CHAPTER 1

INTRODUCTION

1.0. DEFINITION OF DYSARTHRIA

Speech produced without any interruption at an optimal rate, that is, without any unusual pauses is considered as fluent. In fluent speech there is the smoothness with which sounds, syllables, words and phrases are joined together during production. Fluent speech production requires a complex and coordinated functioning of the various processes such as respiration, phonation, articulation, prosody and resonance. But if any of the mechanisms falters in its function due to some neurological impairment, it would affect the total speech output and thus would appear to be unintelligible to the listener. This disordered speech is known as dysarthria. The person suffering from dysarthria produces speech that lacks in clarity. The speech sounds are susceptible to misarticulation.

Dysarthria is a motor speech disorder whereby the fluent speech is disrupted and the extent of disruption depends on the severity of the
lesion in the central and/or peripheral nervous system. In dysarthria the disruption of the fluent speech is caused by the paralysis, weakness or incoordination of the speech musculatures involving the various components such as respiration (breathing), phonation (sound produced from the vibration of the vocal folds), articulation (movement of the vocal organs such as tongue, lips), resonance (the amplification of the vocal tone) and prosody (quality and intensity of the voice).

Hence Darley, Aronson and Brown (1975:2) define dysarthria as 'a collective name for a group of related speech disorders that are due to disturbances in muscular control of speech mechanism resulting from impairment of any of the basic motor processes involved in the execution of speech.'

They define the five basic processes of respiration, phonation, articulation, resonance and prosody in the following manner. According to Darley et al (1975:3-5),

'Respiration provides the raw material for speech...In phonation the breath stream sets into vibration the adducted vocal folds of the larynx...This breath stream with periodic and aperiodic components must be shaped and modified through two additional processes. Resonance is the selective amplification of the vocal tone; the pharynx,
oral cavity, and nasal cavity serve as resonators that reinforce certain components of the tone...Ultimately the breath stream is shaped into phonemes (articulation) through impedances produced by the various articulators: the tongue, the teeth, and the lips...The term prosody comprises all the variations in time, pitch, loudness that accomplish emphasis, lend interest to speech, and characterize individual and dialectal modes of expression.

1.1. EXISTING LITERATURE

groups of neurologically impaired speakers (1969) and Kruel, E.J. in the article entitled Neuromuscular control examination (NMC) for Parkinsonism: Vowel prolongations and diadochokinetic and reading rates (1972) study perceptually the quality of phonation and the oral reading rate of the patients with parkinsonism. Again Darley, F. L., A. E. Aronson and J. R. Brown (1975) in the book entitled Motor Speech Disorders describe the specific nature of the speech disturbances associated with lesions of the motor system with main emphasis on the dysarthric English speech. This monumental study is also known as the Mayo Clinic study as it was conducted there. In the Mayo clinic study, brief samples of contextual speech were studied, the degree of impairments in each of several speech and voice dimensions were scaled to arrive at a differential diagnostic patterns of dysarthria. Yorkston, Kathryn M. and David R. Beukelman have prepared an assessment protocol named Assessment of intelligibility of dysarthric speech (1981). Frenchay Dysarthria Assessment (1983) related to the English dysarthric speech is a detailed work by Enderby, P.

