement of vocal fatigue.

EXPERIMENT - II

ADMINISTRATION OF QUESTIONNAIRE

The questionnaire was administered to 55 teachers of four schools in Mysore. The number of current symptoms were tabulated for each subject. Based on number of symptoms present 10 subjects selected for the next phase of study. The symptoms observed are presented in Table-3.

SUBJECT	1	2	3	4	5	6	7	8	9	10
AGE IN YEARS/ SEX	39/F	36/M	43/M	37/F	31/F	40/F	31/F	38/F	40/M	38/M
CURRENT SYMPTOMS										
Dryness in throat	+	+		+	+	+	-	+	+	+
Vocal fatigue	+	+		+	+	+	-	+	-	-
Scratchy sensation		-		-	+	+	-	+	-	-
Discomfort	+	-		+	+	-	-	-	-	+
Effort to talk	+		+	-	+	+	+	-	-	-
Voice break-		+		+	+	+				
Troat clearing				+			-	-	-	-
Shortness of Breath		-		-	-	-	-	-	-	-
Pain in the-throat		-		-	+	-	-	-	-	-
Burning sensation		-		-	+	-	-	-	-	-
Voiceless ness	+	+								
Total	5	4	1	5	8	5	1	3	1	2

From the analysis of responses for 10 subjects selected for the study. It was seen that the number of current symptoms ranged from one to eight. The female subjects showed more number of symptoms than the male subjects. Among the current symptoms in teachers-dryness in throat, vocal fatigue (voice tires easily or changes in quality) and talking needs a lot of effort were most frequently reported symptoms.

The subjects were then divided into two groups i.e. groupII and groupIII on the basis of number of current symptoms experienced. GroupII subject had (0-3) symptoms and GroupIII had (4-8) symptoms.

EXPERIMENT-III

GROUPII TEACHERS (0-3 SYMPTOMS)

Teachers with 0-3 symptoms formed Group II. There were three males and two females in this group. These subjects were given similar task as group I and acoustic parameters measured were subjected to analysis. The mean, S.D for males and females are given in Table-4 and Graphs 2a and 2b.

PARAMETER	SEX		PI	P2	P3
Fo(Hz)	M	MEAN	121.76	122.34	124.95
		S.D	29.92	18.28	15.41
	F	MEAN	220.95	202.94	214.22
		S.D	5.84	3.85	3.96
TO(Hz)	M	MEAN	8.82	7.99	3.12
		S.D	1.34	1.04	1.02
	F	MEAN	4.52	4.95	4.90
		S.D	0.11	0.14	.26
Fhi(Hz)	M	MEAN	140.99	137.32	134.58
		S.D	24.42	21.49	17.03
	F	MEAN	233.07	218.55	212.74
		S.D	12.97	12.19	9.5
Flo(Hz)	M	MEAN	113.05	117.39	117.208
		S.D	20.64	18.18	71.43
-	F	MEAN	208.89	172.71	194.14
		S.D	12.62	33.54	16.9
STD(Hz)	M	MEAN	3.007	2.04	3.30
		S.D	2.06	0.81	2.82
	F	MEAN	6.32	6.57	6.34
		S.D	8.35	8.83	5.82

Fftr(Hz)	M	MEAN	9.63	7.24	7.77
		S.D	8.08	6.42	7.46
	F	MEAN	2.04	2.34	3.22
		S.D	1.52	1.16	3.31
Fatr(H2)	M	MEAN	5.51	4.95	4.21
		S.D	4.55	3.75	3.96
	F	MEAN	3.15	3.34	3.23
		S.D	1.65	2.21	3.98
Jita(usec)	M	MEAN	150.35	125.15	128.66
		S.D	96.90	78.48	96.64
	F	MEAN	31.13	67.72	40.49
		S.D	29.44	51.32	33.01
Jitt(%)	M	MEAN	1.85	1.38	1.54
		S.D	1.006	0.82	1.18
	F	MEAN	0.71	1.27	0.80
		S.D	0.65	1.05	0.63
RAP(%)	M	MEAN	1.09	0.81	0.93
		S.D	.6009	0.49	0.68
	F	MEAN	0.407	0.77	0.48
		S.D	0.36	0.63	0.38
PPQ(%)	M	MEAN	1.11	0.80	0.95
		S.D	0.63	0.48	.33
	F	MEAN	0.41	0.77	0.47
		S.D	0.37	0.61	0.35
sPPQ(%)	M	MEAN	1.64	0.99	1.12
		S.D	2.001	0.76	0.72
	F	MEAN	0.52	1.32	0.57
		S.D	0.61	1.65	0.36
vFo(%)	M	MEAN	2.42	1.65	1.68
		S.D	1.74	0*21	1.03
	F	MEAN	4.05	4.04	1.08
		S.D	7.33	7.54	0.55
ShdB	M	MEAN	0.68	0.45	0.82
		S.D	0.68	2.51	1.63
	F	MEAN	0.28	0.52	0.34
		S.D	1.04	0.29	0.12

Shim(%)	M	MEAN	7.91	5.13	5.04
		S.D	7.33	1.93	2.37
	F	MEAN	3.23	5.75	3.87
		S.D	0.56	3.0	1.42
APQ(%)	M	MEAN	4.26	3.99	3.83
		S.D	2.53	2.09	1.87
	F	MEAN	2.34	4.06	2.73
		S.D	0.62	2.80	0.98
sAPQ(%)	M	MEAN	5.83	5.89	5.54
		S.D	3.78	4.61	3.81
	F	MEAN	3.35	4.92	3.57
		S.D	3.97	2.18	1.27
VAM (%)	M	MEAN	12.76	11.54	10.85
		S.D	9.305	3.48	4.56
	F	MEAN	9.19	12.81	9.22
		S.D	2.28	7.45	2.93
NHR	M	MEAN	0.15	0.145	0.149
		S.D	0.07	5.04	0.34
	F	MEAN	0.12	0.18	0.12
		S.D	2.34	8.77	2.49
VTI	M	MEAN	7.24	7.52	0.88
		S.D	4.78	1.82	3.39
	F	MEAN	5.39	5.69	4.93
		S.D	14.40	2.78	2.72
SPI	M	MEAN	20.54	16.41	18.06
		S.D	20.25	0.15	2.15
	F	MEAN	11.85	13.70	18.53
		S.D	0.11	15.5	23.95
FTRI(%)	M	MEAN	0.608	0.41	0.91
		S.D	0.31	1.91	1.95
	F	MEAN	0.35	0.46	0.34
		S.D	1.826	0.14	0.20
ATRI (%)	M	MEAN	3.61	-3.92	3.16
		S.D	2.19	6.103	1.98
	F	MEAN	3.38	4.19	3.70
		S.D	2.73	2.57	2.20

