CHAPTER 5
AN ANALYSIS OF THE
DYSARTHRIC BENGALI SPEECH

5.0. INTRODUCTION

It has already been discussed in the previous chapters that 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 oral structures such as tongue, lips), resonance (amplification of the voice) and prosody (quality and intensity of the voice). Hence, Darley, Aronson and Brown (1975:3) defined 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.'
There is a lack of awareness among the individuals suffering from dysarthria and also among their family members. Most of the dysarthric individuals shy away from the society out of the fear of talking. However, it has to be kept in mind that social isolation is not the remedy. Rather, identification and evaluation of the problem will generate awareness among the individuals and the community and inspire them to seek for remedial measures. Hence, in order to identify the nature of the problem, a detailed analysis of the dysarthric Bengali speech is necessary.

For doing so the recorded data of the one hundred and twenty eight patients have been thoroughly analysed. Though the analysis has been done primarily from the perceptual viewpoint, a acoustic analysis of some selected data (see Section 1.3.4) of the recorded speech has also been done. Along with it the acoustic analysis of the phonation /a/ by 9 spastic dysarthric patients and 8 hypokinetic dysarthric patients have been done.

This chapter is the main focus of the study and it deals with the analysis of different kinds of speech deficits affecting the various domains of respiration, articulation, phonation, prosody and resonance in the six types of dysarthria, namely, spastic dysarthria, flaccid dysarthria, mixed
dysarthria, hypokinetic dysarthria, hyperkinetic dysarthria and ataxic dysarthria in Bengali (see Section 2.7).

5.1. DETAILS OF SUBJECTS IN SIX TYPES OF DYSARTHRIA

128 patients are involved in the present study from the Out patient department of Bangur Institute of Neuroscience and Psychiatry.

The subjects have been selected on the basis of the following criteria:

1. All the subjects should have Bengali as their mother tongue.

2. All the subjects should be literate.

3. They should be diagnosed of having neurological disorder leading to dysarthria.

The age range of the subjects is from 12 to 73 years. Out of them twenty-six (20.3%) are females. The low ratio of the female is owing to their less participation in this study. Only the consenting participants are included in the study. Almost all the individuals come from urban locations. They are all literates with the minimum education of standard VIII to the maximum education of post graduation and equivalent.
The following table 5.1 (see Appendix C: 2-7) shows the age profile and distribution of neurological disorders with their anatomical substrates for subjects suffering from different types of dysarthria. Although the age range is wide, majority of the subjects are middle-aged adults.

Table 5.1: Age profile and distribution of neurological disorders with their anatomical substrates for the study subjects.

<table>
<thead>
<tr>
<th>Dysarthria type</th>
<th>Age range</th>
<th>Age Median</th>
<th>Etiology</th>
<th>Anatomical substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spastic</td>
<td>12-73</td>
<td>50</td>
<td>Cerebrovascular accident, Pseudobulbar palsy</td>
<td>Upper Motor Neuron</td>
</tr>
<tr>
<td>[n = 35]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flaccid</td>
<td>12-65</td>
<td>45</td>
<td>Bulbar palsy, Muscular dystrophy</td>
<td>Lower Motor Neuron</td>
</tr>
<tr>
<td>[n = 14]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypokinetic</td>
<td>32-70</td>
<td>63.5</td>
<td>Parkinson's disease</td>
<td>Basal Ganglia</td>
</tr>
<tr>
<td>[n = 24]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyperkinetic</td>
<td>14-65</td>
<td>36</td>
<td>Chorea, Dystonia</td>
<td>Basal Ganglia</td>
</tr>
<tr>
<td>[n = 13]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ataxic</td>
<td>22-65</td>
<td>34</td>
<td>Spinocerebellar ataxia, Cerebellar hematoma</td>
<td>Cerebellum</td>
</tr>
<tr>
<td>[n = 11]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>12-65</td>
<td>26</td>
<td>Wilson's disease, Pseudobulbar palsy with Parkinson's disease, Multisystem atrophy</td>
<td>UMN, LMN, Basal Ganglia</td>
</tr>
<tr>
<td>[n = 31]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: UMN- Upper Motor Neuron, LMN- Lower Motor neuron, n- number of the subjects
SPASTIC DYSARTHRIA

In spastic dysarthria the anatomical substrate affected is the upper motor neuron (see Section 2.7.1). The total number of patients involved in this study is 35. Of them only 4 individuals are female. The age range of the patients is 12-73 and the median age is 50, which suggests that most of the individuals are middle-aged. The various causes that lead to this kind of dysarthria for the participating patients are Cerebrovascular accident and Pseudobulbar palsy.

FLACCID DYSARTHRIA

In flaccid dysarthria the anatomical substrate affected is the lower motor neuron (see Section 2.7.2). The total number of patients is 14. Out of them 4 are female. The age range of the patients is 12-65 and the median age is 45. Most of the individuals are middle-aged. The main causes that lead to this dysarthria for the participating patients are Bulbar palsy and Muscular dystrophy.

HYPOKINETIC DYSARTHRIA

In hypokinetic dysarthria the anatomical substrate affected is the Basal Ganglia (see Section 2.7.3). The total number of patients involved in this study is 24. Of them only 2 individuals are female. The age range of the patients is 32-70. The median age is 63.5, which suggests that most
of the individuals are of senior age group. The chief cause that leads to this kind of dysarthria is Parkinson's disease for the participating patients.

**HYPERKINETIC DYSARTHRIA**

In hyperkinetic dysarthria the anatomical substrate affected is the Basal ganglia (see Section 2.7.4). The total number of patients involved in this study is 13. Of them only 2 individuals are female. The age range of the patients is 14-65. The median age is 36. It suggests that most of the individuals are young members. The main causes that lead to this kind of dysarthria for the participating patients are Chorea and Dystonia.

**ATAXIC DYSARTHRIA**

In ataxic dysarthria the anatomical substrate affected is the cerebellum (see Section 2.7.5). The total number of patients involved in this study is 11. In this dysarthria the majority number is of females, that is, 6. The age range of the patients is 22-65 and the median age is 34, which suggests that most of the individuals are young. The various causes that lead to this kind of dysarthria for the participating patients are Spinocerebellar ataxia and Cerebellar hematoma.
MIXED DYSARTHRIA

In mixed dysarthria the anatomical substrate affected is the upper motor neuron, Lower Motor Neuron, Basal Ganglia and Cerebellum (see Section 2.7.6). The total number of patients involved in this study is 31. Of them only 8 individuals are female. The age range of the patients is 12-65 and the median age is 26, which suggests that most of the individuals are young. The causes that lead to this kind of dysarthria for the participating patients are Wilson's disease, Pseudobulbar palsy with Parkinson's disease and Multisystem atrophy.