Ziegler, W., E. Hartmann and D. von Cramon have reported the work with the German-speaking dysarthrics in the article Word identification testing in the diagnostic evaluation of dysarthric speech (1998). Various significant works have also been done in the area of acoustic analysis
of the dysarthric speech. Lehiste, I. in the article Some acoustic characteristics of dysarthric speech (1965) mention the use of sound spectrograph to measure the speech aspects acoustically. Recent work by Kent, R. D., G. Weismer, J. F. Kent and J. C. Rosenbek have focused on the development of "explanatory" tests of intelligibility in the article Toward phonetic intelligibility testing in dysarthria (1989). Further with the help of perceptual and acoustic analysis Weismer, G. and R. E. Martin have begun to explore specifically which phonetic, acoustic and even physiological features may be contributing to a given speech disorder and elucidated those in the article named Acoustic and perceptual approaches to the study of intelligibility (1992). Computer-based analysis systems are becoming increasingly popular in the present day because of the accuracy and ease with which it can deliver assessment results. Ray D. Kent, Houri K. Vorperian, and Joseph R. Duffy in the article Reliability of the Multi-Dimensional Voice Program for the Analysis of Voice Samples of Subjects With Dysarthria (1999) have introduced robustness and reliability of the computer based analysis program that can calculate acoustic parameters from a dysarthric voice sample and have the potential for rapid quantitative assessments of voice in both research and clinical applications. Ray D. Kent, Jane F. Kent and Gary Weismer in the article entitled What dysarthrias can tell us about the neural control of speech (2000) discuss about how the

In this connection it is to be mentioned that the phonological structure including the prosodic features of speech is a language dependent phenomenon. So findings from the studies on dysarthrics speaking other languages cannot be applied to the dysarthrics speaking Bengali.

According to the 1991 census, in India, Bengali holds the 2nd position in terms of the number of individuals whose mother tongue is Bengali. In West Bengal a large number of people are suffering from various neurological disorders such as stroke, Parkinson’s disease etc. where their speech gets affected to a major degree leading to dysarthria. But because of the dearth of awareness about dysarthria, very few know what characterizes it and in what manner the problem of dysarthria can
be confronted with. So far the speech therapists have dealt with the dysarthric patients from the clinical point of view. In West Bengal, at present there is a dearth of proper awareness for the need of such study. To the best of our knowledge no previous research work has so far been done from the point of view of linguistics for the analysis of the dysarthric Bengali speech by taking insights from neurology.

1.2. AIMS & OBJECTIVES

The objective of the study is firstly to identify the various parameters related to speech, both perceptual and acoustic, which are present in dysarthric Bengali speech of various types. The perceptual analysis may be viewed with respect to the five domains namely, respiration, phonation, articulation, resonance and prosody. The acoustic parameters reflect objectively the production process, which can be visualized through spectrograms and the speech signals. But in this connection it must be mentioned that the chief emphasis is on the perceptual analysis of the recorded data.

Secondly, the objective of the study is to identify the sounds affected during speech production due to dysarthria and thereby to aid in the future management of therapy for dysarthria. Further, the speech
sounds distorted during the time of production due to the disease once identified, will help to trace whether any changes in the phonological pattern of the language have occurred.

On the basis of this analysis an attempt has been made to standardize the linguistic assessment that can help in identifying the nature of the neurological disorder and thus can contribute to its monitoring.

1.3. METHODOLOGY

The present research work was administered on the clinically diagnosed dysarthric individuals at the Neuromedicine Out Patient Department of the Bangur Institute of Neuroscience and Psychiatry, previously known as Bangur Institute of Neurology, Kolkata. An ‘Articulatory Test Material’ consisting of a set of words and sentences was used as a stimulus to elicit response from them and their audio-recorded speech were perceptually analysed by three raters including the researcher. The total time duration of the test for each patient varied from 25-40 minutes depending on the age and the receptive capability of the patient.

To supplement the perceptual analysis, acoustic analysis of some areas was also done. The statistical analysis followed these in order to
validate the results. Further, the statistical analysis was also applied to validate the Articulatory Test Material that was developed for the sole purpose of the study.

1.3.1. SUBJECTS

The present study was conducted on 128 subjects (Male 102, female 26). The subjects participated voluntarily. They were made aware of the purpose of the study and the consenting individuals agreed to perform the test. The subjects were all right handed and they had Bengali as their mother tongue. The age-range of the subjects was 12-73 years. In this study an attempt was made to include all the age groups so that a comprehensive understanding of the problem could be attained. Subjects of the age of 12 years were included in the study as it is accepted that children's ability to learn language continues to be strong until the onset of puberty. The critical period for language acquisition is from 2 years to puberty.