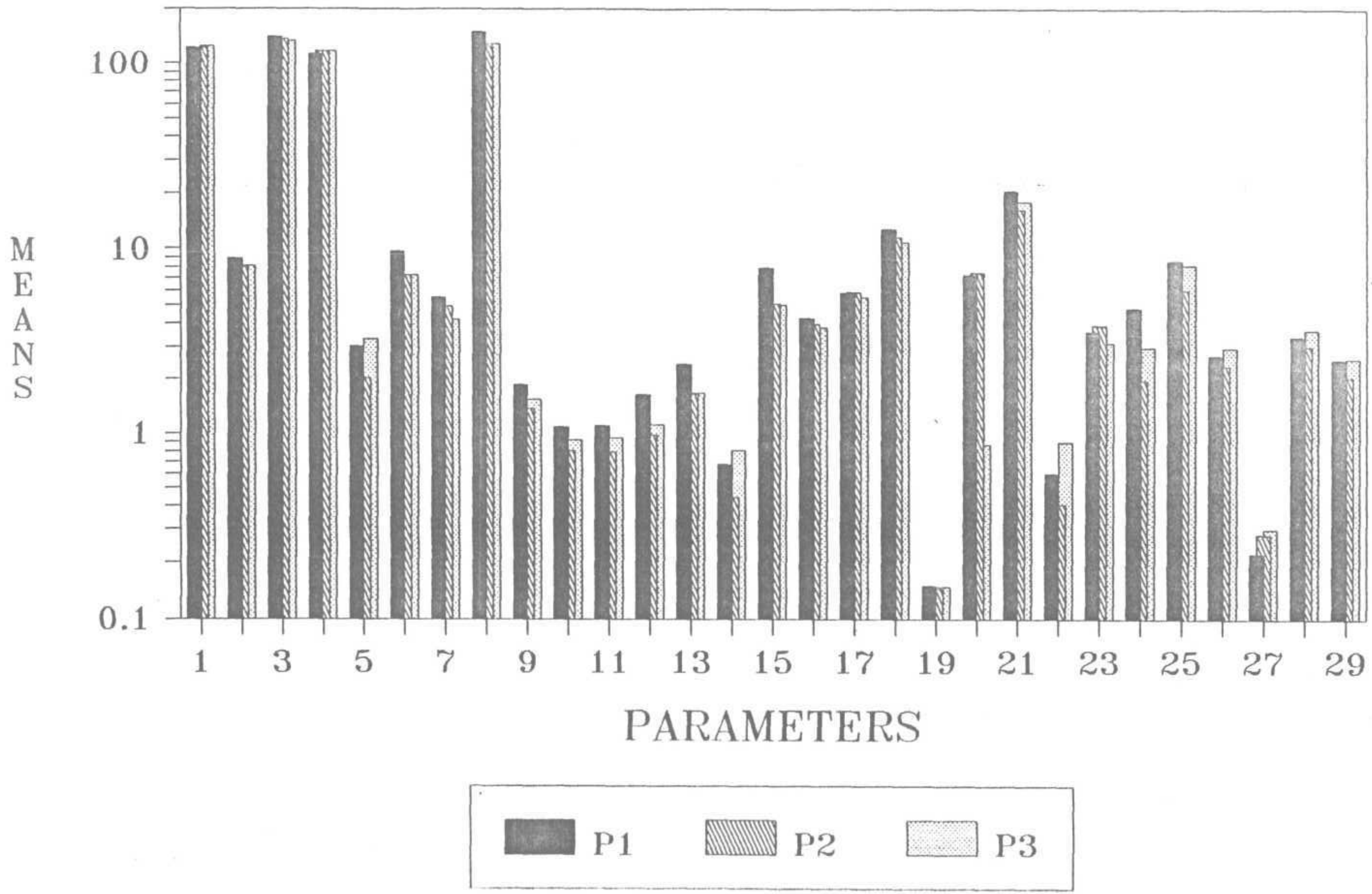
DUB(%)	M	MEAN	4.82	1.98	3.0
		S.D	0.69	0	0
	F	MEAN	0.64	0.17	0.34
		S.D	4.63	0.72	0.62
DSH	M	MEAN	8.61	6.03	8.25
		S.D	0.26	0.96	0.22
	F	MEAN	1.66	1.91	1.66
		S.D	0.37	3.6	4.44
DUV(%)	M	MEAN	2.68	2.38	2.97
		S.D	0.72	0.43	.67
	F	MEAN	.12	.70	0
		S.D	2.35	1.85	0
NUB	M	MEAN	0.22	0.28	0.3
		S.D	0.42	1.28	0.2
	F	MEAN	.55	.16	0.13
		S.D	4.03	.70	0
NSH	M	MEAN	3.407	3.05	3.703
		S.D	0.12	0	0.19
	F	MEAN	1.44	5.88	1.44
		S.D	0.32	8.23	3.86
NUV	M	MEAN	2.55	2.07	2.59
		S.D	.11	.61	5.89
	F	MEAN	0	.61	0
		S.D	0.7	1.61	0

Examination of table and graphs showed difference in means across the phonations.

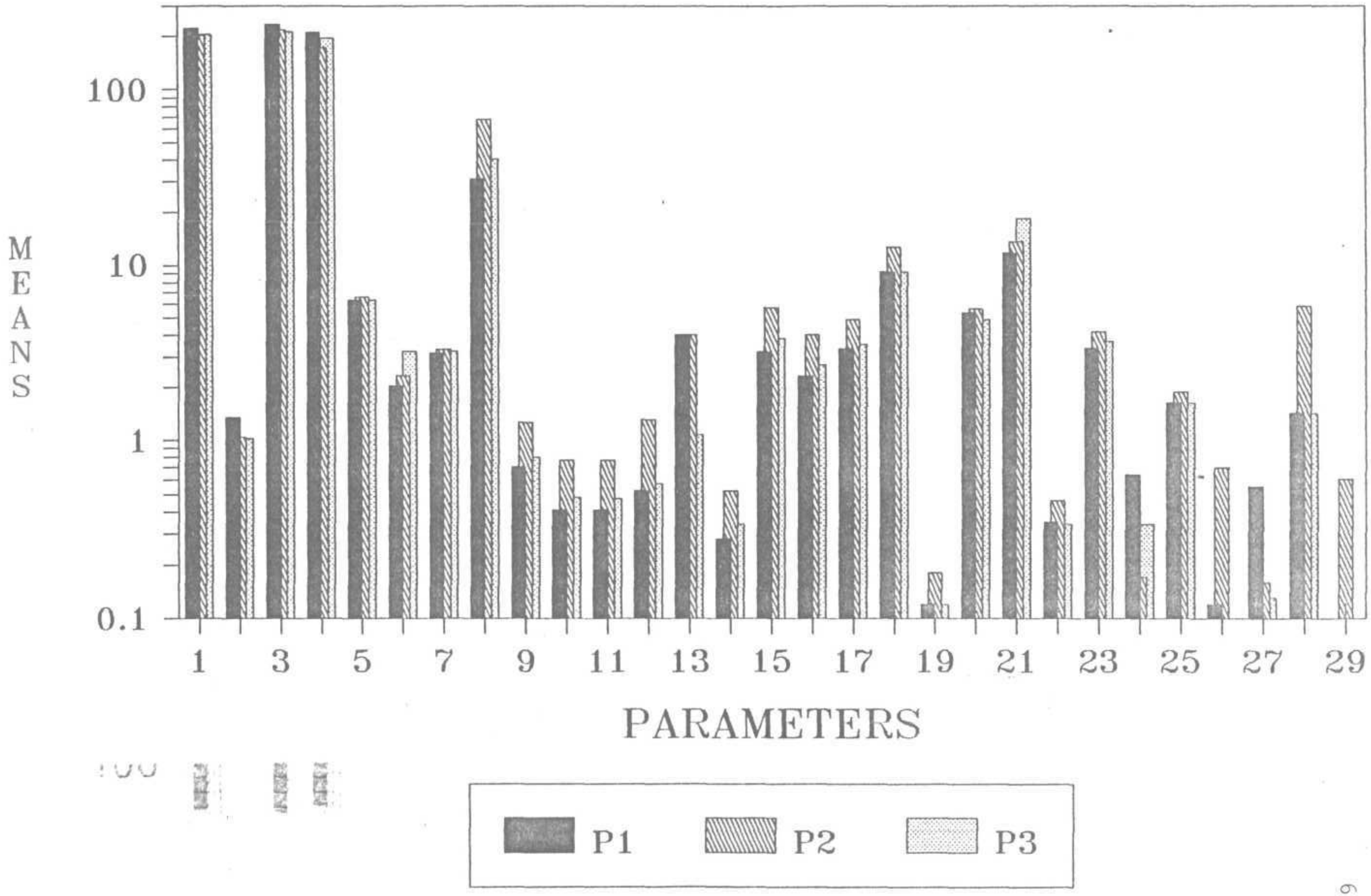
Prefatigue phonation (p1), phonation after 1/2 hour of reading (p2) and phonation after 1 hour of reading(p3).

No parameters showed difference in terms of means across all the three phonations in the male subjects. However Jita (31.13-67.72-0.49 msec.) and SPI (11.85-13.7-18.53msec.)

GRAPH-2a: means of the acoustic paramaters in male teachers (group-II) across phonations.