5.2. ANALYSIS OF THE DEFECTIVE LINGUISTIC PARAMETERS THROUGH PERCEPTUAL ANALYSIS

To make the study based on the perceptual analysis of the recorded data more objective, the analysis is done by three raters including the researcher. The raters have judged all the subjects on the basis of all the twenty-four parameters as already described and defined in Section 1.3.3. Both intra-rater and inter-rater validations are done with the help of a statistician. The intra-rater validation has been done with a gap of six months as per the advice of the statistician. In the validation exercise done with all the 128 subjects, the Intra Class Correlation for the intra-rater and inter-rater validation is calculated by SPSS 11.0 2-
way Mixed Model Absolute Agreement. Further, the intra-rater validation between ratings on two different occasions is also calculated by Spearman's rank correlation coefficient. In both the cases the intra class correlation coefficient is above 0.9 for most of the 24 parameters in both intra-rater and inter-rater validation; the minimum value obtained being 0.74. (Appendix C: Table 24 -26). This suggests that the intelligibility assessment is not biased by foreknowledge of the speech stimulus. And it further asserts that the Articulatory Test Material that has been used for identifying the dysarthric patients is both accurate and reliable.

The prevalence of different linguistic parameters, under the five domains of respiration, phonation, articulation, resonance and prosody for each type of dysarthria namely spastic, flaccid, hypokinetic, hyperkinetic, ataxic and mixed dysarthria have been summarized in Table 5.2. (see Appendix C: Table 23). Parameters present in only a few subjects (less than 25% within a particular type of dysarthria) have been excluded.

Further, depending upon the statistically significant differences in the frequency of various parameters among different dysarthria types, it has been found that individual parameters could help to distinguish certain
dysarthria types from others (see Appendix C: Table 8-22). These results have been detailed below.

Table 5.2: Prevalence of different linguistic defects in the 6 dysarthria types.

<table>
<thead>
<tr>
<th>Spastic</th>
<th>Flaccid</th>
<th>Hypokinetic</th>
<th>Hyperkinetic</th>
<th>Ataxic</th>
<th>Mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC (74.2%)</td>
<td>IC (78.5%)</td>
<td>IC (75%)</td>
<td>IC (92.3%)</td>
<td>IC (90.9%)</td>
<td>IC (80.6%)</td>
</tr>
<tr>
<td>SV (71.4%)</td>
<td>HN (78.5%)</td>
<td>HV (60.5%)</td>
<td>SV (76.9%)</td>
<td>EES (63.6%)</td>
<td>ML (61.2%)</td>
</tr>
<tr>
<td>RS (51.4%)</td>
<td>ML (57.1%)</td>
<td>ML (45.8%)</td>
<td>IAB (53.8%)</td>
<td>IAB (63.6%)</td>
<td>RS (58%)</td>
</tr>
<tr>
<td>ML (42.8%)</td>
<td>BV (50%)</td>
<td>IOR (45.8%)</td>
<td>VT (46.1%)</td>
<td>HV (54.5%)</td>
<td>PP (51.6%)</td>
</tr>
<tr>
<td>SR (40%)</td>
<td>RS (42.8%)</td>
<td>SHR (41.6%)</td>
<td>RS (46.1%)</td>
<td>DV (36.3%)</td>
<td>EES (51.6%)</td>
</tr>
<tr>
<td>HN (40%)</td>
<td>PP (35.7%)</td>
<td>RS (41.6%)</td>
<td>IS (46.1%)</td>
<td>RS (36.3%)</td>
<td>HN (45.1%)</td>
</tr>
<tr>
<td>DV (28.5%)</td>
<td></td>
<td>SR (38.4%)</td>
<td>PP (27.2%)</td>
<td>SV (35.4%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ML (30.7%)</td>
<td></td>
<td>ML (27.2%)</td>
<td>IAB (29.3%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>VR (27.2%)</td>
<td>VR (29%)</td>
</tr>
</tbody>
</table>

Note: This table includes only those parameters, which were present in at least 25% of the subjects.

SPASTIC DYSARTHRIA

In spastic dysarthria the following speech defects have been observed. Except for the domain of respiration all the other four domains namely, phonation, articulation, prosody and resonance are affected here.

PHONATION
In spastic dysarthria, strained voice is displayed by 71.4% of the subjects, and monoloudness by 42.8%.

ARTICULATION
The articulation domain is also affected considerably. 74.2% of the subjects display imprecise consonants.

PROSODY
Defects related to prosody are displayed through reduced stress and slow rate, seen in 51.4% and 40% of the subjects respectively.

RESONANCE
Hypermnasality, a resonance domain parameter, is found in 40% of the subjects.
FLACCID DYSARTHRIA

In flaccid dysarthria the following defects are observed. Except the domain of respiration all other four domains of phonation, articulation, resonance and prosody are affected.

PHONATION

Phonation defects are manifested through the presence of monoloudness in 57.1% and breathy voice quality in 50% of the subjects.

ARTICULATION

In flaccid dysarthria, imprecise consonant is the predominant defect affecting 78.5% of the subjects. The coexistence of the prolonged phoneme defect, in 35.7%, and distorted vowel in 28.5% of the subjects indicate that the articulation domain is badly affected. Large range of severity is in imprecise consonants. Clinically it is the result of the damage to the facial and hypoglossal nerves. Further, damage to the Trigeminal nerve can result in difficulty in elevating the jaw sufficiently to bring the articulators into contact with each other. Moreover, bilateral damage to the cranial nerve VII will impact vowels requiring lip rounding as in /O, o, u/.
PROSODY
In addition, the prosodic defect of reduced stress is found in 42.8% of the subjects.

RESONANCE
Hypernasality affecting 78.5% of the subjects.

HYPOKINETIC DYSARTHRIA

The following speech defects are observed in hypokinetic dysarthria. Phonation, articulation and prosody are only the three domains that are affected.

PHONATION
In hypokinetic dysarthria, phonatory defects are pronounced, manifesting through the presence of monoloudness in 45.8% of the subjects and the harsh voice quality in 60.5% of the subjects.

ARTICULATION
The articulatory domain is greatly affected as almost 75% of the subjects display imprecise consonants.
PROSODY
Reduced stress, a prosodic defect, also affects 41.6% of the subjects along with increase in overall rate, which affects at least 45.8% of the subjects. Short rushes are also found in 41.6% of the subjects.

HYPERKINETIC DYSARTHRIA

The following speech defects are observed in hyperkinetic dysarthria. All the four domains of phonation, articulation, prosody and resonance are affected. The domain of respiration is an exception.

PHONATION
Phonation defects are also frequent, with strained voice affecting 76.9%, vocal tremor affecting 46.1% and monoloudness affecting 30.7% of the subjects.