The subjects belonged to not only the urban locality but also the rural areas. The subjects speaking Standard Colloquial Bengali were included in this study. Their educational qualification ranged from school level to post-graduation and above. Subjects exhibiting dysarthria of
different neurological etiologies underwent the linguistic articulatory test to confirm the type of dysarthria.

1.3.2. ARTICULATORY TEST MATERIAL

An 'Articulatory Test Material' consisting of a set of words and sentences was used as a stimulus to elicit response from the dysarthric subjects. As it has already been mentioned, the total time duration of the test for each of the dysarthric subjects varied from 25-40 minutes depending on their age and the receptive capability. The Articulatory Test Material comprises of two categories - a basket of 176 words and a block of text consisting of 9 sentences in Standard Colloquial Bengali (SCB). The 9 sentences in the text block include all Bengali vowel and consonant phonemes. The 9-sentence text was read out by the dysarthric subjects at the conversational rate. This helped to identify the various parameters within the domains of respiration, phonation, articulation, resonance and prosody.

The word basket includes words selected on the basis of frequency of their usage in day-to-day Bengali. These 176 words are selected on the basis of the random survey that was conducted by the researcher on the streets of Kolkata, in the university campus and inside the hospital.
 Individuals of various age groups selected randomly were asked to say three words on any Bengali consonant, consonantal cluster and vowel phoneme in the initial, medial and final positions of words. The words were noted down and later the words for each vowel, consonant and consonantal cluster having the highest frequency counts, were used in the Articulatory Test Material. Moreover, on the basis of the native speaker's intuition of the language usage the words were finalised. The book (Mallik, BP & et al: 1998) on the frequency counts in the Bengali prose based on samples of writing in vernacular newspapers' articles, advertisements and in juvenile literature for the children and adolescents were also consulted while finalizing the words for the test material. These frequency counts according to the author of the book (Mallik, BP & et al: 1998) 'provide essential and reliable information of a statistical linguistic nature about the structure of the Bengali language.'

The 176 words have heterogeneous syllable structures and consist of all the possible structures available in SCB. They are as follows: V, CV, CVC, VC, CCV, CCVC, CCCV, CCCVC, CVCC, VV, CVV, VVC, CVVC, CCVV, CCVVC, CCCVV.
The words are made up of the strings of sounds joined together. So in this study, an attempt has been made to analyse each and every sound production on the basis of their occurrences in the initial, medial and final positions of words. It also focuses on how the dysarthric subjects handle the consonant clusters in the initial, medial and final positions of words.

1.3.3. PERCEPTUAL ANALYSIS

Subjects' productions were recorded using a Sony TCM-150 cassette recorder with built-in microphone at a constant mouth-to-microphone distance of 5 centimeters. The speakers were asked to produce each stimulus word and sentence following the test material. Orthographic representations of the stimulus material were provided in front of the speakers. The words and sentences were written on individual cards. If the subjects could not read the text spontaneously because of some physical discomfort, short phrases are modeled by the examiner and repeated by the subjects.

The patients were asked to do the following tasks:
a) To read out the 176 words.

b) To read out the 9 sentence passage.

c) To read out the Bengali consonants.

d) To count from 1 to 20 in a comfortable pace in order to determine the rate of speech.

e) To repeat the syllables /pO, tO, kO/ (these are the standard forms of syllables which are tested) for 20 times in isolation and also together in order to determine the alternate motion rate or diadochokinetic rate. Diadochokinetic rate is the test of the alternate motion rate of the articulators in which the patients are asked to repeat syllables of /pO, tO, kO/ rapidly. It may be the repetition of the overlapping series of these syllables or the repetition of the single syllables. This act thus helps to capture whether the movements of the articulators have become slow, or fast in comparison to the normal rate.

f) To speak about themselves or on any particular topic in order to determine the rate of speech, voice quality, loudness etc as part
of the parameters under respiration, phonation, prosody and resonance.