GRAPH-2b: means of the acoustic paramaters in female teachers (group-II) across phonations.



showed difference between Pl,p2,p3 respectively in the female subjects. Jita showed difference across p1 and p2 (150.35-115.15 msec) and (150.35-138.66msec) between p1 and p3 in the male subjects. For the female subjects parameters showing difference across p1 and p2 and p1 and p3 were Fo(220.95-202.94Hz), (220.95-204.22Hz),, Fhi(233.07-218.55Hz), (233.07-212.74Hz), Flo(208.89-172.71Hz). (208.89-199.Hz), Jita(31.13-67.72msec), (31.13-40.49 msec). The male subjects showed a difference in VT1 between p1 and p3(7.24-0.58), P2 and p3(7.52-0.88). Female subjects showed a difference in Jitt between p1 and p2 (1.85-1.38%), p2 and p3 (1.38-1.54%)

Prefatigue phonation(pl) and phonation after 1/2 hour of reading(p2)

The following parameters showed difference only across pi and p2. In males they were SPl(20.54-16.41) and Jita_(150.35-125.15Msec) and in Female subject sPPQ(1.64-0.99%), Shim(3.23-5.75%), NSH(1.44-5.88), APQ(3.35-4.92%), vAM(9.19-12.81%), SPI(11.85-13.70) showed difference.

Prefatigue phonation (PI) and phonation after 1 hour of reading (p3).

In males Fhi(140.99-134.58Hz) showed difference only across p1 and p3.

Phonation after 1/2 hour of reading (p2) and phonation after 1 hour of reading (p3).

VTI showed differences across p2 and p3 in female subjects(5.69-4.93)

Paired T test was used for further analysis of the data and the following parameters showed statistically significant difference across phonation at .05 level.

TABLE-4a:Parameters showing significant difference across phonations and their T values

	PI vs P2	PI vs P3	P2 vs P3
	STD (2.26)	Shim (2.21)	
	Jita (2.22)		
	Jitt (2.56)		
	RAP (2.50)		
Males	PPQ (2.70)		
	vFo (2.22)		
	SPI (2.41)		
	FTRI (3.40)		
	Fo (12.30)	Fo (9.04)	Flo (-2.72)
	TO (-9.92)	TO (-8.19)	Jita (2.75)
	Fhi (4.33)	Fhi (5.68)	Jitt (2.78)
	Flo (3.80)	Flo (5.16)	RAP (2.99)
	Jita (-2.97)	SPI (-2.72)	PPQ (2.78)
	Jitt (-2.53)		sPFQ (1.56)

Females	RAP (-2.78)	vFo (1.62)
	sPPQ (-1.97)	sAPQ (2.17)
	ShdB (-3.36)	NHR (3.13)
	APQ (-3.40)	VAM (1.83)
	sAPQ (-3.01)	VTI (1.37)
	NHR (-3.41)	
	NSH (-2.43)	

Prefatigue phonation(pl), Phonation after 1/2 hour reading (p2) and phonation after 1 hour of reading(p3)

Table revealed that only Lowest fundamental frequency showed significant difference across ail the three phonations in female subjects. Average fundamentals frequency, Average pitch period, Highest fundamental frequency, showed significant difference across p1 and p2 and p1 and p3 in the female subjects. In addition Jitter percent, Absolute Jitter Relative average perturbation, Smoothed pitch perturbation quotient, and noise to harmonic ratio showed significant difference between p1 and p2 and p2 and p3 in them.

Thus the hypothesis II-a stating that there is no significant difference between prefatigue phonation(pl), phonation after 1/2 hour reading(p2), phonation after 1 hour of reading(p3) was partly accepted and partly rejected as F10 showed significant difference across the phonation in female subject. Here also no linear trend observed in terms of amount by which each parameters is affected across phonations.

Prefatigue (p1) and phonation after 1/2 hour of reading(p2)

Among males the following parameters showed significant difference across p1 and p2 only- Average fundamental frequency, Absolute Jitter, Jitter percent, Relative average perturbation, pitch perturbation Quotient, variation in fundamental frequency, soft phonation index and FO tremor intensity index and only Amplitude perturbation quotient and Number of Sub-Harmonic segments in female subjects.

Thus the hypothesis-lib stating that there is no significant difference between prefatigue phonation(pl) and phonation after 1/2 hour of reading (p2) is partly accepted and partly rejected as some parameters showed significant changes across phonation PI and p2. Further it can be concluded that even among teachers (group II) half an hour of reading was sufficient to induce fatigue.

Prefatigue phonation(pl) and phonation after 1 hour of reading(p3)

Shimmer% showed significant difference in males subjects only across p1 and p3.

Hypothesis II-c stating that there was no significant difference between prefatigue phonation(pl) and phonation after % hour of reading (p3) is partly accepted and partly rejected as some parameters showed significant difference across p1 and p3.

Phonation after 1/2 hour of reading (p2) and phonation after 1 hour of reading (p3).

In female subjects Variation in Fundamentals frequency, peak amplitude variation, Voice turbulence index showed significant difference between p2 and p3 only.

Hypothesis stating that there was no significant difference between phonation after 1/2 hour of reading (p2) and phonation after 1 hour of reading (p3) is partly accepted and partly rejected as some parameters showed significant difference between p2 and p3.

In female subjects more number of acoustic parameter ware affected across phonation i.e., 22 whereas only 10 parameters were affected in males.

Average fundamental frequency (Fo), Average pitch period (TO), Highest fundamentals frequency (Fhi), lowest fundamental frequency (Flo),. Absolute Jitter (Jita),Jitter _ percent (Jitt), Relative average perturbation (RAP), Smoothed pitch perturbation quotient (sSPQ), pitch perturbation quotient (PPQ) shimmer Percent, smoothed amplitude perturbation quotient (sAPQ), soft phonation index(SPl), Noise to harmonic ratio showed significant difference across phonation in males and females. Thus it can be concluded that Fundamental frequency related parameters (Fo,To,Fhi,Flo), short and long term frequency perturbation measures (Jita, Jitt, RAP, PPQ, sPPQ) and Noise related measurements (NHR,SPI) and short and long term amplitude perturbation measurement (Shim%,sAPQ) are the sensitive parameters which could be used to study vocal fatigue in teachers.

Group III-TEACHERS (4-8 symptoms)

Teachers with 4-8 symptoms formed group III. It comprised of four females and one male. Similar reading task was given as group I & II. Acoustic parameters were subjected to analysis and are presented in terms of mean and S.D across phonation p1, p2, p3 in Table - 5 and Graph 3a and 3b respectively.

PARAMETER	SEX		PI	P2	P3
Fo (Hz)	M	MEAN	135.31	129.02	129.80
		S.D	11.55	1.69	3.26
	F	MEAN	203.78	210.2	218.43
		S.D	7.7	10.05	12.84
TO (Hz)	M	MEAN	6.49	7.74	7.93
		S.D	0.57	0.09	0.74
	F	MEAN	4.92	4.76	4.62
		S.D	0.237	0.21	0.32
Fhi (Hz)	M	MEAN	140.21	133.73	133.74
		S.D	18.90	2.31	4.66
	F	MEAN	218.33	219.63	231.39
		S.D	17.31	37.19	20.22
F10 (Hz)	M	MEAN	120.46	123.39	123.5
		S.D	25.61	7.69	6.32
	F	MEAN	177.07	172.25	172.25
		S.D	37.85	34.88	37.30