ARTICULATION
Imprecise consonant affects 92.3% of hyperkinetic dysarthric subjects.

RESONANCE
The resonatory feature of inappropriate silence is found among 46.1% of the subjects.
PROSODY
Prosodic defects include reduced stress in 46.1%, slow rate in 38.4% and irregular articulatory break in 53.8% of the subjects.

ATAXIC DYSARTHRIA
The following speech defects are observed in ataxic dysarthria. The three domains of phonation, articulation and prosody only are affected.

PHONATION
Phonation components which are usually affected are voice quality being harsh in 54.5% of the subjects and monoloudness in 27.2% of the subjects.

ARTICULATION
All the parameters of the articulatory domain are present in a considerable number of subjects. Of them the prevalence of imprecise consonants is highest with 90.9%, followed by the presence of distorted vowel in 36.3% of the subjects and prolonged phoneme in 27.2% of the subjects.
**PROSODY**

In ataxic dysarthria, the prosodic domain is largely affected – 63.6% of the patients had defects of both excess and equal stress and irregular articulatory break. Variable rate and reduced stress are found in at least 27.2% and 36.3% of the subjects respectively.

**MIXED DY SAR THRIA**

Mixed dysarthria, as the name suggests, displays a large number of defects representing different dysarthria types. The domains of phonation, articulation, resonance and prosody are affected.

**PHONATION**

The phonatory defects are manifested with the presence of mono loudness in 61.2% of the subjects and strained voice in 35.4% of the subjects.

**ARTICULATION**

The articulation domain is considerably affected, as imprecise consonant is present in 80.6% of the subjects along with prolonged phoneme in 51.6% of the subjects.
RESONANCE

Hypernasality, the resonance defect is found in almost 45.1% of the subjects.

PROSODY

In this study, excess and equal stress is present in 51.6% of the subjects and irregular articulatory breaks are present in 29.3% of the subjects. The prosodic defects such as reduced stress and variable rate are also found in 58% and 29% of the subjects respectively.

5.2.1. DISCUSSION

The present study has attempted to define the linguistic defects to be encountered in six types of dysarthric Bengali speech. It is observed that excluding the domain of respiration the other four domains that are mainly affected in the six types of dysarthria are the domains of phonation, articulation, resonance and prosody. Only in hypokinetic dysarthria and ataxic dysarthria the resonance domain is not affected. In the present study, however, the domain of respiration does not show any significant impact on the condition of the patients in any of the dysarthrias. Further, it is observed that even all the parameters are not essential for describing the defects in each type of dysarthria. Out of the
full range of linguistic parameters that may be assessed in cases of
dysarthria, a more limited number can suffice to describe the defect. It is
found that 17 out of the original 24 assessed, suffice to describe and
distinguish between the various dysarthria types.

They are as follows:

PHONATION

1. Monoloudness (ML)
2. Vocal tremor (VT)
3. Strained voice (SV)
4. Breathy voice (BV)
5. Harsh voice (HV)

ARTICULATION

6. Imprecise consonant (IC)
7. Distorted vowel (DV)
8. Prolonged phoneme (PP)

RESONANCE

9. Hypernasality (HN)
The above linguistic observations are quite important, as it would help in planning the speech therapy or the augmentative and alternative communication techniques for the dysarthric individuals (see Section 6.1). The processes of articulation consist of the parameters that are necessary for speech to be clearly understood, like the precise production of the consonant phonemes and the vowel phonemes. If, instead, an individual produces imprecise consonants and distorted vowels, his speech becomes unintelligible to others. Similarly, the prosody of speech is excessively important as it contains the essence of a sentence produced by a speaker. It is the prosodic feature of the speech that adds melody and rhythm to it. The various prosodic parameters include intonation, stress and the rate of the speech. These
parameters spread over more than a single consonant or a vowel, which forms words, and hence they are often referred to as the suprasegmental aspects of speech. It has been observed that these parameters are affected to a greater or lesser extent in the various types of dysarthrias. If the laryngeal subsystem is weak, it affects the phonation domain of the patients through the change of the voice quality and loudness level as observed in the present study. When the velopharyngeal subsystem is not working, it leads to disturbances in the resonance domain and the speech becomes hypernasal. Thus, in dysarthria the fluency of the speech is disrupted and the dysarthric speakers need more time to get their message across. As a result the speech of the individual may be difficult to understand. He becomes thus both physically disabling and socially isolating.

Coming to the field of neurology it can be said that the correlation between the linguistic defects and the dysarthria types may prove to be a pointer to the type of neurological lesions that may underlie the defect, and therefore, may help in planning subsequent intervention and management of the disease. Since many of the parameters overlap in the six types of dysarthria, it may become confusing at times to identify the type of dysarthria with the help of the parameters only. Hence, an attempt has also been made to identify certain parameters, which may help to distinguish one dysarthria type from the other type (see Appendix C: Table 8-22). Since mixed dysarthria
comprises of more than one type, it cannot be isolated from other dysarthria types.

Table 5.3: Parameters distinguishing between different dysarthria types.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Distinguishing between</th>
</tr>
</thead>
<tbody>
<tr>
<td>DV</td>
<td>Flaccid &amp; Hypokinetic, Ataxic &amp; Hypokinetic</td>
</tr>
<tr>
<td>PP</td>
<td>Flaccid &amp; Hypokinetic, Ataxic &amp; Hypokinetic</td>
</tr>
<tr>
<td>VT</td>
<td>Hyperkinetic &amp; Spastic, Hyperkinetic &amp; Hypokinetic, Ataxic &amp; Spastic</td>
</tr>
<tr>
<td>SV</td>
<td>Spastic &amp; Flaccid, Spastic &amp; Hypokinetic, Spastic &amp; Ataxic, Hyperkinetic &amp; Flaccid, Hyperkinetic &amp; Hypokinetic, Hyperkinetic &amp; Ataxic</td>
</tr>
<tr>
<td>BV</td>
<td>Flaccid &amp; Spastic, Flaccid &amp; Hypokinetic, Flaccid &amp; Hyperkinetic, Flaccid &amp; Ataxic</td>
</tr>
<tr>
<td>HV</td>
<td>Hypokinetic &amp; Spastic, Hypokinetic &amp; Flaccid, Hypokinetic &amp; Hyperkinetic, Ataxic &amp; Spastic, Ataxic &amp; Flaccid, Ataxic &amp; Hyperkinetic</td>
</tr>
<tr>
<td>SHR</td>
<td>Hypokinetic &amp; Spastic, Hypokinetic &amp; Flaccid, Ataxic &amp; Spastic, Hypokinetic &amp; Hyperkinetic</td>
</tr>
<tr>
<td>IOR</td>
<td>Hypokinetic &amp; Spastic, Hypokinetic &amp; Flaccid, Hypokinetic &amp; Hyperkinetic, Hypokinetic &amp; Ataxic</td>
</tr>
<tr>
<td>IS</td>
<td>Hyperkinetic &amp; Spastic, Hyperkinetic &amp; Flaccid, Hyperkinetic &amp; Hypokinetic, Hyperkinetic &amp; Ataxic</td>
</tr>
<tr>
<td>EES</td>
<td>Ataxic &amp; Spastic, Ataxic &amp; Flaccid, Ataxic &amp; Hypokinetic, Ataxic &amp; Hyperkinetic</td>
</tr>
<tr>
<td>IAB</td>
<td>Hyperkinetic &amp; Spastic, Hyperkinetic &amp; Flaccid, Hyperkinetic &amp; Hypokinetic, Hyperkinetic &amp; Ataxic</td>
</tr>
<tr>
<td>VR</td>
<td>Ataxic &amp; Flaccid, Ataxic &amp; Hypokinetic</td>
</tr>
</tbody>
</table>