The test protocols used for the perceptual analysis are easily applicable and the test format is easily discernable by all and sundry. It is practical as it is less time consuming and can be conducted on a patient having poor physical stamina. The test covers all the areas needed for speech production, that is, respiration, phonation, articulation, prosody and resonance. Altogether 24 parameters under 5 major domains were assessed in the perceptual analysis. They are as follows along with the definition of the terms:

RESPIRATION

1. Forced inspiration-expiration (FIE) – Extra effort is used for the incoming-outgoing air during speech production.
2. Audible inspiration (Ai) – Audible intake of air during speech.

PHONATION

3. Vocal tremor (VT) – Trembling voice during speech.
5. **Alternate loudness (AL)** – Loudness of voice alternates between high and low.

6. **Loudness decay (LD)** – Voice shows progressive diminution of loudness.

7. **Excessive loudness (EL)** – Voice is abnormally loud.

8. **Strained voice (SV)** – Voice has a strangled quality (as if requiring considerable effort for production) resulting from too tight adduction of vocal folds.

9. **Breathy voice (BV)** – Voice has a weak and thin quality, resulting from incomplete adduction of the vocal folds.

10. **Hoarse voice (HV)** – Voice is harsh and raspy.

11. **Aspiration (ASP)** – Speech associated with extra puff of air.

**ARTICULATION**

12. **Imprecise consonant (IC)** – In Bengali there are basically two types of consonants, namely interrupted and continuants. Interrupted are broadly differentiated by their place of articulation. Again for each of the place of articulation there may be four different manners of articulation. For interrupted, therefore, there should be adequate precision for both place and manner of articulation. Any departure from these, which is perceptually disturbing, is considered as
imprecise. Among the continuants are the fricatives, nasals, laterals
and r-sounds. For precise production of the fricatives the place of
articulation is important for Bangla whereas for nasal murmurs the
amount of nasality is important. For laterals, lateralisation is the only
important consideration.

Defects occurring during the production of consonant sounds can
also take place when there is a loose contact between the articulator
and the point of articulation or sometimes when the articulator is
pressed against the place of articulation for a longer period, which
may produce gemination.

13. Distorted vowel (DV) – When the phonetic quality deviates from
that required for the intended vowel in such a way that there is
difficulty in the perception of the vowel.

14. Prolonged phoneme (PP) – The duration of a continuant
phoneme is lengthened abnormally during production.

All these parameters are normally evaluated through perception.
However most of them can also be objectively assessed through
instrumentation.

RESONANCE

15. Hypernasality (HN) – Voice has excessively nasal quality.
16. **Nasal Emission (NE)** – There is emission of the airstream through the nose during word production.

**PROSODY**

17. **Reduced stress (RS)** – Speech lacks in proper emphasis during the time of production.

18. **Excess or equal stress (EES)** – There is stress of equal degree on each word of a sentence and even on normally unstressed portions of speech.

19. **Slow rate (SR)** – Speed of word production is slow.

20. **Variable rate (VR)** – Speed of word production alternates between fast and slow.

21. **Increase in overall rate (IOR)** – Speed of word production increases progressively from beginning to end.

22. **Short rushes (SHR)** – There are short rushes of word production separated by pauses.

23. **Inappropriate silence (IS)** – Speech is interrupted by appropriately long pauses.

24. **Irregular articulatory break (IAB)** – There are unpredictable and unnecessary pauses in between syllables.
The perceptual analysis refers to the method of analysis, which employs the auditory perception of the examiners. The speech samples that were collected from patients in the form of audio-recorded files were submitted for perceptual analysis. Each patient was identified by an alphanumeric code. Three individuals including the researcher did the perceptual analysis on the recordings of the subjects. The other two individuals were totally unaware of the nature of the dysarthric speech and they belonged to separate fields of knowledge. So, before they started their work, the researcher gave a preliminary idea about the way of conducting the rating to them.