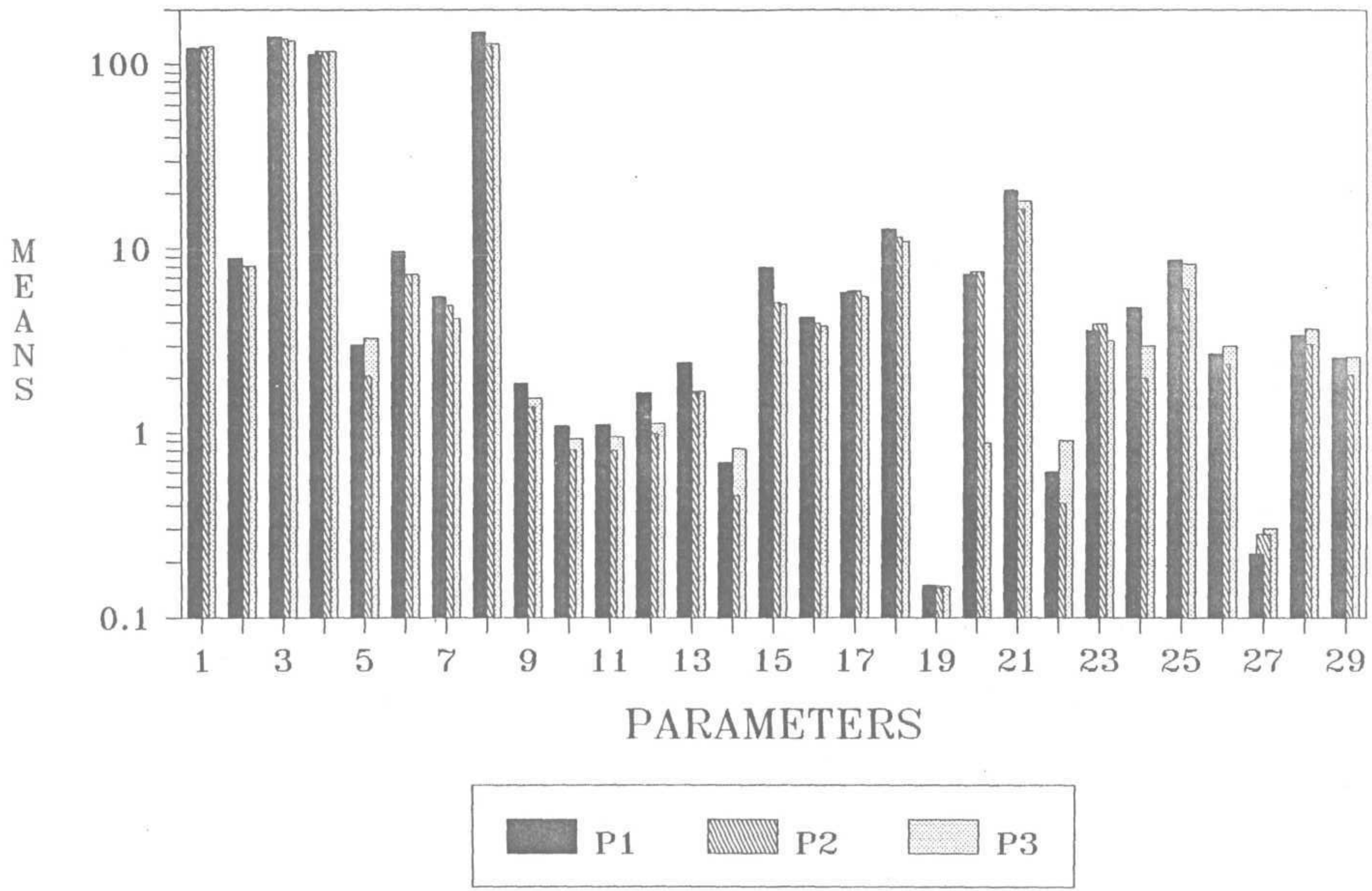
STD (Hz)	M	MEAN	4.89	4.58	4.31
		S.D	5.87	0.46	0.66
	F	MEAN	3.77	3.27	2.71
		S.D	2.04	1.06	1.26
Fftr (Hz)	M	MEAN	6.84	6.59	5.34
		S.D	7.76	7.46	7.02
	F	MEAN	2.74	2.33	2.65
		S.D	3.33	2.27	2.96
Fatr (Hz)	M	MEAN	6.42	6.69	6.73
		S.D	5.89	3.55	4.61
	F	MEAN	3.64	2.58	2.70
		S.D	4.12	1.32	3.72
Jita (usec)	M	MEAN	78.64	72.14	76.60
		S.D	29.26	28.55	56.8
	F	MEAN	49.88	46.27	29.35
		S.D	38.19	26.65	21.41
Jitt (%)	M	MEAN	1.76	0.93	0.86
		S.D	.94	0.36	0.73
	F	MEAN	1.1006	0.95	0.64
		S.D	.76	0.54	.47
RAP (%)	M	MEAN	0.44	0.55	0.52
		S.D	0.54	0.22	0.45
	F	MEAN	1.88	0.57	0.38
		S.D	7.53	0.33	.29
PPQ (%)	M	MEAN	1.07	0.53	0.38
		S.D	.59	0.20	0.39
	F	MEAN	0.64	0.55	.37
		S.D	.44	0.31	.26
sPPQ	M	MEAN	1.52	0.59	0.597
		S.D	1.30	0.21	0.36
	F	MEAN	2.9	0.7	0.47
		S.D	1.6	0.29	.11
VFO	M	MEAN	1.9	1.22	1.007
		S.D	0.8	0.36	0.5
	F	MEAN	2.20	1.56	1.23
		S.D	4.79	.52	1.42

ShdB	M	MEAN	.55	0.40	0.42
		S.D	.26	0.11	9.48
	F	MEAN	1.2	.292	.23
		S.D	1.42	.22	.91
Shim	M	MEAN	6.06	4.56	4.89
		S.D	3.55	1.31	1.08
	F	MEAN	2.80	3.24	2.56
		S.D	1.12	1.48	1.105
APQ	M	MEAN	3.58	3.08	3.30
		S.D	1.27	0.97	0.74
	F	MEAN	1.99	2.30	1.80
		S.D	.69	1.48	3.86
SAPQ	M	MEAN	4.90	3.77	4.37
		S.D	1.54	0.93	0.95
	F	MEAN	3.30	3.68	2.93
		S.D	1.40	1.45	2.28
VAM	M	MEAN	11.19	10.06	10.14
		S.D	7.29	5.98	7.90
	F	MEAN	8.04	11.21	9.57
		S.D	3.33	4.21	3.94
NHR	M	MEAN	0.13	0.14	0.14
		S.D	3.53	2.31	1.75
	F	MEAN	.21	.11	.10
		S.D	.45	2.11	2.36
VTI	M	MEAN	5.34	4.28	5.04
		S.D	2.68	0.16	1.89
	F	MEAN	0.45	4.78	3.89
		S.D	1.80	2.49	0.002
SPI	M	MEAN	32.80	27.95	26.31
		S.D	33.59	21.31	26.11
	F	MEAN	20.35	21.71	18.56
		S.D	22.03	24.70	20.48
FTRI	M	MEAN	0.43	0.30	0.26
		S.D	0.16	0.14	0.05
	F	MEAN	0.40	0.41	1.56
		S.D	0.22	0.21	1.01