Abbreviations: DV= distorted vowel; PP= prolonged phoneme; VT = vocal tremor; SV = strained voice; BV = breathy voice; HV = harsh voice; SHR = short rushes; IOR= increase in
By analyzing the Tables 5.2 and 5.3 a group of parameters may be selected, which help to identify the five types of dysarthria, namely spastic, flaccid, hypokinetic, hyperkinetic and ataxic separately. The parameters, which are common in both the tables 5.2 and 5.3 for the dysarthrias, are selected as the distinctive features in identifying a dysarthria type.

From the tables 5.2 and 5.3 it can be hypothesized that for spastic dysarthria the parameters strained voice and hypernasality may prove to be helpful in distinguishing it from other types of dysarthria.

Similarly, for flaccid dysarthria the significant parameters, which help in identification, are hypernasality and breathy voice.

For hypokinetic dysarthrias the parameters are harsh voice, short rushes, and increase in overall rate.

In case of hyperkinetic dysarthria the distinctive parameters are vocal tremor, inappropriate silence and irregular articulatory break.

For ataxic dysarthria the significant parameters, which would help in distinguishing it from the other types, are excess or equal stress,
irregular articulatory break, distorted vowel, prolonged phoneme and harsh voice.

These parameters are represented below in a tabular form for each dysarthria type in table 5.4.

Table 5.4: Significant parameters for each dysarthria type which help to distinguish between dysarthria.

<table>
<thead>
<tr>
<th>Spastic</th>
<th>Flaccid</th>
<th>Hypokinetic</th>
<th>Hyperkinetic</th>
<th>Ataxic</th>
</tr>
</thead>
<tbody>
<tr>
<td>SV</td>
<td>HN</td>
<td>HV</td>
<td>VT</td>
<td>EES</td>
</tr>
<tr>
<td>HN</td>
<td>BV</td>
<td>SHR</td>
<td>IS</td>
<td>IAB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IOR</td>
<td>IAB</td>
<td>DV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PP</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HV</td>
<td></td>
</tr>
</tbody>
</table>

**Abbreviations:** BV = breathy voice; DV = distorted vowel; EES = excess or equal stress; HN = hypermasality; HV = harsh voice; IAB = irregular articulatory break; IOR = increase in overall rate; IS = inappropriate silence; PP = prolonged phoneme; SHR = short rushes; SV = strained voice; VT = vocal tremor.

### 5.3. TYPES OF IMPRECISE CONSONANTS IN SIX DYSARTHRIA TYPES

While analyzing the speech characteristics of the various Bengali individuals suffering from dysarthria, which obviously deviate from those
of the normal Bengali individuals, it is observed that the existence of imprecise consonants is a common feature of all dysarthria types.

The types of consonants that are found to get imprecise during production in each type of dysarthria are as follows (the examples are given in section 5.3.7):

**SPASTIC DYSARTHRIA**

- Voiceless aspirated velar stop /kh/ becoming voiceless, unaspirated velar stop /k/
- Voiced aspirated velar stop /gh/ becoming voiced, unaspirated velar stop /g/
- Voiced aspirated dental stop /dh/ becoming voiced, unaspirated dental stop /d/
- Voiceless aspirated retroflex stop /Th/ becoming voiceless, unaspirated retroflex stop /T/
- Voiced aspirated retroflex stop /Dh/ becoming voiced, unaspirated retroflex stop /D/
- Voiceless alveo-palatal fricative /S/ becoming voiceless aspirated alveo-palatal affricate / ch/
- Voiceless unaspirated retroflex stop /T/ becoming voiceless unaspirated dental stop /t/
- Voiced unaspirated retroflex stop /D/ becoming voiced unaspirated dental stop /d/
- Voiced alveolar trill /r/ and alveolar lateral /l/ dropped in clusters /sr/, /gr/, /kl/, /gl/
- Voiceless dental fricative /s/ dropped in the cluster /spr/

**FLACCID DYSARTHRIA**

- Vowels /i, e, E, O, o, u/ distorted
- Voiceless alveo-palatal fricative /S/ becoming voiceless aspirated alveo-palatal affricate /ch/
- Voiceless unaspirated retroflex stop /T/ becoming voiceless unaspirated dental stop /t/
- Voiced unaspirated retroflex stop /D/ becoming voiced unaspirated dental stop /d/
- Voiced alveolar trill /r/ and alveolar lateral /l/ dropped in clusters /sr/, /gr/, /kl/, /gl/
- Voiceless dental fricative /s/ dropped in the cluster /spr/

**HYPOKINETIC DYSARTHRIA**

- Voiceless dental fricative /s/ dropped in the cluster /spr/
• Voiced alveolar trill /r/ and alveolar lateral /l/ dropped in clusters /sr/, /gr/, /kl/, /gl/
ATAXIC DYSARTHRIA

- Vowels /i, e, E, o, u/ lengthened
- Voiceless aspirated velar stop /kh/ becoming voiceless unaspirated velar stop /k/
- Voiced aspirated velar stop /gh/ becoming voiced unaspirated velar stop /g/
- Voiced aspirated dental stop /dh/ becoming voiced unaspirated dental stop /d/
- Voiceless aspirated retroflex stop /Th/ becoming voiceless unaspirated retroflex stop /T/
- Voiced aspirated retroflex stop /Dh/ becoming voiced unaspirated retroflex stop /D/
- Voiced alveolar trill /r/ and alveolar lateral /l/ dropped in clusters /sr/, /gr/, /kl/, /gl/,
- Voiceless dental fricative /s/ dropped in the cluster /spr/

MIXED DYSARTHRIA

- Final /i, e, o/ distorted
- Voiced alveolar trill /r/ dropped in clusters /sr/, /gr/, /kl/, /gl/
5.3.1. TYPES OF IMPRECISE CONSONANTS FOUND IN DYSARTHRIA IN GENERAL

The types of the imprecise consonants occurring in the six types of dysarthria are assembled below with the description of the nature of changes.