The analysis was not done on the spot, as finer defects require time and repeated hearing for assessment. Detailed phonetic transcription of the recorded data sample was done which helped in the detection of the speech sounds that had been added, omitted, substituted or distorted. The rating was done as 'yes' or 'no' for each parameter under the five domains, that is, whether a parameter was present or absent for the particular patient or not. The raters rated independently. The raters paid attention to each parameter and scored accordingly.

Following this the statistical analysis was done with the help of a statistician using Statistica version 6.0 (Statsoft Incorporation, Tulsa, Oklahoma, USA; 2000) software.
1.3.4. ACOUSTIC ANALYSIS

The five domains namely, respiration, phonation, articulation, resonance and prosody which are normally examined through perception for determining abnormality leading to the diagnosis of the disease leave their tale-tell marks in the acoustic structure of the resulting signal. It may be interesting to know to what extent an objective acoustic analysis of the signal can lead to the detection of these abnormalities. An attempt had been made in this study towards this. Some clinical procedure viz, Multi-Dimensional Voice Program (MDVP) already exists towards the detection of pathological abnormalities in the sustained phonation /a/. This was examined in relation to the selected diseases namely spastic and hypokinetic dysarthria. Apart from that other problems related to abnormal prolongation of phonemes, imprecise consonants and distorted vowels were also examined from graphical representations of the sound belonging to both the spectral and signal domains. In essence, the idea was to see where and to what extent objectivity could be introduced in assessing the pathological conditions.

The Multi Dimensional Voice Program software is extensively used in clinical practice for voice related disorders. In dysarthria the phonatory problem is an important feature. The aforesaid program is
recommended for dysarthria (Kent et al, 2003). The prevalence of spastic dysarthria and hypokinetic dysarthria is highest in India\(^1\) hence these two types of dysarthrias were selected for the present purpose.

The Multi-Dimensional Voice Program (MDVP) software option for CSL is available at the Indian Statistical Institute, Kolkata. The equipment was kindly allowed by the institute to be used for the present study. Because of some constraints there the numbers of the patients for the analysis was cut down. On the basis of the acuteness of the disease as observed through perceptual analysis, 9 for spastic dysarthria and 8 for hypokinetic dysarthria were only selected for a pilot study.

The MDVP is suitable for analyzing abnormalities in the voiced segment of speech sounds. It, therefore, stands to reason to select such phonation, which has least interference in the production of the sound. The oral vowels are one such. Of all the oral vowels in Bengali /a/ is the most open and the height of the tongue hump is also least. This vowel therefore is likely to affect the source voice least. That is why the vowel /a/ was selected for the study. Following this the audio recorded sustained phonation /a/ of the aforesaid patients were fed into MDVP

\(^1\) Indian Council of Medical Research (ICMR) Project on 'Epidemiology of Major Neurological Disorders – A Random Sample Survey in the City of Kolkata', Oct 2002- Sep 2005
software for the voice analysis. Next the statistical analysis was done in order to do a comparative study between the dysarthric groups and the control group.

As put forwarded by Kent (Kent et al, 2003: 287), the following thirty-four parameters are grouped into nine domains, viz, Fo parameters, Frequency Perturbation Parameters, Amplitude Parameters, Voice Irregularity Parameters, Voice Break Related Parameters, Subharmonic Analysis, Noise Parameters, Tremor Parameters and Parameters Related to Experimental Constraints.

The definitions of these thirty-four parameters are taken from the Software Instruction Manual of Multi Dimensional Voice Program (MDVP), 2003.

**F₀ PARAMETERS**

1. **Fhi (Highest fundamental Frequency /Hz/)** - It is the frequency, i.e. the inverse of time period of the lowest pitch period found from all extracted pitch periods.