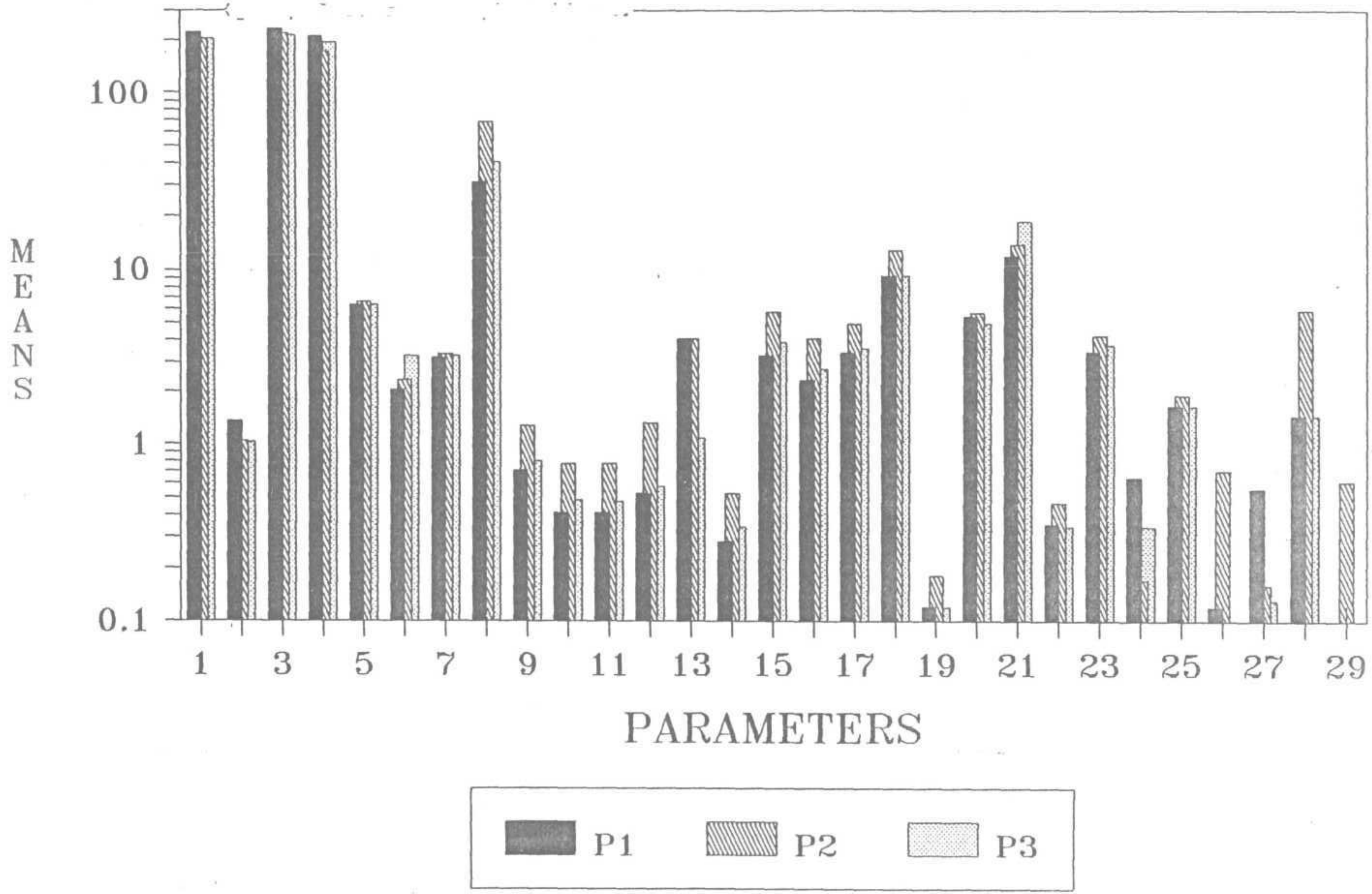
ATRI	M	MEAN	4.08	3.14	2.84
		S.D	3.40	2.21	0.87
	F	MEAN	3.00	3.33	3.40
		S.D	1.83	1.76	1.88
DVB	M	MEAN	0	0	0
		S.D	0	0	0
	F	MEAN	0.01	0	0
		S.D	0.10	0	0
DSH	M	MEAN	1.98	1.03	0.75
		S.D	3.24	0.2	2.32
	F	MEAN	1.16	1.56	0.54
		S.D	3.86	3.53	1.88
DUV	M	MEAN	2.04	2.46	1.66
		S.D	6.13	7.7	3.35
	F	MEAN	0.58	0.61	0.63
		S.D	1.89	0.32	0.38
NVB	M	MEAN	0	0	0
		S.D	0	O -	0
	F	MEAN	0	0	0
		S.D	0	0	0
NSH	M	MEAN	1.55	0.3	0.66
		S.D	2.35	0	2
	F	MEAN	0.88	1.36	0.47
		S.D	3.12	3.06	1.61
NUV	M	MEAN	1.77	1.44	1.44
		S.D	5.33	10.12	2.92
	F	MEAN	5.36	5.55	5.55
		S.D	1.43	0.23	0.37

Inspection of Table - 5 and Graph - 3a and 3b showed that there was difference in the means of the following parameters across phonations .

GRAPH-3a: means of the acoustic paramaters in male teacher (gruop-III) across phonations.



GRAPH-3b: means of the acoustic paramaters in female teachers (gruop-III) across phonations.



Prefatigue phonation (PI), phonation after % hour of reading (P2) and phonation after 1 hour of reading:

F0(203.78-210.2-218.43Hz) in females was different across all the three phonations. In male subjects, the following parameters showed difference between PI and P2 and PI and P3. Fo (135.31-129.08 Hz), (135.31-129.80Hz), TO (6.49-7.47Hz), (6.49-7.93Hz). Fhi(140.21-133.73Hz), (140.21-133.74Hz). The female subjects showed difference in Jita between PI and P3 and P2 & P3 i.e.(49.88 -29.35), (46.27-27.35).

Prefatigue phonation (PI) and phonation after % hour of reading (P2):

Male subject showed difference in sAPQ between PI & P2 (4.90-3.77%), VAM,VTI showed difference between PI & P2 in female subjects. The values are (8.04-11.21%) for VAM and (0.45-4.78) for VTI.

Prefatigue phonation (PI) and phonation after 1 hour of reading (P3) :

The female subjects showed difference in Fhi between PI and P3 (218.33-231.39Hz) .

The data was further subjected to statistical analysis to verify the observations using paired T test. The following showed statistically significant difference across phonations at 0.05 level in males and females.

TABLE - 5a. Parameters affected across phonations and corresponding T values in male and females

	PI vs P2	PI vs P3	P2 vs P3
MALE	Fo (5.63) TO (-6.10) Fhi (5.96) PPQ (2.31) sAPQ (3.77) FTRI (2.34)	TO (-6.04) Fhi (5.92) vFo (2.79) FTRI (4.32)	Flo (-2.5)
FEMALES -	Fo (-4.94) TO (4.94) VAM (-3.77)	Fo (4.93) TO (3.29) STD (2.33) Jita (3.34) Jitt (2.98) RAP (2.95) PPQ (3.05) sPPQ (3.67) vFo (3.04) sAPQ (3.27) VAM (2.12) NHR (2.05) VTI (2.5)	Fo (-9.6) TO (6.99) Fhi (-3.85) SPI (2.88) -

Prefatigue phonation (PI), phonation after % hour of reading (P2) and phonation after 1 hour reading (P3):

The female subjects showed significant difference across phonations PI, P2, P3 in Average fundamental frequency and Average pitch period in terms of means. The male subject showed significant difference in Average pitch period, Fo tremor intensity index and Highest fundamental frequency between phonations PI & P2 and PI & P3. The female subjects showed similar results in peak amplitude variation.

Hypothesis III a - stating that there was no significant difference between pre-fatigue phonation (PI), phonation after half hour reading (P2) and phonation after one hour of reading (P3) was partly rejected and partly accepted as some parameter showed difference across phonations.

Prefatigue phonation (PI) and phonation after % hour of reading :

Average fundamental frequency , smoothed amplitude perturbation quotient and pitch perturbation quotient showed significant difference in the male subject between phonations PI and P2.

Thus hypothesis III b- stating that there was no significant difference between prefatigue phonation PI and phonation after half hour of reading P2 was partially accepted and partially rejected as some parameters showed significant difference across phonation PI and P2 . Here also half hour was sufficient to induce vocal fatigue .

Prefatigue phonation (PI) and phonation after 1 hour of reading (P3):

In the male subject Variation in fundamental frequency was seen and in females significant difference was seen in Highest fundamental frequency and soft phonation index.

Thus hypothesis III c- stating that there was no significant difference between Prefatigue phonation (PI), phonation after one hour reading (P3) is partly accepted and partly rejected and some parameters where affected due to one hour of reading.

Phonation after % hour of reading (P2) and phonation after 1 hour of reading (P3):

The male subject showed significant difference in Lowest fundamental frequency across phonation P2 & P3 only. Likewise the female subjects showed significant difference in parameters of standard deviation of Fo, Absolute Jitter, Jitter percent, Relative Average perturbation, pitch perturbation quotient, Smoothed pitch perturbation quotient, Variation in fundamental frequency, Smoothed amplitude perturbation quotient, Peak amplitude variation, Noise to harmonic ratio and Voice turbulence index .

Hypothesis III-d stating that there was no significant difference between phonation after - % hour of reading (?2) and phonation after 1 hour of reading (P3) was partly accepted and partly rejected as some parameters were affected across P2 and P3.

In the male subject only nine parameters were affected across phonations in terms of significant differences shown in comparison with 16 parameters as shown by females . Average fundamental frequency, standard deviation of Fo, Highest fundamental frequency, Lowest fundamental frequency, Jitter Percent, Absolute Jitter, pitch perturbation quotient. Variation in fundamental frequency and peak amplitude variation indicated changes across phonations more frequently in male and female subjects. Thus fundamental frequency related parameters (Fo, TO, Fhi, Flo,), short and long tern frequency perturbation measures (Jita, Jitt, PPQ, vfo) and short and long term amplitude perturbation measures are the most sensitive parameters which can be used to study vocal fatigue in teachers.