- Voiceless alveo-palatal fricative /S/ becoming voiceless aspirated alveo-palatal affricate / ch/

- Vowels /i, e, E, O, o, u/ lengthened

Examples:

the vowels /i, a/ are lengthened in /itiS/ 'history'
the vowels /e, u/ are lengthened in /ekuS/ 'twentyone'
the vowel /E/ is lengthened in /Ek/ 'one'
the vowels /a, o/ are lengthened in /alo/ 'light'
the vowels /O, e/ are lengthened in /Onek/ 'many'
the vowel /o/ is lengthened in /chobi/ 'picture'
the vowels /u, e/ are lengthened in /dure/ 'far'
• Voiceless aspirated velar stop /kh/ becoming voiceless unaspirated velar stop /k/

Here the substitution process (see Section 3.4.3.) is taking place. /kh/ has been replaced by /k/. Substitution is an universal process taking place in dysarthic speech.

Examples:
/kham/ ‘envelope’ becoming /kam/
/pakhi/ ‘bird’ becoming /paki/
/cokh/ ‘eye’ becoming /cok/

• Voiced aspirated velar stop /gh/ becoming voiced unaspirated velar stop /g/

Here too the substitution process (see Section 3.4.3.) is taking place. /gh/ has been replaced by /g/. In this case the feature of aspiration is missing whereby /gh/ becomes /g/.

Examples:
/ghoRi/ ‘clock’ becoming /gori/
/aghat/ ‘bruises’ becoming /agat/
/bagh/ 'tiger' becoming /bag/

- Voiced aspirated dental stop /dh/ becoming voiced unaspirated dental stop /d/

Here also the substitution process (see Section 3.4.3.) has taken place. In this case also the feature of aspiration is missing. In the examples below it is interesting to observe that with the conversion of /dh/ into /d/ some semantic changes also occur, as in the first example where /dhan/ 'grain' becomes /dan/ 'offering'.

Examples:

/dhan/ 'grain' becoming /dan/
/gadha/ 'donkey' becoming /gada/
/oSudh/ 'medicine' becoming /ochud/
(change of /S/ into /ch/ given later)

- Voiceless aspirated retroflex stop /Th/ becoming voiceless unaspirated retroflex stop /T/

Here too the substitution process (see Section 3.4.3.) is taking place. In this case also the feature of aspiration is missing. In the third example
with the conversion of /Th/ into /T/ a semantic change is noticeable where /kaTh/ 'wood' becomes /kaT/ '(you) bite'.

Examples:

/Thakur/ 'God' becoming /Takur/
/ciThi/ 'envelope' becoming /ciTi/
/kaTh/ 'wood' becoming /kaT/

• Voiced aspirated retroflex stop /Dh/ becoming voiced unaspirated retroflex stop /D/

Here also the substitution process (see Section 3.4.3.) is taking place and the feature of aspiration is missing.

Examples:

/Dheu/ 'wave' becoming /Deu/
/Odhel/ 'plenty' becoming /ODei/

• Voiceless unaspirated retroflex stop /T/ becoming voiceless unaspirated dental stop /t/
Here the substitution process (see Section 3.4.3.) is taking place. /T/ has been substituted by /t/. Semantic change has also taken place in the first example where /Taka/ ‘money’ is becoming /taka/ ‘(you) look’.

Examples:

/Taka/ ‘money’ becoming /taka/
/choTo/ ‘small’ becoming /choto/

• Voiced unaspirated retroflex stop /D/ becoming voiced unaspirated dental stop /d/

Here also the substitution process is taking place. /D/ has been substituted by /d/.

Examples:

/Dim/ ‘egg’ becoming /dim/
/gOnDar/ ‘rhinoceros’ becoming /gOndar/

• Voiceless alveo-palatal fricative /S/ becoming voiceless aspirated alveo-palatal affricate / ch/

In this case the substitution process is taking place with the substitution of /S/ with /ch/. Semantic change has also taken place in the third
example where /ghaS/ 'grass' is becoming /gach/ 'tree'. Here, two changes have occurred, i.e., /gh/ has become /g/ with the loss of aspiration and /S/ has been substituted by /ch/.

Examples:

/Saban/ 'soap' becoming /chaban/
/SOSa/ 'cucumber' becoming /chOcha/
/ghaS/ 'grass' becoming /gach/

- Voiced alveolar trill /r/ dropped in clusters /sr/, /gr/

In this case the omission error under syllabic structure process (see Section 3.4.3.) as put forwarded by Grunwell is taking place. /r/ is dropped in the clusters /sr/ and /gr/. The CCV structure changes to CV as the medial consonant has been dropped. Thus, the characteristic of the onset of the syllable has been changed.

Examples:

/sromik/ 'labourer' becoming /chomik/
/gram/ 'village' becoming /gam/

- Voiced alveolar lateral /l/ dropped in clusters /kl/, /gl/
Here also the omission error under syllabic structure process (see Section 3.4.3.) as put forwarded by Grunwell is taking place. /l/ is dropped in the clusters /kl/ and /gl/. The CCV structure changes to CV as the medial consonant has been dropped. Thus, the characteristic of the onset of the syllable has been changed.

Examples:

/kianto/ 'tired' becoming /kanto/ (this is a borrowed Sanskrit word which means 'lover')

/glani/ 'fatigue' becoming /gani/

• Voiceless dental fricative /s/ dropped in the cluster /spr/

In this case also the omission error under syllabic structure process (see Section 3.4.3.) as put forwarded by Grunwell is taking place. /s/ is dropped in the clusters /spr/. The CCCV structure changes to CCV as the initial consonant has been dropped. Thus, the first member of the onset of the syllable has been dropped.