2. **Flo (Lowest Fundamental Frequency /Hz/)** - It is the frequency, i.e. the inverse of time period of the highest pitch period found from all extracted pitch periods.
3. **Fo (Average Fundamental Frequency /Hz/) - It is the average of all extracted momentum² fundamental frequency values (reciprocal of pitch periods).**

4. **Mfo (Mean Fundamental Frequency /Hz/) - It is the mean of all extracted momentum² fundamental frequency values.**

5. **PFR (Phonatory Fundamental Frequency Range) - Range between Fhi and Flo expressed in number of semi-tones (semitone refers to the ratio of two frequencies expressed in logarithmic scale).**

6. **STD (Standard Deviation of the Fundamental Frequency /Hz/) - It gives a measure of how the fundamental frequencies are distributed within the analyzed voice sample.**

Human vocalic signal is not exactly periodic; it is quasiperiodic which means that two consecutive waveforms are not exactly equal. They may differ in all the basic parameters defining a signal. This period-to-period differentiation may be of pitch period (jitter), amplitude (shimmer) and complexity (usually represented by noise to harmonic ratio).

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² The definition of momentum is not available in the Software Instruction manual of Kay Elemetrics Corp. The experimental relationship of Mfo and Fo will be discussed later.
FREQUENCY PERTURBATION PARAMETERS

7. Jita (Absolute Jitter /usec/) - An evaluation of the period-to-period variability of the pitch period within the analyzed voice sample. Voice break areas are excluded.

8. Jitt (Jitter Percent /%) - Relative evaluation of the period-to-period (very short term) variability of the pitch within the analyzed voice sample. Voice break areas are excluded.

9. PPQ (Pitch Period Perturbation Quotient /%) - 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.

10. RAP (Relative Average perturbation /%) - Relative evaluation of the period-to-period variability of the pitch within the analyzed voice sample with a smoothing factor of 3 periods. Voice break areas are excluded.

11. vFo (Fundamental Frequency Variation /%) - Relative standard deviation of the period-to-period calculated fundamental frequency. It reflects the very long-term variations of Fo for all analyzed voice samples.

12. SPPQ (Smoothed Pitch Period perturbation Quotient /%) - Relative evaluation of the short- or long-term variability of
the pitch period within the analyzed voice sample at smoothing factor defined by the user. The factory setup for the smoothing factor is 55 periods. Voice break areas are excluded.

AMPLITUDE PARAMETERS

13. **APQ (Amplitude Perturbation Quotient /%/) -** Relative evaluation of the period-to-period variability of the peak-to-peak amplitude within the analyzed voice sample at smoothing level of 11 periods. Voice break areas are excluded.

14. **SAPQ (Smoothed Amplitude Perturbation Quotient /%/) -** Relative evaluation of the short- or long-term variability of the peak-to-peak amplitude within the analyzed voice sample at smoothing factor defined by the user. The factory setup 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.

15. **ShdB (Shimmer in dB /dB/) -** Evaluation in 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.
16. **Shim (Shimmer Percent /%/) -** Relative evaluation 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.

17. **vAm (Peak Amplitude Variation /%/) -** Relative standard deviation of the period-to-period calculated fundamental frequency. It reflects the very long-term variations of Fo for all analyzed voice samples.

**VOICE IRREGULARITY PARAMETERS**

18. **DUV (Degree of Voiceless /%/) -** Estimated relative evaluation of nonharmonic areas (where Fo cannot be detected) in the voice sample. In case of nonsustained phonation from the beginning to the end of the data acquisition, DUV will evaluate also the pauses before, after and/or between the voice sample(s).

19. **NUV (Number of Unvoiced Segments) -** Number of unvoiced segments in the total signal detected during the autocorrelation analysis.
VOICE BREAK RELATED PARAMETERS

20. **DVB (Degree of Voice Breaks [%])** - Ratio of the total length of areas representing voice breaks to the time of the complete voice sample.

21. **NVB (Number of Voice Breaks)** - It shows how many times the generated Fo was interrupted from the beginning of the first until the end of the last voiced area.