Hypothesis IV

Inspection of tables and graphs revealed that there was no difference across the phonations PI P2 P3 in terms of different parameters in normals (group I), group II and group III teachers. Thus the hypothesis IV a stating that there was a significant difference in terms of means across phonation in normals, group I and group II teachers in terms of different parameters is rejected. Table showing the sensitive parameters affected in each group of subjects due to fatigue task.

TABLE - 6: Sensitive parameters affected in each group of subjects across phonations

	GROUP-I (Normals)	GROUP-II (0-3 symptoms)	GROUP-III (4-8 symptoms)
p	Fo	Fo	Fo
A	TO	TO	STD
R	Fhi	Fhi	Fhi
A	Flo	Flo	Flo
M	Jita	Jita	Jita
E	Jitt	Jitt	Jitt
T	RAP	RAP	PPQ
E	PPQ	PPQ	vFo
R		sPPQ	VAM
S		sAPQ	
		SPI	
		NHR	

Observation on Table showed that as a group teachers showed more number of parameters affected than normals, however there were not much differences among the teacher groups i.e. group II and group III who differed in terms of number of current symptoms.

Thus the hypothesis IV b stating that there was no significant difference in normals, group I teachers (0 -3 symptoms) and group II teachers (4-8 symptoms) in terms of number of parameters affected is partly accepted and part rejected as there was difference in terms of number of parameters affected between normals, group II and group III teachers but not between group I and II teachers. Hence it can be concluded that teachers are more susceptible to vocal fatigue because of their teaching activities as compared to normals. Also there was no correlation between the number of current symptoms as shown by the questionnaire study and the number of parameters affected as found through multidimensional analysis of voice.

Thus it can be concluded that fundamental frequency related parameters, short and long term frequency perturbation related measurement could be used to assess the fatiguability. Hence the purpose of the study was achieved

SUMMARY AND CONCLUSIONS

In the present study multi-dimensional voice program model 4305 was used to acquire, analyse and display the following 31 voice parameters from a single vocalization. These extracted parameters were available as a numerical values file which was subjected to statistical analysis.

1. Average Fundamental Frequency (Fo)
2. Average Pitch Period (TO)
3. Highest Fundamental frequency (Fhi)
4. Lowest fundamental frequency (Flo)
5. Standard Deviation of Fo (STD)
6. Fo-tremor frequency (Fftr)
7. Amplitude Tremor frequency (Fatr)
8. Absolute Jitter (Jita)
9. Jitter percent (Jitt)
10. Relative average perturbation (RAP)
11. Pitch perturbation quotient (PPQ)
12. Smoothed pitch perturbation quotient (sPPQ)
13. Fundamental frequency variation (vFo)
14. Shimmer in dB (ShdB)
15. Shimmer percent (Shim)
16. Amplitude perturbation quotient (APQ)
17. Smoothed amplitude perturbation quotient (sAPQ)
18. Peak-amplitude variation (vAM)
19. Noise to harmonic Ratio (NHR)
20. Voice Turbulence Index (VTI)
21. Soft phonation Index (SPI)
22. Fo Tremor intensity Index (FTRI)
23. Amplitude tremor Index (ATRI)
24. Degree of voice breaks (DVB)
25. Degree of sub-Harmonics (DSH)
26. Degree of voiceless (DUV)
27. Number of voice breaks (NVB)
28. Number of sub-Harmonic segments (NSH)
29. Number of unvoiced segments (NUV)

The parameters were measured in three groups of subjects. Group I comprised of normals (4 males and 1 female). Three sets of phonations for vowels /a/ , /i/ ,/u/ were recorded in prefatigue phonation (P1), phonation after half hour reading (P2) and phonation after one hour reading (P3)

A questionnaire was designed for teachers who experienced problems due to teaching . It was administered on 55 teachers from four schools in Mysore city. 10 teachers were selected based on the number of current symptoms experienced. They formed group II (0-3 symptoms) with (3 males, 2 females) and group III (4-8 symptoms) with (1 male,4 females).These teachers underwent similar tasks as group I subjects and phonations P1,P2,P3 were recorded. The results were subjected to statistical analysis. (paired T test and descriptive statistics) using NCSS computer programme.

The results indicated the following:

1. In normals (group I), teachers with 0-3 symptoms (group II) and teachers with 4-8 symptoms (group III), there was significant difference across phonations in some of the parameters. These parameters could be considered sensitive to vocal fatigue(using multi-dimensional analysis of voice program). They are Fundamental frequency related measurements (Average fundamental frequency , Average pitch period , Highest fundamental frequency, Lowest fundamental frequency, Standard deviation in F0, short and long term frequency perturbation measures (Absolute Jitter , Jitter percent , Relative average perturbation , Pitch perturbation quotient, smoothed pitch perturbation quotient, fundamental frequency variation). Interestingly , in teachers short and long term amplitude perturbation measurements - (smoothed amplitude perturbation quotient, peak amplitude variation)

and noise related measurements (Noise to harmonics ratio and soft phonation index) were also affected.

2. It was observed that half hour of reading was sufficient to induce vocal fatigue both in normals and teachers as it brought about changes in the acoustic parameters. However there was no linear trend in the amount by which each parameter was affected with increasing fatiguing task. Thus half hour duration of reading was sufficient to study vocal fatigue.

3. As a group the female subjects showed more number of parameters affected than the male subjects in each group.

4. There was no significant difference across the phonations in group I (normals), group II (0-3 symptoms) teachers and group IV (4-8 symptoms) teachers in terms of means in the parameters measured . But there was difference observed in terms of number of parameters affected across the groups . Teachers showed more number of parameters affected across the groups and they showed more number of parameters affected than normals but there was no difference observed between the two teacher groups. Thus no correlation was obtained between the questionnaire report and the acoustic correlates . It can be concluded that the teachers were more susceptible for vocal fatigue than normals and recording of voice in natural conditions at school would have shown more parameters affected.

The sensitive parameters as found in this study could be used to find out the susceptibility of vocal fatigue that is when the parameter are affected after % hour cf reading it can be considered the particular individual is susceptible for vocal fatigue.

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APPENDIX - I

The definition of the 29 parameters as given in the MDVP manual are as follows:-

1. AVERAGE FUNDAMENTAL FREQUENCY (Fo)/Hz/

Average value of all extracted period to period fundamental frequency values. Voice break areas are excluded.

Fo is computed from the extracted period to period pitch data as:

$$Fo = \frac{1}{N} \sum_{i=1}^{N} Fo^{(i)}$$

where $Fo^{(i)} = \frac{1}{TO^{(i)}}$ = period to period fundamental frequency.

$TO^{(i)}$, $i = 1,2,\ldots N$ - extracted pitch period data

N = PER - number of extracted pitch periods.

2. AVERAGE PITCH PERIOD (TO)/msec/

Average volume of all extracted pitch period values voice break areas are excluded.

$$TO = \frac{1}{N} \sum_{i=1}^{N} TO(i)$$

where $TO^{(i)}$, $i = 1,2,\ldots.N$ - extracted pitch period data.

N = PER - number of extracted pitch periods.

3. HIGHEST FUNDAMENTAL FREQUENCY (FHI)/Hz/

The greatest of all extracted period to period fundamental frequency values. Voice break areas are excluded. It is computed as

$$Fhi = \max\ [Fo^{(i)}]\quad i = 1,2,\_\_\_\_N.$$

where $Fo(i) = \frac{1}{TO^{(i)}}$ period to period fundamental

frequency values.

To(i), i = 1,2,...N - extracted pitch period data.

4. LOWEST FUNDAMENTAL FREQUENCY (FLO)/Hz/

The lowest of all extracted period to period fundamental frequency values voice break areas are excluded.

$$FLO = \min\ [Fo^{(i)},\quad i = 1,2,\_\_\_\_N,$$

where $Fo(i) = \frac{1}{To(i)}$ - period fundamental frequency values

To(i) = i = 1,2,....N - extracted pitch period data.

5. STANDARD DEVIATION OF FUNDAMENTAL FREQUENCY (STD)/Hz/

Standard deviation of all extracted period to period fundamental frequency values. Voice break areas. are excluded.

$$STD = \sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (Fo - Fo^{(i)})^2}$$

$$\text{where } Fo = \frac{1}{N} \sum_{i=1}^{N} Fo^{(i)} = \frac{1}{To^{(i)}} \text{ - period to period}$$

fundamental frequency values

To(i) = 1,2,....N - extracted pitch period data.