Example:

/spriSSo/ 'touchable' becoming /priSSo/

Thus, the following phonological changes are observed which are presented below in table 5.5.
Table 5.5 A: Phonological Changes in Single Segments

<table>
<thead>
<tr>
<th>NORMAL SPEECH</th>
<th>DYSARTHRIC SPEECH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Vowels</td>
<td>becoming</td>
</tr>
<tr>
<td>2. Aspirated stops</td>
<td>becoming</td>
</tr>
<tr>
<td>3. Sibilant /S/</td>
<td>becoming</td>
</tr>
<tr>
<td>4. Retroflex stops /T,D/</td>
<td>becoming</td>
</tr>
<tr>
<td>1. lengthened</td>
<td>2. Unaspirated stops</td>
</tr>
<tr>
<td>3. Affricate /ch/</td>
<td>4. Dental stops /t,d/</td>
</tr>
</tbody>
</table>

Table 5.5 B: Phonological Changes in Consonantal Clusters

<table>
<thead>
<tr>
<th>NORMAL SPEECH</th>
<th>DYSARTHRIC SPEECH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. consonant + r</td>
<td>becoming</td>
</tr>
<tr>
<td>2. consonant + I</td>
<td>becoming</td>
</tr>
<tr>
<td>1. consonant (r dropped)</td>
<td></td>
</tr>
<tr>
<td>2. consonant (I dropped)</td>
<td></td>
</tr>
</tbody>
</table>

3. In /spr/, /s/ is dropped but in /str/, /s/ is not dropped. It can be inferred that in /spr/ the /s/ is a dental sound and /p/ is bilabial. Since the place of articulation for both the sounds are different, the patient articulates only the bilabial sound by dropping the initial dental sound. But in case of /str/, both /s/ and /t/ are dental sounds. As the place of articulation is the same, the patient can produce both the
sounds together. In some patients the pronunciation of /r/ is also dropped in both /spr/ and /str/.

5.4. SPEECH DEFICITS AT THE SENTENCE LEVEL

In dysarthric Bengali speech, the speech deficits at the sentence level are found in terms of stress, clause terminals and pitch (see Section 4.4).

PITCH

There is no change on the pitch level. The sentences are produced at the mid pitch level of 2. There is hardly any variation of pitch.

Examples:

2 2 2 2 2 2 2 2 2 2 2 1
/amar bagane Onek RONbeRONer phuler gach ache/

'I have many types of colourful flower plants in my garden.'

2 2 2 2 2 2 2 1
/narkel gache Onek Dab hOY/

'The coconut tree bears many green coconuts.'
CLAUSE TERMINALS

At the level of the clause terminals the problem is related to the placement of the sustained clause terminals in the sentence. The dysarthric individuals suffer from irregular articulatory break and as a result they find it difficult to place the sustained clause terminals at the appropriate places.

In dysarthric speech,

Examples:

/bhor bElaY jOkhon dhiredhire Surjo oThe ami gache jOl diy/
'At dawn when the sun rises slowly, I water the trees.'

/takhon Onek Sundor projapoti ar moumachi khEl a kOre/
'Then many beautiful butterflies and bees play.'

In normal speech,

Examples:

/bhor bEl aY jOkhon dhiredhire Surjo oThe ami gache jOl diy/
'At dawn when the sun rises slowly, I water the trees.'
In ataxic dysarthria the dysarthric individuals are usually affected by excess or equal stress. Sometimes the stress falls on parts of the words where it is not required.

In dysarthric speech,

Example:

/" baganer " paSe " EkTa " choTo " pukur " ache/  
'There is a small pond beside the garden.'

In normal speech,

Example:

/baganer "paSe EkTa choTo pukur ache/  
'There is a small pond beside the garden.'
5.5. ACOUTIC DESCRIPTION OF THE IMPRECISE
CONSONANTS IN THE WORDS

The imprecise consonants irrespective of the type of dysarthria are
shown acoustically in the following words (Fig: 5.1 to 5.52) in
comparison with the normal production of the words.

Figure 5.1 to Figure 5.52: Acoustic analysis of the words

<table>
<thead>
<tr>
<th>Patient</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>ekuS</td>
<td>ekuS</td>
</tr>
</tbody>
</table>

Figure: 5.1

In Figure 5.1, first vowel /e/ is lengthened; there is an unnatural occlusion
before friction /S/ making it /ch/.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>alo</td>
<td>alo</td>
</tr>
</tbody>
</table>

Figure: 5.3

In Figure 5.3, the first vowel /a/ is devoiced and lengthened.
In Figure 5.5, voicing for terminal consonant /gh/ is absent making it /g/.

In Figure 5.7, there is inadequate aspiration before the onset of voicing changing /bh/ into /b/.

In figure 5.9, syllables are lengthened; /r/ is absent in the triple cluster /tro/. 
In 5.11, the last syllable /bi/ is absent.

In 5.13, there is prolongation of friction converting affricate /cl/ into a perceptual sibilant /Sl/.

In figure 5.15, /a/ lengthened in both syllables; affricate /j/ converted into voiced fricative /zi/; aspiration for /h/ absent.
<table>
<thead>
<tr>
<th>Patient</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Figure: 5.17" /></td>
<td><img src="image2" alt="Figure: 5.18" /></td>
</tr>
</tbody>
</table>

In figure 5.17, retroflexion noticed converting /d/ into /D/; Voice bar for the terminal consonant absent converting /g/ into /k/.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Figure: 5.19" /></td>
<td><img src="image4" alt="Figure: 5.20" /></td>
</tr>
</tbody>
</table>

In figure 5.19, the nucleus vowel /e/ is elongated; there is unnecessary occlusion before sibilant /S/ converting the phoneme into perceptual affricate /c/.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5" alt="Figure: 5.21" /></td>
<td><img src="image6" alt="Figure: 5.22" /></td>
</tr>
</tbody>
</table>

In Figure 5.21 there is aspiration before /E/.
In figure 5.23, the medial aspirated /h/ and terminal fricative /S/ is absent.

In figure 5.25, the aspiration is absent in the first consonant converting /kh/ into /k/. Lateral /l/ is converted into an elongated tap producing /l/ like sound.

In figure 5.27, the tap of /l/ is missing; nasality due to the opening of the velum for nasal /m/ continued unnaturally throughout up to the beginning of the nucleus vowel of the next syllable.
Fig 5.29, hypernasality is present throughout.

Fig 5.30, the initial /p/ is articulated with a friction converting it into /f/.

In figure 5.32, nasalization is present throughout.

In figure 5.34, the tap of /r/ is missing making it /l/. The occlusion for the consonant /l/ is missing making it like a vowel like sound.
In figure 5.36, there is unnecessary occlusion after /S/ converting the phoneme into perceptual affricate /ch/.  

In figure 5.38, there is unnecessary occlusion after /s/ converting the phoneme into perceptual affricate /ch/.  

In figure 5.40, the initial /s/ is absent in the consonantal cluster /spr/ converting into /pr/.  

<table>
<thead>
<tr>
<th>Patient</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sap</strong></td>
<td><strong>Sap</strong></td>
</tr>
<tr>
<td><img src="image1" alt="Figure 5.36" /></td>
<td><img src="image2" alt="Figure 5.37" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patient</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>snan</strong></td>
<td><strong>snan</strong></td>
</tr>
<tr>
<td><img src="image3" alt="Figure 5.38" /></td>
<td><img src="image4" alt="Figure 5.39" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patient</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>spriSSSo</strong></td>
<td><strong>spriSSSo</strong></td>
</tr>
<tr>
<td><img src="image5" alt="Figure 5.40" /></td>
<td><img src="image6" alt="Figure 5.41" /></td>
</tr>
</tbody>
</table>
In figure 5.42, the lateral /l/ has been prolonged.