SUBHARMONIC ANALYSIS

22. **DSH (Degree of Sub-harmonics [%])** - It is the estimated relative evaluation of sub-harmonic (i.e. a component frequency less than fundamental) to Fo components in the voice sample.

23. **NSH (Number of Sub-Harmonic Segments)** - Number of sub-harmonic segments found during analysis.

NOISE PARAMETERS

24. **VTI (Voice Turbulence Index)** - 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 and amplitude variations, voice breaks, and sub-harmonic components are minimal. VTI measures the relative energy level of high-frequency noise.

25. **SPI (Soft Phonation Index)** - Average ratio of the lower-frequency harmonic energy in the range 70-1600 Hz to the higher-frequency harmonic energy in the range 1600-4500 Hz.

26. **NHR (Noise-to-Harmonic Ratio)** - Average ratio of the inharmonic spectral energy in the frequency range 1500-4500 Hz to the harmonic spectral energy in the frequency range 70-4500 Hz. This is a general evaluation of noise present in the analyzed signal.

**TREMOR PARAMETERS**

27. **ATRI (Amplitude Tremor Intensity Index /%/)** - Average ratio of the amplitude of the most intense low-frequency amplitude modulating component (amplitude tremor) to the total amplitude of the analyzed voice signal.

28. **Fatr (Amplitude-Tremor Frequency /Hz/)** - The frequency of the most intensive low-frequency amplitude-modulating component in the specified amplitude-tremor analysis range. If
the corresponding ATRI value is below the specified threshold, the Fatr value is zero.

29. **Fftr (Fo-Tremor Frequency /Hz/)**- The frequency of the most intensive low-frequency Fo-modulating component in the specified Fo-tremor analysis range. If the corresponding FTRI value is below the specified threshold, the Fftr value is zero.

30. **FTRI (Frequency Tremor Intensity Index /%/)**- Average ratio of the frequency magnitude of the most intensive low-frequency modulating component (Fo-tremor) to the total frequency magnitude of the analyzed voice signal.

PARAMETERS RELATED TO EXPERIMENTAL CONSTRAINTS

31. **PER (Pitch Periods)** – Number of pitch periods in the whole signal detected during the period-to-period pitch extraction.

32. **SEG (Total number of Segments)** - Computed during the autocorrelation analysis.

33. **To (Average Pitch Period /ms/)**- Average of all extracted pitch periods.

34. **Tsam /sec/**- Length of Analyzed Data Sample.
1.4. PLAN OF WORK

The present work is divided into six chapters. The first chapter contains the introduction to the research theme, existing literature, aims and objectives, methodology and the plan of work. The second chapter deals with the description of the nervous system and the nature of the six types of dysarthria. The third chapter focuses on the interrelationship between dysarthria and linguistics. The fourth chapter is concerned with the description of the skeletal structure of the Bengali phonology. In this connection it can be mentioned that while studying the speech production of the dysarthric individuals it has been observed that the distortions are seen mainly on the level of the speech sounds. Therefore, it is important to note how a dysarthric individual is pronouncing each consonant, consonantal cluster and vowel sound in isolation, in single words and in conversational speech. Pronunciation often seems to be better in one-word responses than in conversation. Infact fine motor control and coordination is more involved in producing a long sentence than in one word response. It is at the level of misappropriating articulation of speech sounds. So, to study the nature of the dysarthric speech the task that appears to be the most important is to study its phonetic as well as phonological nature. The present study attempts to investigate in that line so far as the dysarthric Bengali
speech is concerned. Further, it is necessary to look at the acoustics of the speech produced by the dysarthric patients since any production disorder will leave its telltale mark on the acoustics. These are discussed in the chapters 4 and 5 whenever felt relevant. The first four chapters in fact prepare the ground for the fifth one, that is, a linguistic analysis of the dysarthric Bengali speech, which is the main issue of the present study. This chapter focuses on how far the speech of the dysarthric Bengali individuals deviates from that of the normal Bengali individuals. The sixth, that is, the final chapter includes the concluding remarks.

REFERENCES