N = number of extracted pitch period data.

6. Fo - TREMOR FREQUENCY (FFTR)/Hz/

The freqency of the most intensive low frequency Fo modulating component in the specified Fo - tremor analysis range. If the corresponding FTRI values is below the threshold, the Fftr value is zero.

7. AMPLITUDE TREMOR FREQUENCY (FATR)/Hz/

The frequency of the most intensive low frequency amplitude modulating component in the specified amplitude tremor analysis range. If the corresponding ATRIA value is below the specified threshold, the Fatr value is zero.

8. ABSOLUTE JITTER(JITA)/usec/

An evaluation of the period to period variability of the pitch period within the analyzed voice sample. Voice break areas are excluded.

Jita is computed as:

$$Jita = \frac{1}{N-1} \sum_{i=1}^{N-1} |To^{(i)} - To^{(i+1)}$$

where To(i) = i = l,2,....N - extracted pitch period data.

N = PER - number of extracted pitch periods.

Absolute Jitter measures of the pitch short term (cycle-to-cycle) irregularity of the pitch periods in the voice sample. This measure is widely used in the research literature on voice perturbation (Iwata and Vonleden 1970). It is very sensitive to the pitch variations occuring between consecutive pitch periods. However, pitch extraction errors may affect absolute jitter significantly.

The pitch of the voice can vary for a number of reasons, cycle-to-cycle irregularity can be associated with the inability of the vocal cords to support a periodic vibration for a defined period. Usually this type of variation is random. They are typically associated with hoarse voices.

Both Jita and Jitt represent evaluations of the same type of pitch perturbation. Jita is an absolute measure and shows the result in micro-seconds which makes it dependent on the average fundamental frequency of voice. For this reason, the normative values on Jita for men and women differ significantly. Higher pitch results into lower Jita. That's why, the Jita value of two subjects with different pitch are difficult to compare.

9. JITTER PERCENT (JITT)

Relative evaluation of the period-to-period (every short term) variability of the pitch within the analyzed voice sample voice break areas are excluded. It is computed as

$$Jitt = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}\left|To^{(i)} - To^{(i+1)}\right|}{\frac{1}{N}\sum_{i=1}^{N} To^{(i)}}$$

where To(i) , i=l,2,. . . . . . .N - extracted pitch period data.

N = PER - number of extracted pitch periods.

Jitter percent measures the very short term (cycle-to-cycle) irregularity of the pitch period of the voice.Jitt is a relative measure and the influence of the average fundamental frequency of the subject is significantly reduced.

10. RELATIVE AVERAGE PERTURBATION (RAP)/%/

Relative evaluation of the period-to-period variability of the pitch within the analyzed voice sample with smoothing factor of 3 periods. Voice breaks areas are excluded. It is computed as:

$$RAP = \frac{\frac{1}{N-2}\sum_{i=2}^{N-1}\left|\frac{To^{(i-1)}+To^{(i)}+To^{(i+1)}}{3} - To^{(i)}\right|}{\frac{1}{N}\sum_{i=1}^{N} To^{(i)}}$$

where To^**"^ = i=l,2,....N - extracted pitch period data.

N = PER - number of extracted pitch periods.

Relative Average perturbation measures the short term(cycle-to-cycle with smoothing factor of 3 periods) irregularity of the pitch period of the voice. The smoothing reduces the sensitivity of RAP to pitch extraction errors. However, it is less sensitive to the very short term period-to-period variations, but describes the short term pitch perturbation of the voice very well.

The pitch of the voice can vary for a number of reasons, cycle-to-cycle irregularity can be associated with the inability of the vocal cords to support a periodic vibration with a defined period. Hoarse and/or breathy voices may have an increased RAP.

11. PITCH PERIOD PERTURBATION QUOTIENT (PPQ)/%/

Relative evaluation of the period-to-period variability of the pitch within the analyzed voice sample with a smoothing factor of 5 periods. Voice break areas are excluded. PPQ is computed as,

$$PPQ = \frac{\frac{1}{N-4} \sum_{i=1}^{N-4} \left| \frac{1}{5} \sum_{r=0}^{4} To^{(i+r)} - To^{(i+2)} \right|}{\frac{1}{N} \sum_{i=1}^{N} To^{(i)}}$$

where To(i) ,=l,2,......N - extracted pitch period data,
N = PER - number of extracted pitch periods.

PPQ measures the short term (cycle-to-cycle with a smoothing factor of 5 periods) irregularity of the pitch period of the voice. The smoothing reduces the sensitivity of PPQ to pitch-extraction errors while it is less sensitive to period-to-period variations, it describes the short-term pitch perturbation of the voice very well. Hoarse and/or breathy voices may have an increased PPQ.

12. SMOOTHED PITCH PERIOD PERTURBATION QUOTIENT (SAPQ)/X/

Relative evaluation of the short or long term variability of the pitch period within the analysed voice sample at smoothing factor defined by the user. The factory setup for the smoothing factor defined by the user. The factory setup for the smoothing factor is 55 periods, voice break areas are excluded.

$$SAPQ = \frac{\frac{1}{N-sf+1} \sum_{i=1}^{N-sf+1} \left| \frac{1}{sf} \sum_{r=0}^{sf-1} A^{(i+r)} - A^{(i+m)} \right|}{\frac{1}{N} \sum_{i=1}^{N} A^{(i)}}$$

where A(i)= i=l,2,. . . . . ..N extracted peak to peak

N = number of extracted impulses amplitude data.

Sf= smoothing factor SSPQ allows the experimenter to define his own pitch perturbation measure by changing the smoothing factor from 1 to 99 periods. This is desirable because in the scientific literature researchers use pitch perturbation measures with different smoothing factors or without smoothing.

With a small smoothing factor, SSPQ is sensitive mostly to the short-term pitch variation of the voice impulses.

With a smoothing factor of 1 (no smoothing), SSPQ is identical to Jitter variations occuring between consecutive pitch periods. Usually this type of variation is random. It is typical for hoarse voices. However, pitch extraction errors may object Jitter percent significantly.

13. CO-EFFICIENT OF Fo VARIATION (VFO)/%/

Relative standard deviation of the fundamental frequency. It reflects, in general, the variation of Fo (short term to long term), within the analyzed voice sample. Voice break areas are excluded.

$$VFO = \frac{\sigma}{Fo} = \frac{\sqrt{\frac{1}{N} \sum_{i=1}^{N} \left[\frac{1}{N} - Fo^{(i)} - Fo^{(i)} \right]^2}}{\frac{1}{N} \sum_{i=1}^{N} Fo^{(i)}}$$

$$\text{where } Fo = \frac{1}{N} \sum_{i=1}^{N} Fo^{(i)}$$

$Fo(i) = \frac{1}{To(i)}$ period to period Fo values.

N = PER - number of extracted pitch periods.

VFO reveals the variations in the fundamental frequency. The VFO value increases regardless of the type of pitch variation. Either random or regular short term or long term variations increase the value of VFO. Because the sustained phonation normative thresholds assume that the Fundamental frequency should not change, any variations in the fundamental frequency are reflected in VFO. These changes could be frequency tremors (i.e., periodic modulation of the voice) or non periodic changes, very high jitter or simply rising or falling pitch over the analysis length.

14. SHIMMER IN dB (shdb)/db/:

Evaluation is dB of the period-to-period (very short term) variability of the peak-to-peak amplitude within the analyzed voice sample voice break areas are excluded.

$$shdB = \frac{1}{N-1} \sum_{i=1}^{N-1} \left| 20 \log \left(A^{(i+1)} / A^{(i)} \right) \right|$$

where A(i)= i=l,2,.......N - extracted peak to peak amplitude data.

N - number of extracted impulses.

Shimmer in dB measure the very short term cycle-to-cycle irregularity of peak-peak amplitude of the voice. This measure is widely used in the research literature on voice perturbation (Iwata & Von Leden 1970). It is very sensitive to the amplitude variation occuring between consecutive pitch periods. However, pitch'extraction errors may affect shimmer percent significantly.