In figure 5.44, the vowel /i/ has been prolonged. Tongue is retroflexed producing /T/ instead of /l/.

In figure 5.46, the tap of /t/ is missing in the initial cluster /tr/. The medial vowel /i/ is slightly prolonged.
5.6. STUDY OF DIADOCHOKINETIC RATE

The lingual mobility and control of movements of the articulators are affected in dysarthria. In order to judge the accuracy and speed of the movements of the lips and the tongue, administration of the measurement of diadochokinetic rate proves to be useful. Diadochokinetic rate is the test of the alternate motion rate of the articulators. The patients were asked to repeat the syllables /pO, tO, kO/ rapidly as repetition of the overlapping series of these syllables or the repetition of the single syllables. This test assisted in understanding whether the movements of the articulators have become slow, or fast in comparison to the normal rate. Table 5.6 (see Appendix C: 27-33) gives a comparison of the rates of production for /pO, tO, kO/ for twenty times repetitively in isolation and also in unison.

Table 5.6: Comparative study of the diadochokinetic rate of the six dysarthria types with the normal

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Spastic</th>
<th>Flaccid</th>
<th>Hypokinetic</th>
<th>Hyperkinetic</th>
<th>Ataxic</th>
<th>Mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>p</td>
<td>7.9</td>
<td>11.8</td>
<td>12.1</td>
<td>10.1</td>
<td>12.3</td>
<td>12.8</td>
<td>14.8</td>
</tr>
<tr>
<td>t</td>
<td>7.9</td>
<td>11.9</td>
<td>11.9</td>
<td>9.4</td>
<td>12.3</td>
<td>13.9</td>
<td>15.6</td>
</tr>
<tr>
<td>k</td>
<td>8</td>
<td>12.3</td>
<td>12.6</td>
<td>9.6</td>
<td>12.8</td>
<td>12.9</td>
<td>17</td>
</tr>
<tr>
<td>ptk</td>
<td>10.6</td>
<td>19.4</td>
<td>20.1</td>
<td>13.2</td>
<td>18.6</td>
<td>18.9</td>
<td>25.4</td>
</tr>
</tbody>
</table>

Note: The time is expressed in terms of seconds
From the above table it is observed that the average rate for the isolated production for /p, t, k/ is 7.9 secs for the normal and 10.6 secs in case of the production in unison. The rates for the six types of dysarthria are as follows:

SPASTIC DYSARTHRIA

The average time taken for the production of the syllables /pO, tO, kO/ in isolation is 12.0secs and 19.4 secs in unison. The time taken in both cases are much more than the time in cases by the normal.

FLACCID DYSARTHRIA

The average time taken for the production of the syllables /pO, tO, kO/ in isolation is 12.1secs and 20.1 secs in unison. The time taken in both cases are much more than the time in cases by the normal.

HYPOKINETIC DYSARTHRIA

The average time taken for the production of the syllables /pO, tO, kO/ in isolation is 9.7 secs and 13.2 secs in unison. The time taken in both cases are much more than the time in cases by the normal.
HYPERKINETIC DYSARTHRIA

The average time taken for the production of the syllables /pO, tO, kO/ in isolation is 12.4 secs and 18.6 secs in unison. The time taken in both cases are much more than the time in cases by the normal.

ATAXIC DYSARTHRIA

The average time taken for the production of the syllables /pO, tO, kO/ in isolation is 13.2 secs and 18.9 secs in unison. The time taken in both cases are much more than the time in cases by the normal.

MIXED DYSARTHRIA

The average time taken for the production of the syllables /pO, tO, kO/ in isolation is 14.3 secs and 25.4 secs in unison. The time taken in both cases are much more than the time in cases by the normal.

Though the time taken for the production of syllables /pO, tO, kO/ is slow for all the dysarthrias in comparison with the normal, the time taken most is in mixed dysarthria and least in hypokinetic dysarthria. The production rate is almost near to normal in case of the hypokinetic
dysarthria. Thus, it can be inferred that the rate of movements of the articulators has been affected in the dysarthrias. It is most affected in the mixed and ataxic types of dysarthria.

5.7. ACOUSTIC ANALYSIS OF THE SUSTAINED PHONATION OF THE VOWEL /a/ BY THE SPASTIC AND HYPOKINETIC DYSARTHRIC SUBJECTS

For each record of the phonation /a/ of each subject when fed to the MDVP software gave as an output the values for all the 34 parameters as mentioned in Section 1.3.4. All these parameters for all patients and all normal informants produced two databases, one for the patient and one for the normal subjects. All the patients and the normal subjects were male adults. For each parameter mean and standard deviation were calculated for the normal informants. If a particular parameter of a patient is outside mean ± standard deviation then that parameter is taken to be indicative of the disease.

5.7.1. SELECTION OF PARAMETERS

It may be noted that some of the parameters grouped under the nine domains (see Section 1.3.4) may correlate with each other strongly. So,
it may be interesting to know whether all of them are really necessary. Statistical correlation shows the degree of dependence of two sets of data. Correlation coefficients for each parameter with all others have been calculated for different patients of the hypokinetic and spastic group separately and are presented in Appendix C: 37-38. The pair of parameters for which the correlation is high and close to the value of 0.9 are considered to be highly correlated. In fact, such correlations between all parameters when arranged properly yield a matrix, which is symmetric about the diagonal. Therefore, only half of the non-diagonal elements need to be examined. The number of elements counts to 561.

An examination of them reveals the parameters, which are highly correlated between themselves. These form different groups. For example, in the second group below Fhi, STD and PFR belong to the \( F_0 \) domain, SPPQ to the domain of frequency parameters; ATRi to the domain of tremor parameters; DVB and NVB to the domain of voice break related parameters. Sometimes the elements of one group may belong to different domains (see Section 1.3.4). It is, therefore, necessary to carefully examine them for the selection of members of the subset. This is done below with reference to the aforesaid tables (see Appendix C: 37-38).
• $F_0$, $MF_0$, $T_0$ and PER are highly correlated so anyone can be chosen. Average is a better statistical representation of a data set. Therefore, either $MF_0$ or $T_0$ can be chosen.

• $Fhi$, STD, PFR, SPPQ, ATRI, DVB and NVB are highly correlated. So, anyone of them could be selected. Though STD in a statistical sense relates to $Fhi$, $Fhi$ may indicate the pathological condition. Therefore only $Fhi$ may be taken. Since PFR can be derived from $Fhi$ and Flo through a mathematical formula, hence this cannot be independent parameter.