The amplitude of the voice can vary for a number of reasons. Cycle-to-cycle irregularity of amplitude can be associated with the inability of the vocal folds to support a periodic vibration for a defined period and with the presence of turbulent noise in the voice signal usually this type of variation in random. It is typically associated with hoarse and breathy voices. APQ is the preferred measurement for shimmer because it is less sensitive to pitch extraction errors while still providing a reliable indication of short-term amplitude variability in the voice.'

Both shim and shdB are relative evaluations of the same type of amplitude perturbation but they use different measures for the result percent and dB.

15. SHIMMER PERCENT (SHIM)/X/

Relative evaluation of the period-to-period (very short term) variation of the peak-to-peak amplitude within the analyzed voice sample voice break means are excluded.

$$shim = \frac{\frac{1}{N-1} \sum_{i=1}^{N-1} \left| A^{(i)} - A^{(i+1)} \right|}{\frac{1}{N} \sum_{i=1}^{N} A^{(i)}}$$

where A(i), i=l,2,.......N - extracted peak to peak amplitude N = number of extracted impulses.

Shimmer percent measure the very short term (cycle-to-cycle) irregularity of the peak-to-peak amplitude of the voice.

16. AMPLITUDE PERTURBATION QUOTIENT (APQ)/%/

Relative evaluation of the period-to-period variation, variability of the peak-to-peak amplitude within the analyzed voice sample at smoothing of 11 periods. Voice break areas are excluded.

$$APQ = \frac{\frac{1}{N-4} \sum_{i=1}^{N-4} \left| \frac{1}{5} \sum_{r=0}^{4} A^{(i+r)} - A^{(i+2)} \right|}{\frac{1}{N} \sum_{i=1}^{N} A^{(i)}}$$

where A(i), i=l,2,........N extracted peak to peak amplitude. N = number of extracted impulses.

APQ measures that the short term (cycle-to-cycle with smoothing factor of 11 periods) irregularity of the peak-to-peak amplitude of the voice while it is less sensitive to the period-to-period amplitude variations it still describes the short term amplitude perturbation of the voice very well breathy and hoarse voice usually have an increased APQ. APQ should be regarded as the preferred measurement for shsimmer in MDVP.

17. SMOOTHED AMPLITUDE PERTURBATION QUOTIENT (SAPQ)/%/

Relative evaluation of the short or long term variability of the peak-tp-peak amplitude within the analyzed voice sample at smoothing for the smoothing factor is 55 periods (providing relatively long-term variability the user can change this value as desired) voice break areas are excluded.

$$SAPQ = \frac{\frac{1}{N-sf+1} \sum_{i=1}^{N-sf+1} \left| \frac{1}{sf} \sum_{r=0}^{sf-1} A^{(i+r)} - A^{(i+m)} \right.}{\frac{1}{N} \sum_{i=1}^{N} A^{(i)}}$$

where $A(i)$, $i = 1,2, \ldots N$ - extracted peak-to-peak amplitude data.

N = number of extracted impulses.

sf = smoothing factor.

SAPQ allows user to define their own amplitude perturbation measure by changing the smoothing factor from 1 to 99 periods.

18. CO-EFFICIENT OF AMPLITUDE VARIATION (VAM) /%/

Relative standard deviation of peak-to-peak amplitude. It reflects in general the peak-to-peak amplitude variations (short term to long term) within the analyzed voice sample, voice break areas are excluded.

VAM is computed as ratio of the standard deviation to the average value of the extracted peak-to-peak amplitude data as:

$$VAM = \frac{\sqrt{\frac{1}{N} \sum_{i-1}^{N} \left[\frac{1}{N} \sum_{j=1}^{N} A^{(j)} - A^{(i)} \right]^2}}{\frac{1}{N} \sum_{i=1}^{N} A^{(i)}}$$

where A(i) , i=l,2,.....N - extracted peak to peak amplitude data.

N - number of extracted impulses.

VAM reveals the variations in the cycle-to-cycle amplitude of the voice. The VAM value increases regardless of the type of amplitude variation. Either random or regular short term or long term variation increase the value of VAM.

19. NOISE TO HARMONIC RATIO (NHR)

Average ratio of the inharmonic spectral energy in the frequency range 1500-4500 H2 to the harmonic spectral energy in the frequency range 70-4500 H2. This is general evaluation of noise present in the analyzed signal.

20. VOICE TURBULENCE INDEX (VTI)

Average ratio of the spectral inharmonic high frequency energy in the range 2800-5800 Hz to the spectral harmonic energy in the range 70-4500 Hz in areas of the signal where the influence of the frequency noise.

21. SOFT PHONATION INDEX (SPI)

Average ratio of the lower-frequency harmonic energy in the range 70-1600 Hz to the higher frequency harmonic energy in the range 1600-450 Hz.

22. FREQUENCY TREMOR INTENSITY INDEX (FTRI)/%/

Average ratio of the frequency magnitude of the most sensitive low-frequency magnitude of the analyzed voice signal.

23. AMPLITUDE TREMOR INTENSITY INDEX (ATRl)/%/

Average ration of the amplitude of the most intense low-frequency amplitude modulating component to the total amplitude of the analyzed voice signal.

The method for computation is same as FTRI except that here the peak to peak amplitude data has been taken into consideration instead of fo data.

24. DEGREE OF VOICE BREAKS (DVB)/%/

Ratio of the total length of the areas representing voice breaks to the time of the complete voice sample.

$$DVB = \frac{t_1 + t_2 + \dots t_n}{T_{sam}}$$

Where tl, t2 ... tn - length s of the 1st, 2nd... voice break.

T_{sam} - length of analyzed voice data samples,

DVB does not reflect the pauses before the 1st and after the last voiced areas of the recording. It measure the ability of the voice to sustained uninterrupted voicing. The normative threshold is "0" because a normal voice, during the task of sustaining voice, should not have any voice break areas. In cases of phonation with pauses (such as running speech, voice breaks, delayed start or earlier and of sustained phonation) DVB evaluates only the pauses between the voiced areas.

25) DEGREE OF SUBHARMONIC COMPONENTS (DSH)/X/

Relative evaluation of sub-harmonic to Fo components in the voice sample.

26) DEGREE OF VOICE LESS (DUV)/X/

Estimated relative evaluation of nonharmonic areas (where Fo cannot be detected)in the voice samples.

27) NUMBER OF VOICE BREAKS (NVB)

Number of trimes the fundamental period was interrupted during the voice sample (measured from the first detected period to the last period).

28) NUMBER OF SUBHARMONIC SEGMENTS (NSH)

Number of autocorrelation segments where the pitch was found to be a sub-harmonic of Fo.

29) NUMBER OF UNVOICED SEGMENTS (NUV)

Number of unvoiced segments detected during the autocorrelation analysis.

APPENDIX II

QUESTIONNAIRE

BIOGRAPHICAL INFORMATION :

l.NAME : SEX :

ADD : . SCHOOL/COLLEGE:-

2. Since how long have you been a teacher?
3. At what grades/levels do you teach?
4. How many hours per week do you teach?
5. Do you teach continuously without intervals? If yes, describe.
6. Do you speak more than you use blackboard?
7. Do you do any other work involving speech either before or after school?
8. How much time do you spend in talking to others?
9. Is there lot of noise at the place of work?
10. Are you suffering from any medical illness? Please describe.

CURRENT SYMPTOMS

Please indicate if you experience any of the following symptoms during or after teaching___

11. Dryness of the throat YES/NO
12. Voice tires or changes quality easily while talking YES/NO.
13. Scratchy sensation in the throat YES/NO
14. Discomfort in the throat YES/NO
15. A feeling that talking is an effort or hardwork YES/NO
16. Voice breaks or cracks during speaking YES/NO
17. A constant need to clear the throat YES/NO
18. Shortness of breath while speaking YES/NO

19. Pain in the throat YES/NO

20. Burning sensation in the throat YES/NO

21. Voicelessness - midsentence YES/NO

22. Voicelessness - endsentence YES/NO

CAREER LINKED SYMPTOMS

23. Since you began teaching has your voice improved :r worsened than before.

24. Have you taken any treatment for voice problems : surgical/medical/voice therapy.

25. Have you cutdown on number of teaching hours became of the problem

YES/NO