• SPPQ, ATRI, DVB and NVB represent a different physical parameter. SPPQ and ATRI may be taken as an independent parameter.

• Jitt, Jita, RAP, PPQ, NHR, DUV, NUV and FTRI are highly correlated. Amongst them Jitt, Jita, RAP and PPQ relate to the same fundamental parameter of pitch. However for hypokinetic dysarthria Jita appears to be a necessary parameter.
- SPPQ, Fhi, STD, PFR, PPQ, \( V_F_0 \), Shdb, Shim, APQ, SAPQ, Vam, NHR, ATR, DVB, DUV, NVB and NUV are highly correlated.

- \( V_F_0 \) is fundamentally related to STD and it is also correlated with SPPQ, so it may be taken as an independent indicator of the patient condition.

- Shdb is highly correlated with Shim, APQ, SAPQ, Vam, NHR, ATR, DVB and NVB. Shdb, Shim, APQ, SAPQ and Vam represent the same fundamental physical reality, that is random perturbation of amplitude and they are highly correlated. Therefore only one of them can be taken. In this case Shim has been selected.

- NHR represents the random perturbation of complexity, which is an independent physical parameter. It is therefore taken as one of the diagnostic parameter though it shows close relation with jitter and shimmer parameters.

- DUV, NUV, DVB and NVB represent a totally different physical reality. DUV and NUV are highly correlated and therefore DUV
may be taken. DVB and NVB are highly correlated, and so DVB may be taken as an independent parameter.

- DSH, NSH and DVB are highly correlated. But DSH and DVB represent different fundamental physical parameters. Both may be taken as independent parameters.

- SEG basically depends on the signal processing algorithm and therefore it may not be considered as indicative of the pathological condition.

- Fftr, fatr, VT1 and SPI are not correlated with any other parameters. So all of them may be taken.

- Tsam is an experimental constraint, which is almost same for every patient. Therefore, Tsam and Per does not have any contribution towards the condition of the patient.

Thus the list of parameters selected is as follows:

Parameters selected for the subset:

1) Mfo (Mean Fundamental Frequency /Hz/)
2) Fhi (Highest fundamental Frequency /Hz/)
3) Flo (Lowest Fundamental Frequency /Hz/)
4) vFo (Fundamental Frequency Variation /%/)
5) Fftr (Fo-Tremor Frequency /Hz/)
6) Fatr (Amplitude-Tremor Frequency /Hz/)
7) Jitt (Jitter Percent /%/)
8) Jita (Absolute Jitter /usec/)
9) SPPQ (Smoothed Pitch Period perturbation Quotient /%/)
10) Shim (Shimmer Percent /%/)
11) NHR (Noise-to-Harmonic Ratio)
12) VTI (Voice Turbulence Index)
13) SPI (Soft Phonation Index)
14) FTRI (Frequency Tremor Intensity Index /%/)
15) ATRI (Amplitude Tremor Intensity Index /%/)
16) DSH (Degree of Sub-harmonics /%/)
17) DUV (Degree of Voiceless /%/)
18) DVB (Degree of Voice Breaks /%/)

5.7.2. SIGNIFICANT PARAMETERS FOR IDENTIFICATION OF PHONATION DEFECTS IN SPASTIC AND HYPOKINETIC DYSARTHRIA

Tables 5.7A and 5.8A present the data in a tabular form for the eighteen parameters selected through the process of correlation for spastic and
hypokinetic dysarthria respectively. As already stated, a parameter (Appendix C: 35-36) is taken to be indicative of the disease if it's value is outside the range defined by mean ± standard deviation for the distribution for normal patients (Appendix C: 34). In tables 5.7 and 5.8 the cell values are 0, 1 or blank. 0 represents those parameters of the patients, which are in the normal range, 1 represents those, which are diseased according to the aforesaid definition, and blank represents the parameter that is not calculated by MDVP.

Tables 5.7 B and 5.8 B give the data of the parameters of the phonation domain observed in the perceptual study for the spastic dysarthria and hypokinetic dysarthria respectively. In these tables 1 represents the presence of parameters indicative of the disease whereas 0 indicates the absence of them.

In these tables the penultimate row gives the ratio of the number of ones to the total number of the parameters. This may be taken as a measure of the degree of the acuteness of the disease. The last row represents a ranking of the patients according to this degree of disease. Ranking 1 represents the most severe and the degree of the disease increases with the increase of the number.
An attempt has been made to see whether the ranking of the patients are close or not for the acoustic and for the perceptual analysis.

Table 5.7 A: Acoustically analysed Phonation Parameters present in Spastic dysarthria

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An examination of the last column of the table 5.7A reveals that Fhi, Jita, Jitt, Duv, FTRI, and NHR may be called significant for the detection of the spastic dysarthria as they are found quite frequently. These indicate that spastic dysarthria is characterized by a high value of the fundamental frequency and their random perturbation as well as excessive noise in the source speech signal along with its excessive occurrence replacing voicing in sustained phonation. The frequency of occurrence of FTRI in the sample patients is highest indicating that these patients are likely to exhibit tremulousness during phonation.

Table 5.7 B: Perceptually analysed Phonation Parameters present in Spastic dysarthria

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By comparing table 5.7 A and 5.7 B it can be hypothesized that the rankings are more or less close for almost all the patients except for patient number 9. So it can be inferred that assessment from the measurement of the acoustic parameters, which are objective, leads to similar assessments obtained from perceptual analysis of certain phonatory parameters usually used for diagnosis of this disease.

Table 5.8 A: Acoustically analysed Phonation Parameters present in Hypokinetic dysarthria

<table>
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<tr>
<th>Patient No.</th>
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</table>
An examination of the last column of the table 5.8B reveals that Fhi, Jita, Jitt, sPPQ, FTRI, ATRI, Fatr, NHR, VTI, and SPI may be called significant for the detection of the hypokinetic dysarthria as they are found quite frequently. These indicate that hypokinetic dysarthria is characterized by a high value of the fundamental frequency and their random perturbation as well as excessive noise in the source speech signal.

The frequency of occurrence of FTRI, ATRI and Fatr in the sample patients is high indicating that these patients are likely to exhibit tremulousness during phonation. Further high VTI suggests incomplete glottic closure and high SPI suggests weak vocalization (MDVP, 2003:28-29).
Table 5.8 B: Perceptually analysed Phonation Parameters present in Hypokinetic dysarthria

<table>
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<th>Patient No.</th>
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By comparing table 5.8 A and 5.8 B it can be concluded that the rankings are statistically more or less close for almost all the patients except for the patient number 2. Comments made in the paragraph under table 5.7 B is applicable here also.

REFERENCES